

Program

4th International Conference on Electrophoretic Deposition: Fundamentals and Applications

October 2-7, 2011

CasaMagna Marriott Hotel, Puerto Vallarta, Mexico

Conference Chair

Prof. Aldo R. Boccaccini

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Conference Co-Chairs

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We would like to acknowledge the generous support of the United States National Science Foundation's Particulate and Multiphase Processes Program.



Sunday, October 2, 2011

16:00 – 18:00	Registration
18:00 – 20:00	Welcome Reception and Dinner

Notes

- *Technical sessions will be in the Vallarta IV.*
- *Poster Sessions will be in the Vallarta V*
- *Meals will be held in the:*
 - *Breakfast – Restaurant Champions & Main Garden (will advise on site each day's location)*
 - *Lunch – Mikado Restaurant*
 - *Dinner:*
 - *Sunday – Beach Patio*
 - *Monday – El Patio*
 - *Tuesday – Beach Patio*
 - *Wednesday – Vallarta VI-VIII*
 - *Thursday – Las Casitas Garden*
- *Audiotaping, videotaping and photography of presentations are prohibited.*
- *Speakers – Please have your presentation loaded onto the conference computer prior to the session start (preferably the day before).*
- *Speakers – Please leave at least 3-5 minutes for questions and discussion.*
- *Please do not smoke at any conference functions.*
- *Turn your mobile telephones to vibrate or off during technical sessions.*
- *Be sure to make any corrections to your name/contact information on the Master Participant List or confirm (by your initials) that the listing is correct. A corrected copy will be sent to all participants after the conference.*

Monday, October 3, 2011

07:30 – 08:30 Breakfast

08:30 – 08:45 Conference Introduction

SESSION I: ADVANCED EXPERIMENTAL TECHNIQUES I

Session Chair: Omer van der Biest

08:45 – 09:05 ELECTROPHORETIC MICRO DEPOSITING
Rolf Clasen
Saarland University, Saarbrücken, Germany

09:05 – 09:25 DEPOSITION OF METAL AND METAL-OXIDE COATINGS USING NANOFUID
PRECURSORS
Vahid Firouzdar
Department of Engineering Physics, University of Wisconsin-Madison, USA

09:25 – 09:45 HYBRID ELECTROPHORETIC DEPOSITION WITH ANODIZING PROCESS FOR
SUPERHYDROPHILIC SURFACES ENHANCING CRITICAL HEAT FLUX IN POOL
BOILING
Young Soo Joung
Massachusetts Institute of Technology, USA

09:45 – 10:05 THE ORIENTATION OF BARIUM FERRITE FILMS: APPLIED MAGNETIC FIELD
VERSUS ELECTROPHORETIC DEPOSITION
Darja Lisjak
Jozef Stefan Institute, Slovenia

10:05 – 10:25 TEXTURED Ti_3SiC_2 BY EPD IN A STRONG MAGNETIC FIELD
Mrinalini Mishra
National Institute for Materials Science, Japan

10:25 – 11:00 Coffee Break

SESSION II: ADVANCED EXPERIMENTAL TECHNIQUES II

Session chair: Jan Ma

11:00 – 11:20 ORIENTATION CONTROL OF HEMATITE VIA TRANSFORMATION OF TEXTURED
GOETHITE PREPARED BY EPD IN A STRONG MAGNETIC FIELD
Tetsuo Uchikoshi
National Institute for Materials Science, Japan

11:20 – 11:40 GROWTH DYNAMICS OF CDS-PAMAM DENDRIMERS NANOCOMPOSITES STUDIED
IN THE PRESENCE AND THE ABSENCE OF AN ELECTRIC FIELD
Perla Méndez
Centro de Investigación y Desarrollo Tecnológico en Electroquímica S.C., Mexico

11:40 – 12:00 PULSE PULSE/REVERSE ELECTRIC FIELDS FOR EPD OF THERMAL BARRIER
COATINGS
Heather McCrabb
Faraday Technology, Inc., USA

12:30 – 14:00 Lunch

14:00 – 16:30 *Ad hoc* sessions and/or free time

Monday, October 3, 2011 (continued)

16:30 – 17:00 Afternoon Coffee

SESSION III: EPD IN CERAMIC PROCESSING

Session chair: Jan Talbot

17:00 – 17:30

Keynote

ELECTROPHORETIC DEPOSITION OF CERAMIC COMPACTS FROM AQUEOUS SUSPENSIONS

Rolf Clasen, University of Saarland, Germany

17:30 – 17:50

FLY ASH/RARE EARTH OXIDE COATINGS BY EPD: PROCESSING AND CHARACTERIZATION

Ana Maria Arizmendi-Morquecho

Centro de Investigacion en Materiales Avanzados, S.C. Unidad Monterrey, Mexico

17:50 – 18:10

ELECTROPHORETIC DEPOSITION OF THIN-FILM ENERGY-STORAGE DEVICES

Diana Golodnitsky

Tel Aviv University, Israel

18:10 – 18:30

CATODIC ELECTRODEPOSITION AND CHARACTERIZATION CERIA STABILIZED ZIRCONIA FILM USING XPS, TEM, SEM AND AFM

M. Eugenia Contreras Garcia

FIQ Universidad Michoacana de San Nicolas de Hidalgo, Mexico

19:00 – 20:30

Dinner

20:30 – 21:30

Social Hour

Tuesday, October 4, 2011

07:30 – 08:30 Breakfast

SESSION IV: NANOSTRUCTURED MATERIALS AND FILMS I

Session chair: James Dickerson

08:30 – 09:00 **Keynote**
ASSEMBLING AND PACKING OF NANOSTRUCTURES UNDER AN ELECTRIC FIELD
Begoña Ferrari, Instituto de Cerámica y Vidrio, CSIC, Spain

09:00 – 09:20 HIGH VOLTAGE ELECTROPHORETIC DEPOSITION OF VERTICALLY-ALIGNED NANOFORESTS FOR SCALABLE NANOMANUFACTURING OF ELECTROCHEMICAL ENERGY STORAGE DEVICES
Dennis Desheng Meng
Multi-Scale Energy Systems (MuSES) Laboratory, Michigan Technological University, USA

09:20 – 09:40 THIN FILMS OF EUROPIUM(III) DOPED-TIO₂ PREPARED BY ELECTROPHORETIC DEPOSITION FROM NANOPARTICULATE SOLS
Mario Borlaf
Instituto de Cerámica y Vidrio, Spain

09:40 – 10:00 OPTIMIZATION OF AQUEOUS ELECTROPHORETIC DEPOSITION OF NANOSTRUCTURED TITANIA FILMS FOR DYE-SENSITIZED SOLAR CELL APPLICATION
Nima Parsi Benekohal
McGill University, Montreal, Canada

10:00 – 10:20 TUNABLE SURFACE WETTING IN TRANSFERABLE FILMS OF GRAPHENE OXIDE
James H. Dickerson
Vanderbilt University, USA

10:20 – 11:00 Coffee Break

SESSION V: NANOSTRUCTURED MATERIALS AND FILMS II

Session chair: James Dickerson

11:00 – 11:20 FUNCTIONALLY GRADED, NANOSTRUCTURED MATERIALS VIA PATTERNED ELECTROPHORETIC DEPOSITION
Andrew J. Pascall
Lawrence Livermore National Laboratory, USA

11:20 – 11:40 FABRICATION OF 2-DIMENSIONAL IRON OXIDE NANOPARTICLE SUPERLATTICES BY ELECTROPHORETIC DEPOSITION
Alex Krejci
Vanderbilt University, USA

11:40 – 12:00 ASSEMBLING OF ZNO NANOFILAKES WITHIN ORGANISED THICK FILMS
Maria Verde
Instituto de Cerámica y Vidrio, CSIC, Spain

12.00 – 12.20 EPD OF METAL OXIDE NANOPARTICLES FROM POLYOL-BASED COLLOIDAL SUSPENSIONS
Carmen Galassi
CNR-ISTEC, Faenza, Italy

Tuesday, October 4, 2011 (continued)

- 12.20 – 12.40 MECHANICAL PROPERTIES OBTAINED BY NANOINDENTATION OF
NANOSTRUCTURED TITANIA-ALUMINA FILMS
María Eugenia Contreras-García
IIM, UMSNH, Mexico
- 13:00 – 14:30 Lunch
- 14:30 – 16:30 **Optional excursion**
Ad hoc sessions and/or free time
- 16:30 – 17:00 Afternoon Coffee
- SESSION VI: NANOSTRUCTURED MATERIALS AND FILMS III***
Session Chair: James Dickerson
- 17:00 – 17:20 ELECTROPHORETIC ASSEMBLY OF TiO₂ NANOCRYSTALS IN NON POLAR-
SOLVENTS
Maria Isabel Gonzalo-Juan
Vanderbilt University, USA
- 17:20 – 17:40 ZN BASED STRUCTURES THROUGH HOMOGENEOUS PACKING AND SEEDING OF
ZNO NANOPARTICLES BY EPD
Amador Caballero
Instituto de Ceramica y Vidrio, Madrid, Spain
- SESSION VII: NOVEL APPROACHES AND MODELLING***
Session chair: Rodrigo Moreno
- 17:40 – 18:00 DIRECT NUMERICAL SIMULATIONS OF ELECTROPHORETIC DEPOSITION OF
CHARGED COLLOIDAL SUSPENSIONS
David Saintillan
University of Illinois at Urbana-Champaign, USA
- 18:00 – 18:20 FUNDAMENTALS OF ELECTROPHORETIC INFILTRATION FOR COMPOSITE
MATERIAL FABRICATION
Cullen Buie
Massachusetts Institute of Technology, USA
- 18:30 – 19:30 ***SESSION VIII: POSTER SESSION I***
- 19:30 – 21:00 Dinner
- 21:00 – 22:00 ***POSTER SESSION I*** (continued) *and Social Hour*

Wednesday, October 5, 2011

07:30 – 08:30 Breakfast

***SESSION IX: EPD INTEGRATED MANUFACTURING TECHNOLOGIES
AND INDUSTRIAL APPLICATIONS I***

Session Chair: Rolf Clasen

08:30 – 09:00

Keynote

EPD OF PHOSPHORS FOR DISPLAY AND SOLID STATE LIGHTING TECHNOLOGIES

Jan B. Talbot

University of California, San Diego, USA

09:00 – 09:20

MACRO- AND MICROSCALE FABRICATION BY FIELD ASSISTED NANOPARTICLE
ASSEMBLY – THE CHALLENGING PATH FROM SCIENCE TO ENGINEERING

Guido Falk

Saarland University, Saarbruecken, Germany

09:20 – 09:40

ELECTROPHORETIC FABRICATION OF RECHARGEABLE MICRO LITHIUM-ION
BATTERY WITH 3D CONFIGURATION

Hirokazu Munakata

Tokyo Metropolitan University, Japan

09:40 – 10:00

EPD OF REVERSE MICELLE PALLADIUM OR PLATINUM NANOPARTICLES ONTO
INDIUM PHOSPHIDE OR GALLIUM NITRIDE FOR HIGH-RESPONSE HYDROGEN
SENSORS

Karel Zdansky

Institute of Photonics and Electronics, Academy of Sciences, Czech Republic

10:00 – 10:20

ELECTROPHORETIC DEPOSITION OF POLYARYLETHETHERETHERKETONE (PEEK)
FROM A MATCHING DENSITY SOLVENT MIXTURE

Janet Hope

LVH Coatings Ltd., UK

10:20 – 10:40

DIELECTRIC MULTILAYER THICK FILMS OF BAO-LN₂O₃-TiO₂ (LN = ND, LA)
PREPARED BY ELECTROPHORETIC DEPOSITION

Paula M. Vilarinho

University of Aveiro, Portugal

10:40 – 11:00

Coffee Break

SESSION X: COATINGS AND COMPOSITES

Session Chair: Tetsuo Uchikoshi

11:00 – 11:30

Keynote

THE ELECTRODEPOSITION OF METAL-MATRIX NANOCOMPOSITES: A PATENT
REVIEW

Gregorio Vargas-Gutiérrez

Cinvestav-Unidad Saltillo, Mexico

Wednesday, October 5, 2011(continued)

- 11:30 – 11:50 INFILTRATION OF 3D FABRIC PREFORM FOR THE FABRICATION OF SICF/SIC COMPOSITE
Aljaž Ivekoviæ
Jožef Stefan Institute, Slovenia
- 11:50 – 12:10 ELECTROPHORETIC DEPOSITION ON NON-CONDUCTING SUBSTRATES FOR SOLID OXIDE FUEL CELL APPLICATION
Laxmidhar Besra
Institute of Minerals & Materials Technology (IMMT), India
- 12:10 – 13:30 Lunch
- 13:30 – 16:30 *Ad hoc* sessions and/or free time
- 16:30 – 17:00 Afternoon Coffee
- SESSION XI: EPD OF BIOMATERIALS AND BIOLOGICAL ENTITIES I***
Session chair: Aldo R. Boccaccini
- 17:00 – 17:20 ELECTROPHORETIC DEPOSITION OF BIOMOLECULES: FUNDAMENTALS AND APPLICATIONS
Omer Van der Biest
K.U.Leuven, Belgium
- 17:20 - 17:40 ALTERNATING CURRENT ELECTROPHORETIC DEPOSITION (AC-EPD) OF LIVING CELLS
Bram Neirinck
K.U.Leuven, Belgium
- 17:40 – 18:00 DESIGN OF EXPERIMENTS (DOE) APPROACH FOR THE ELECTROPHORETIC DEPOSITION OF PEEK COATINGS
Sigrid Seuss
Institute of Biomaterials, University of Erlangen-Nuremberg, Germany
- 18:00 – 18:20 ANTIBACTERIAL PROPERTIES OF NANOSTRUCTURED TITANIA-CERIA FILMS ON E-COLI
María Eugenia Contreras-García
Instituto de Investigaciones Metalúrgicas, UMSNH, Mexico
- 18:20 – 18:40 ELECTROPHORETIC DEPOSITION OF BIOMEDICAL COATINGS BASED ON CHITOSAN/BIOACTIVE GLASS COMPOSITES
Aldo R. Boccaccini
Imperial College London, United Kingdom
- 20:00 – 22:00 Conference Banquet

Thursday, October 6, 2011

07:30 – 08:30 Breakfast

SESSION XII: FUNCTIONAL FILMS AND DEPOSITS

Session chair: Paula M. Vilarinho

08:30 – 09:00

Keynote

STABILITY AND EPD OF CONCENTRATED SUSPENSIONS OF ALUMINA WITH NANOSIZED TITANIA

Rodrigo Moreno

Instituto de Cerámica y Vidrio, CSIC, Spain

09:00 – 09:20

ELECTROPHORETIC DEPOSITION OF POLYETHER ETHER KETONE (PEEK) FROM AN AQUEOUS SUSPENSION.

Beata Zalinska

Materials Science and Engineering, University of Sheffield, United Kingdom

09:20 – 09:40

PREPARATION OF PEROVSKITE-TYPE OXIDE THICK-FILM BY EPD METHOD AND ITS APPLICATION FOR ELECTROCHEMICAL ION-SENSOR DEVICE

Youichi Shimizu

Kyushu Institute of Technology, Japan

09:40 – 10:00

FABRICATION OF BARIUM FERRITE FILMS WITH A HIGH DEGREE OF MAGNETIC ORIENTATION USING ELECTROPHORETIC DEPOSITION

Simona Ovtar

Jozef Stefan Institute, Slovenia

10:00 – 10:30

Coffee break

10:30 – 10:50

HYBRID SUPERCAPACITOR SYSTEMS VIA EPD

Jan Ma

Nanyang Technological University, Singapore

10:50 – 11:10

GROWTH OF TITANIA MESOPOROUS COATINGS INDUCED BY ELECTROPHORESIS

Yolanda Castro

Instituto de Ceramica y Vidrio, CSIC, Spain

11:10 – 11:30

MULTI-WALLED CARBON NANOTUBE AND HEXAMETHYLENE DIISOCYANATE COMPOSITE COATING ON COPPER SUBSTRATE BY EPD

Laxmidhar Besra

Colloids & Materials Chemistry Department, India

11:30 – 12:30

Ad hoc discussions

12:30 – 14:00

Lunch

14:00 – 16:30

Ad hoc sessions and/or free time

16:30 – 17:00

Afternoon Coffee

Thursday, October 6, 2011 (continued)

**SESSION XIII: EPD INTEGRATED MANUFACTURING TECHNOLOGIES
AND INDUSTRIAL APPLICATIONS II**

Session Chair: Begona Ferrari

17:00 – 17:30

Keynote

ELECTROPHORETIC DEPOSITION ON NON CONDUCTING SUBSTRATES: A NEW
APPROACH AND DEVICE APPLICATION DEMONSTRATION

Paula M. Vilarinho

University of Aveiro, Portugal

17:30 – 17:50

EXAMPLES OF EPD PROCESS APPLICATIONS IN THE ELECTRONIC INDUSTRY AND
THEIR CHARACTERISTICS

Rolf Clasen, N.J.M. van Leth

Philips, The Netherlands

17:50 – 19:30

SESSION XIV: POSTER SESSION II

19:30 – 21:00

Dinner

21:00 – 22:00

POSTER SESSION II (continued) *and Social Hour*

Friday, October 7, 2011

07:30 – 08:30 Breakfast

SESSION XV: ADVANCED EXPERIMENTAL TECHNIQUES & NOVEL APPROACHES

Session chair: Gregorio Vargas-Gutiérrez

08:30 – 08:50 THE ROLE OF TRIETHANOLAMINE IN THE ELECTROPHORETIC DEPOSITION OF DIELECTRIC THICK FILMS

Paula M. Vilarinho
University of Aveiro, Portugal

08:50 – 09:10 CHARACTERIZATION OF A CERAMIC POWDER SURFACE BY CONTACT ANGLE MEASUREMENTS AND INFRARED SPECTROSCOPY

Bram Neirinck
K.U.Leuven, Leuven, Belgium

09:10 – 09:30 AC ELECTROPHORESIS, A NEW TECHNIQUE FOR DEPOSITION OF CERAMIC NANOPARTICLES; INTRODUCTION, APPLICATION AND MECHANISM

Babak Raissi
Materials and Energy Research Center, Iran

09:30 – 10:30 **Conclusions** (NEXT EPD CONFERENCE, INDUSTRIAL INVOLVEMENT, SCIENTIFIC NETWORK ON EPD, EUROPEAN PROJECTS, INCREASE PARTICIPATION OF “ELECTROCHEMISTRY COMMUNITY”, EDUCATIONAL MATTERS, ETC.)

Adjournment

Abstracts

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ELECTROPHORETIC MICRO DEPOSITING

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Rolf Clasen, Saarland University, Powder Technology of Glass and Ceramics

For industrial EPD-application aqueous suspensions are favourable due to the high polarity of water enabling high solid loadings and for environmental reasons. For many applications a local deposition might be of interest, therefore the electric field has to be focused on a small point. This is a real problem in aqueous suspensions with a high electrical conductivity.

Previously, an electrode configuration was developed at our institute with two movable point electrodes facing each other. Both electrodes are configured in such a way, that the cross sectional area is the only source of the electric field and the rest of the electrode is shielded (coaxial cable). Due to the small dimensions of the electrodes, selective deposits can be attained. Another possibility is to replace one of the point electrodes by a steady plate. In both arrangements structures with sizes in the millimetre range can be deposited. To improve the resolution, the electrodes must be positioned closer to each other. The limiting factor is, however, the formation of bubbles caused by water electrolysis at both electrodes, which disturb the electric field. Therefore the main problem that has to be solved is to avoid this bubble formation during the deposition process. This is not easy because the current density on a point electrode is high.

In this work, the generation of bubbles was suppressed by using asymmetric pulses of alternating voltage. Additionally, the electric field distribution was calculated (finite element method) to improve the electric field focusing. Furthermore, different EPD parameters were investigated using aqueous suspensions of nanosized alumina powders. In this way, deposits with dimensions similar or smaller than the electrode diameter (200 - 100 μm) were obtained. These deposits present steep edges and are relatively flat on top, thus, their shape is close to a cylinder. The deposition rate is in the order of 0.2 $\text{mg}\cdot\text{cm}^{-2}\cdot\text{s}^{-1}$. The small separation distance between the electrodes leads to high local electric fields, therefore to non-linear effects on the particles movement within the electric field. Such effects are also discussed in this work.

Future possible applications for this EPD micro-technique are prototyping or commercial manufacturing of individual structures like those required in the dental and ceramic printing industry.

DEPOSITION OF METAL AND METAL-OXIDE COATINGS USING NANOFLUID PRECURSORS

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Lucas Wilson, Vahid Firouzdor, Brandon Semurau, Benjamin Hauch, Yong Yang and Todd Allen,
Department of Engineering Physics, University of Wisconsin-Madison

Coatings of titanium, zirconium, vanadium, and their respective oxides are being deposited on ferritic steel substrates with nanofluid precursors using electrophoretic deposition (EPD) and. For EPD approach, the effect of voltage, current density, time and nanoparticle concentration (0.25% to 1%) on coating thickness and quality have been investigated. Depositions have been carried out using organic solutions such as acetone and acetyl acetone, and it has been shown that additions of small quantities of iodine or triethanol-amine (TEA) had a significant influence on current density, deposition rate and coating density. The long term practical goal of this study is to explore the aforementioned coatings for mitigating fuel cladding chemical interactions between the fuel and the cladding in a nuclear reactor. To this end, an experimental system has been built to deposit EPD coatings on the inside surface of long tubes (8mm in diameter) to simulate claddings. The system uses a co-axial electrode and coatings have been deposited on the inside surfaces of tubes up to 150mm in length. To further establish the efficacy of such coatings as diffusion barriers for mitigating fuel cladding chemical interactions, diffusion couple studies have been performed at 550oC for 100 hours of these coatings against cerium which is a commonly used surrogate for metallic uranium fuel. Initial studies have shown promising results. For example, for TiO₂ coated steel a diffusion layer of only 30μm was observed to develop as compared to uncoated steel where the diffusion layer thickness was noted to be upwards of 90μm.

HYBRID ELECTROPHORETIC DEPOSITION WITH ANODIZING PROCESS FOR SUPERHYDROPHILIC SURFACES ENHANCING CRITICAL HEAT FLUX IN POOL BOILING

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Cullen R. Buie*, Department of Mechanical Engineering, Massachusetts Institute of Technology

Superhydrophilic surfaces are fabricated by a hybrid process of electrophoretic deposition (EPD) and anodization in order to enhance the critical heat flux (CHF) in pool boiling. In classic boiling theory it is well known that the critical temperature to commence nucleate boiling depends on surface tension of the liquid and wettability of the heated surface. Several studies have shown that hydrophilic surfaces possess higher CHF than hydrophobic surfaces. The main factors to enhance CHF of a surface are high surface roughness (porosity) and high surface energy, providing superhydrophilicity. In our previous work, EPD was proven an effective method to produce surfaces with high roughness. The multi-scale structures resulting from EPD provide a high number of nucleation sites but also remarkably strengthen hydrophilicity. However, thin films produced by EPD are unlikely to be used for heat transfer surfaces due to the demanding working conditions. To overcome the low durability of EPD-produced surfaces, we suggest a hybrid EPD and anodization process. Here, EPD of ceramic nano-particles creates high roughness surfaces and anodized metal oxide layers reinforce the deposited particles by forming mechanical networks between particles. Thin aluminum plates are used as substrates for the hybrid process and two kinds of TiO₂ particles, both hydrophilic and hydrophobic, are dispersed in the electrolyte. Two parameters; anodization current and the relative suspension concentration of hydrophilic and hydrophobic TiO₂ particles, are varied in order to investigate the effect of wettability on CHF. The mass of the water bath, which is heated with the functionalized aluminum substrate, was measured with respect to time during boiling in order to estimate heat flux. In addition, the durability of the functionalized surfaces is evaluated by tracking the change in heat flux over time. The surfaces will be characterized with scanning electron microscopy, static contact angle measurements, and atomic force microscopy.

THE ORIENTATION OF BARIUM FERRITE FILMS: APPLIED MAGNETIC FIELD VERSUS ELECTROPHORETIC DEPOSITION

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Barium ferrite (BaF; BaFe₁₂O₁₉) is a hard-magnetic material and can be used without an external magnetic field when it is magnetically oriented. The crystallographic orientation of hexagonal plate-like crystals of BaF coincides with the magnetic orientation since the c-crystallographic axis corresponds to its magnetic easy axis. The aim of this work was to compare the orientation of BaF films prepared with electrophoretic deposition (EPD) with those prepared in the presence of a magnetic field.

BaF nanoparticles were synthesized hydrothermally at 160 or 240°C. The 160°C synthesis resulted in very fine particles (of around 10 nm) with a relatively narrow particle-size distribution. The 240°C synthesis, on the other hand, resulted in a broad particle-size distribution with particle diameters varying between 10 and 400 nm. From both types of particles, stable suspensions in 1-butanol were prepared with the addition of dodecylbenzene sulfonic acid as a surfactant. In the case of EPD the particles were deposited from suspensions on a corundum substrate coated with Au or Pt. The electric field varied between 43 and 142 V/m and the deposition time was 15 min. In contrast to this, a magnetic field of 0.5 T was applied only during the drying of the suspension that was dropped on the corundum substrate. The deposits were first fired slowly up to 460°C, in order to decompose the organics, and then sintered at 1150°C. The orientation of the films was determined from the X-ray diffraction analysis and from the magnetic properties. The microstructures of the films were observed with scanning electron microscopy. The particle size and the particle-size distribution of the used suspensions showed the most significant effect on the orientations of the films, and a higher degree of orientation was achieved for the suspension with the larger particles that have a broader size distribution. In contrast to all expectations, the maximum possible orientation of 80-90% was achieved regardless of the nature of the applied field. We will show that the orientation of the BaF films was possible during the EPD due to the shape anisotropy of the BaF particles and that the magnetic field oriented the BaF particles as a result of their magnetic anisotropy.

TEXTURED Ti₃SiC₂ BY EPD IN A STRONG MAGNETIC FIELD

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Ti₃SiC₂ is a representative MAX phase. The MAX phases are a new class of ternary, layered, hexagonal carbides and nitrides, having the general formula, Mn+1AX_n, (MAX), where M is a transition element, A is Group A element and X is carbon or nitrogen; are gaining importance in the world of ceramics due to their unique and intriguing amalgam of metallic and ceramic properties. Ti₃SiC₂ is the most widely studied and understood MAX phase till date. The mechanical properties of this phase and the other MAX phases have been extensively studied. But so far there is no work on the functional properties of this exceptional class of solids. Texture development in ceramics in order to enhance their physical properties is of growing interest recently. There are a few clues towards the effect of texture on the frictional and ductile nature of MAX phases in the literature and recently a couple of work evidencing the enhancement of bulk mechanical properties of the MAX phases as an effect of texture development. The aim of this work is to investigate their functional properties as a function of texture in their microstructure.

We have adopted the facile, precise and established ceramic forming process of EPD in a strong magnetic field for the development of textured Ti₃SiC₂. To begin with the optimum amount of dispersant (PEI) was determined by zeta potential and viscosity measurements. A stable suspension in 50% ethanol and 50% water mixture, maintained at an appropriate pH was chosen for EPD. Thus the suspension parameters and then the EPD parameters were optimized in order to obtain good free standing deposits of Ti₃SiC₂. Consequent application of a strong magnetic field of 12T during EPD resulted in highly textured Ti₃SiC₂ with C-axis oriented perpendicular to the direction of magnetic field. The texture development was corroborated by XRD pole figure measurement.

ORIENTATION CONTROL OF HEMATITE VIA TRANSFORMATION OF TEXTURED GOETHITE PREPARED BY EPD IN A STRONG MAGNETIC FIELD

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Hematite (α -Fe₂O₃) has a corundum structure with a rhombohedral bravais lattice. The thermal stability of hematite is excellent among iron oxides because hematite is the most stable oxide phase. It is magnetically classified in a weak ferromagnetic group at room temperature; however, it is very significant if the magnetic property of the hematite can be improved up to the degree that corresponds to the magnetic property of ferrite materials without doping any elements having low Clarke numbers. Texture control in polycrystalline materials is promising because it can improve their properties equivalent to those of single crystals from inexpensive, commercially-available raw powder. Templated grain growth and hot/sinter forging are well-known techniques to fabricate textured polycrystals but these methods require large, single-crystalline seed particles for abnormal grain growth during sintering. Magnetic alignment is another good method to texture the microstructure, but the dense packing of hematite particles in a magnetic field is difficult due to their ferromagnetic property; they connect to each other and form a chain structure. Therefore, we focused on goethite (α -FeOOH) with an orthorhombic bravais lattice, as a precursor. In this study, textured hematite was fabricated from paramagnetic goethite by electrophoretic deposition in a strong magnetic field followed by thermal treatment via topotactic phase transformation. The completely-textured hematite was obtained by sintering the goethite compact at 1200 degree C. The a,b-axis of the goethite was taken over the c-axis of the hematite through the topotactic phase transformation. The textured hematite showed an anisotropic magnetic property depending on the direction of the crystalline orientation.

GROWTH DYNAMICS OF CDS-PAMAM DENDRIMERS NANOCOMPOSITES STUDIED IN THE PRESENCE AND THE ABSENCE OF AN ELECTRIC FIELD

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Semiconductor nanocomposites synthesis has attracted the attention of research groups worldwide due to their optoelectronic applications. Since their novel optical properties are strongly dependent from the size and the shape adopted by their particles, the control of these parameters during the synthetic process would involve a well understanding about the growth mechanism.

In this investigation, poliamidoamide (PAMAM) dendrimers generation (G3.5 and 4.0, bearing 64 COOH or NH₂ groups, respectively) and G4.0-OH (bearing 64 peripheral OH groups) were employed to synthesize CdS-dendrimer nanocomposites (CdS-nc) in the presence and in the absence of an electric field. Firstly, 0.1mM solutions in MeOH of each type of dendrimers were prepared adjusting the pH in 7.5. 1.0mM methanolic solution of Cd(NO₃)₂ was added to the solutions containing dendrimers generations 4.0 and 4.0-OH (or 0.5mM for the solutions containing dendrimers generation G3.5) under stirring for 24h. Finally, 0.126 mL of each solution containing the respective Cd²⁺-dendrimer complex, were diluted in 1.75mL of pure MeOH and immediately then combined with 0.126 mL of an equivalent solution of Na₂S in MeOH under strong stirring. All the experiments were carried out at 25°C. To estimate the particle radius evolution during the CdS-nc growth, the Brus Equation was fed with the optical band-gap of these nanocomposites, previously registered as a function of the time. These preliminary results suggested that the CdS crystallization occurred inside the dendritic structure.

To better understand the CdS-nc mechanism growth, the experimental data obtained in absence of electric field were fitted to a theoretical model based on the mass transport controlled by diffusion. The results indicated that, while the nanocomposites radii were not affected by the internal chemical structure of the dendrimers, the peripheral dendritic groups (NH₂, COOH or OH, respectively) on the other hand seems to be the determining variable that promotes a well control of the CdS-nc radii. A viable explanation for this phenomenon suggests that the diffusion of the S²⁻ anions is strongly dependent of the electric charge associated to the peripheral groups regarding the pH solution (NH₃⁺, COO⁻ and OH, respectively). The experiments carried out in the presence of an electric field showed in comparison, a quick evolution of the nanocomposites particles radii under these conditions, thus suggesting that the migration of the S²⁻ ions allow to overcome the resistance against the diffusion through the external dendritic groups when PAMAM dendrimers bearing NH₃⁺ peripheral groups are used.

PULSE PULSE/REVERSE ELECTRIC FIELDS FOR EPD OF THERMAL BARRIER COATINGS

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Thermal barrier systems have been employed as protective coating systems for gas turbine components for several decades; providing thermal, oxidation and mechanical protection, thereby extending the component's life expectancy. Thermal barrier systems consist of four primary elements; a thermal barrier coating (TBC), a thermally grown oxide (TGO), a bond coat and a substrate, with each element serving a unique purpose. The TBC topcoat functions primarily as a thermal insulator for the substrate, reducing the underlying metallic substrate temperature by several degrees during turbine operation. Yttrium-stabilized zirconia (YSZ) is the most widely studied and used TBC material. The chemically inert zirconia prevents corrosion, shows good mechanical integrity when introduced to thermal cycling and thermal shock, has a high thermal expansion coefficient similar to many metals, has a high melting point and a low thermal conductivity. The yttrium prevents a phase transformation that contributes to mechanical failure of the coating occurring under stresses at elevated temperatures.

In this work, conventional electrophoretic deposition (EPD) is being combined with pulse and pulse reverse electric fields to deposit YSZ onto turbine alloys for TBC systems. The addition of the pulse and pulse reverse electric fields to the EPD process has demonstrated the capability to decrease the coating roughness, minimize hydrolysis, and decrease coating edge effects commonly encountered in electrochemical deposition processes. Subsequent to EPD from an ethanol based suspension, the green coatings were subjected to a combined binder burnout and sintering process for further coating densification. The coatings have been qualified in terms of surface roughness, microstructure, thermal conductivity, and short and long-term thermal cycling tests.

ELECTROPHORETIC DEPOSITION OF CERAMIC COMPACTS FROM AQUEOUS SUSPENSIONS

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The preparation of ceramic compacts via electrophoretic deposition (EPD) has a lot of advantages like high deposition rates and the formation of homogeneous compacts with high green density even of particles with different sizes. Aqueous suspensions are most favorable for industrial application due to environmental reasons and lower costs. As a fast deposition needs voltages above the decomposition voltage of water the problem of the formation of bubbles has to be solved. There are different concepts to circumvent this problem: (1) oxidizable electrode, (2) oxidizable electrolyte, (3) membrane process, (4) utilization of dynamic and/or non-linear mechanisms. These mechanisms of the processes are discussed in more detail and are also compared to non-aqueous systems. As the EPD is not yet established in the industrial fabrication of a large number of shaped compacts and new processes are always in competition to established processes, a big chance is seen for the preparation of compacts with pure nanopowders or bimodal mixtures with nanopowders. In the field of coatings the EPD is applied on an industrial scale since a long time. Thus this experience should also be considered for the EPD shaping of compacts. A lot of examples of EPD compacts are shown presenting more than 20 years of experience in this field.

FLY ASH/RARE EARTH OXIDE COATINGS BY EPD: PROCESSING AND CHARACTERIZATION

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Ceramic coatings are commonly used for a wide variety of industrial applications. In particular, thermal barrier coatings (TBCs) can be engineered for thermal protection of aircrafts and stationary gas turbines, combustor liners, heat exchanger tubes, panels of re-entry space vehicles and hot components in molten glass manufacturing plants. However, decreased efficiencies in energy conversion systems as well as failure in coatings components are the driving forces towards the development of new thermal protective and insulating materials. Zircon oxide (ZrO_2), Ytria stabilized zirconia (YSZ), Mullite ($3Al_2O_3 \cdot 2SiO_2$) and Zircon mixed with Rare earth oxides (La, Ce, Y) are the ceramic materials used for this purpose. In contrast with metals, these materials have superior oxidation and corrosion resistance, wear resistance, and are better thermal insulators. YSZ is the most used thermal barrier coating with the main disadvantage of tetragonal to monoclinic transformation leading to formation of cracks in the coating. On the other hand, Fly Ash (FA) is a waste material from electricity generation plants. This material has high mullite content which is a promising material for thermal barrier coatings due to its high thermal stability, low thermal conductivity, high resistance in highly oxidative and corrosive environments, high resistance to crack propagation and high thermal shock resistance. In addition, rare earth oxides, (e.g. La_2O_3 and CeO_2) have potential as thermal barrier coatings because they have lower thermal conductivity and higher thermal expansion coefficients than YSZ and ZrO_2 and they are also chemically inert. Therefore, this research is focused on the processing and characterization of electrophoretically deposited coatings based on fly ash modified with rare earth oxides with the aim to form novel materials that can be used as thermal barrier coatings in high temperature applications. The electrophoretic deposition (EPD) technique was selected because of its wide range of applications in the processing of advanced ceramic materials and coatings, high versatility to use with different materials and its cost-effectiveness.

ELECTROPHORETIC DEPOSITION OF THIN-FILM ENERGY-STORAGE DEVICES

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A vast array of mobile applications, from micromedical to high-power automotive devices, has paved the roadmap with unlimited potential for thin-film lithium-ion batteries. One of the approaches to the achievement of increased capacity and power capability of thin-film batteries per footprint is to replace a continuous 2D-substrate with a perforated one with high-aspect-ratio through microchannels, thereby utilizing the inner volume of the substrate. In such a 3D-configuration, each microchannel comprises a thin-film, sandwich-like 3D-concentric microbattery (3D-CMB) unit of two active-material electrode layers (cathode and anode) separated by an ionically-conducting and electronically-insulating separator layer. The larger the number of units connected in parallel, the higher the battery capacity and power capability. Most thin-film electrode and separator materials used in commercial thin-film batteries are deposited by RF, DC magnetron sputtering, PVD and CVD processes. PVD cannot be used on 3D perforated substrates. CVD requires costly, unstable and dangerous organometallic compounds and is typically carried out at high temperatures with very expensive equipment.

We have recently found that two- and three-layer thin-film-battery stacks can be prepared by sequential electrophoretic deposition (EPD) on a given conductive substrate which can also serve as a current collector. A three-layer LiFePO₄/separator/MCMB battery was prepared by EPD on a planar, gold-coated, perforated silicon substrate. The deposition time, applied voltage, type of solvent and additives influence the morphology, adhesion and porosity of EPD battery layers. The separator is a porous solid impregnated with an ion-conductive LiPF₆:(EC/DEC) liquid electrolyte to provide a "composite polymer-ceramic electrolyte". The separator porosity varies between 40-60%. The experimental results of ESEM, XRD, XPS characterization of the modified materials and electrochemical tests of the 2D and 3D batteries will be presented.

CATODIC ELECTRODEPOSITION AND CHARACTERIZATION CERIA STABILIZED ZIRCONIA FILM USING XPS, TEM, SEM AND AFM

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Ceria partially stabilized zirconia (CePSZ) in the cubic fluorite structure has been widely investigated, because of its multiple applications, such as catalyst and electrolyte material of solid oxide fuel cells. CePSZ nanostructured film was deposited on 316 stainless steel using an electrodeposition method. This technique is considered to be an important tool in the formation of nanostructured materials, including films, powders and composites. In this work we used a solution of $ZrOCl_2 \cdot 8H_2O$ - $Ce(NO)_3$, with 3 % concentration of ceria as a stabilized, the electrolysis was performed at 5V , the time of electro deposition was (1.5) minutes this parameter were maintained constant. Then as prepared thin mixed oxides films have been calcined in air at 600°C. To examine the structure and composition of one layer of 3CePSZ deposited on 316 stainless steel. This film was tested with several experimental techniques: XPS, SEM, TEM, EDS and AFM. XPS present peaks Zr 3d and Ce 3d SEM showed that uniform and homogeneous films were obtained which do not show cracks. TEM showed nanostructures with agglomerate sizes between 10-14 nm. EDS showed the peaks of Zr, Ce and the elements of the substrate. AFM results verified that there were no cracks in the surface and that little roughness was present on the film.

Acknowledgments: We Acknowledge to CIC of the UMSNH.

ASSEMBLING AND PACKING OF NANOSTRUCTURES UNDER AN ELECTRIC FIELD

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In colloidal processing, formation of arrays and particle compaction are strongly improved providing a large number of opportunities for structural organisation. However, most colloidal processes suffer limitations when highly concentrated and fluid suspensions of nanoparticles are required. To overcome these limitations, electrically driven processes are proposed. In electrophoresis an electrical force, directional in its nature, is applied by means of an external electric field to stable slurries obtaining 2D and 3D arrays of nanoparticles. Many solid substances are suitable for use in this process. Furthermore, sols and/or suspensions with lower viscosity restrictions can be used for electrically driven assembly of nanoparticles. This circumstance significantly increases its technological applicability. This work focuses on the performance of nanostructured thin films by assembly of different nanoparticles in nature and shape. Flake-like ZnO and spherical YSZ nanoparticles synthesized by precipitation and under hydrothermal conditions, respectively, and stabilised in aqueous media at a low solid concentration (< 0.1 g/l), has been used. Dispersion and suspension parameters, such as ultrasonication time, zeta potential and particle size, have been adjusted to the particle chemistry, shape and suspension concentration. Organised, dense and transparent nanostructures with thicknesses lower than $1 \mu\text{m}$ have been obtained. Morphology and growth of the films have been discussed in terms of forces acting over particles when they approach to the working electrode.

HIGH VOLTAGE ELECTROPHORETIC DEPOSITION OF VERTICALLY-ALIGNED NANOFORESTS FOR SCALABLE NANOMANUFACTURING OF ELECTROCHEMICAL ENERGY STORAGE DEVICES

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We report a novel approach to simultaneously deposit and vertically align 1D nanoparticles (e.g., carbon nanotubes and MnO₂ nanorods) into nanoforests under room temperature. The process is completely compatible with integrated circuit fabrication and Si micromachining. It can also be easily carried out on any conductive, including flexible and transparent, substrates. The process, named high-voltage electrophoretic deposition (HVEPD), has been enabled by three key elements: high deposition voltage for alignment, low dispersion concentration of the nanoparticles to avoid aggregation, and simultaneous formation of a holding layer by electrodeposition. We will report comprehensive investigation on the effects of several key deposition parameters, including the voltage, time, deposition medium, holding mechanism, and concentrations of nanoparticles and precursor of the holding layer. Scanning electron microscopy of the samples is extensively used to reveal the morphology of the deposited sample. The alignment on the vertical direction has also been quantitatively investigated by their superhydrophobicity, electrochemical performance, and capability to electrically connect two separated electrodes. Compared with their randomly oriented counterparts, the aligned nanoforests obtained showed higher electrochemical capacitance, lower electrical resistance and the capability to achieve superhydrophobicity, implicating their potential in a broad range of applications.

In addition to the preliminary work we recently reported to [1], the presentation will especially focus on reducing contact resistance by employing conductive holding layer, introducing hybrid structures to boost electrochemical performance and scale-up fabrication of large-area, nano-architected electrodes for printable supercapacitors.

Reference: [1] S. Santhanagopalan, F. Teng, and D. D. Meng, 'High-Voltage Electrophoretic Deposition for Vertically Aligned Forests of One-Dimensional Nanoparticles,' *Langmuir*, vol. 27, pp. 561-569, 2011.

THIN FILMS OF EUROPIUM(III) DOPED-TiO₂ PREPARED BY ELECTROPHORETIC DEPOSITION FROM NANOPARTICULATE SOLS

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Colloidal sol-gel is a common method used for the obtention of stable and homogeneous sols and thin films. The nanoparticulate sols can be easily deposited by EPD, which is a versatile technique for producing denser and thicker coatings than those produced by other techniques like dipping. A complete characterization of the sols, such as colloidal stability and electrophoretic mobility, which can be determined through zeta potential measurements, as well as the influence of deflocculants in the surface properties, is needed before using electrophoretic deposition. In this work, we have prepared sols of TiO₂ with an alkoxide:water molar ratio of 50:1 and Eu(III) doped-TiO₂ (2 mole % Eu(III)) using as precursors titanium (IV) isopropoxide and europium (III) acetate hydrate, respectively. The stability of the particulate sols was studied in terms of conductivity, zeta potential and viscosity evolution. Stable sols were deposited on stainless steel substrates by electrophoretic deposition under both constant current and constant voltage conditions. Using different intensities and deposition times we have obtained thin films with different features (thicknesses and morphology) and different optical properties. The presence of europium (III) increases particle size, viscosity and peptization time and decreases the band gap of TiO₂. In addition, Eu³⁺ possesses several photoactive excited state transitions [$5D_0 \rightarrow 7F_J$ ($J = 0-4$)] through which the characteristic photoluminescent properties of TiO₂/Eu³⁺ nanoparticle films, exposed to UV light, were observed.

OPTIMIZATION OF AQUEOUS ELECTROPHORETIC DEPOSITION OF NANO-STRUCTURED TITANIA FILMS FOR DYE-SENSITIZED SOLAR CELL APPLICATION

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The fabrication of mesoporous nanotitania films on FTO-glass by electrophoretic deposition (EPD) in aqueous suspension has been studied. In the majority of previous works multi-component organic media have been used that impose environmental challenges to large scale implementation of EPD. Here water is investigated instead as the suspension medium. The influence of the suspension composition, such as the concentration of particles, addition of co-solvent and binder on the physicochemical properties of TiO₂ thin film was investigated. Among the different ratios of added isopropanol (5-40 V/V %) to water, 5% was chosen as the optimum one with respect to suspension stability, surface tension and feasibility of film adhesion to the substrate. Poor adhesion to the substrate due to the electrolysis of water or/and crack formation during drying, are among the obstacles encountered for EPD in aqueous suspension. As reported in this communication these difficulties were largely minimized via the judicious selection of EPD operating current and potential conditions but more importantly the addition of zinc nitrate in the aqueous suspension. During the EPD of TiO₂ particles on the cathode substrate (FTO-glass), zinc hydroxide formed, which acted as a binder. The zinc hydroxide was subsequently converted to zinc oxide by sintering. This zinc oxide has similar electronic properties as titanium dioxide hence is highly suitable for fabrication of photoanodes destined for use in dye-sensitized solar cell (DSCs). As a result of this work, high quality and adhesive TiO₂ films can be produced in an environmentally-friendly aqueous suspension providing a low cost clean alternative to DSC photoanode manufacture.

TUNABLE SURFACE WETTING IN TRANSFERABLE FILMS OF GRAPHENE OXIDE

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Graphene, the single atomic layer sheet of carbon that constitutes graphite, is a material with exceptional electrical conductivity and mechanical strength. Graphene can be isolated by mechanical cleavage of graphite ('Scotch tape method') or can be grown by thermal decomposition of silicon carbide. Producing graphene on a larger scale has proved challenging. One promising, recently popularized approach entails (a) the conversion of graphite to graphite oxide, (b) the exfoliation of graphite oxide to yield separate graphene oxide sheets, and (c) the reduction of the graphene oxide sheets to graphene-like sheets [1]. The colloidal graphene resulting after steps (b) or (c) can be assembled into multilayered composites, using techniques like vacuum filtration and electrophoretic deposition. These multilayered materials demonstrate very good electrical conductivity, tensile strength, and flexibility, which make them promising components for electrical and optical devices.

In this presentation, we report the fabrication of multilayered films assembled from aqueous suspensions of graphene oxide using electrophoretic deposition. We address how to determine the stability of the colloidal system and how the suspension can be tuned over a range of pH values. We then show how macroscopic films of graphene oxide, with an assortment of microstructures, can be produced using electrophoretic deposition. The water contact angle for smooth graphene oxide films was $41.1^\circ \pm 1.2^\circ$ while the inclusion of microscopic voids in the graphene oxide film raised the contact angle to $79.1^\circ \pm 3.5^\circ$. We hypothesize that the changes in surface wetting of these films resulted from changes in the microstructure, not changes in the chemical composition. To verify this hypothesis, we isolated these graphene oxide films as free-standing objects using the "sacrificial layer electrophoretic deposition" (SLED) technique [2]. X-ray photoelectron spectroscopy (XPS) measurements of the films, transferred to silicon substrates, revealed no appreciable differences in the chemical composition of the films.

[1] S. Park and R. S. Ruoff. *Nature Nanotechnology* 4, 217-224 (2009).

[2] S. A. Hasan, D. W. Kavich, and J. H. Dickerson. *Chemical Communications* 3723-3725 (2009).

**FUNCTIONALLY GRADED, NANOSTRUCTURED MATERIALS VIA PATTERNED
ELECTROPHORETIC DEPOSITION**

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Functionally graded materials fabricated with gradients in composition, microstructure, and/or density produce enhanced bulk properties, generally a combination of the precursor material properties. Current graded materials are primarily produced by coarse, layered processing techniques or melt-based approaches which are typically limited to gradients of composition along one axis only. To overcome this limitation new techniques using electrophoretic deposition technology have been developed to fabricate functionally graded, nanostructured materials tailored in three dimensions. In this presentation, we will demonstrate this new capability with both organic and inorganic particles, and compare the results with computer modeling of relevant systems.

This work was performed under the auspices of the United States Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

FABRICATION OF 2-DIMENSIONAL IRON OXIDE NANOPARTICLE SUPERLATTICES BY ELECTROPHORETIC DEPOSITION

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Many potential commercial and industrial applications of nanoparticles rely on fabrication techniques that are facile, rapid, and site-selective which create homogenous, densely packed, defect-free thin films. Evaporation-induced self assembly and Langmuir-Blodgett casting are commonly used techniques in the formation of two-dimensional superlattices, but these methods lack the ability to achieve large-scale ordering as well as robust chemical and structural properties. Electrophoretic deposition (EPD) on other the hand does not have these limitations. EPD is a rapid, safe, and facile method of depositing nanoparticles on a large scale. EPD uses the most favorable attributes of NP deposition to quickly and easily form large scale films.

NP superlattices exhibit enhanced properties over their single nanoparticle counterparts. Exchange coupling between neighboring NPs can affect the magnetic properties. Enhancement of photoluminescence has been seen in large CdSe NPs, and extinguishment of photoluminescence has been seen for smaller CdSe NPs.

We have synthesized monodisperse iron oxide NPs of ~14nm using a solution phase synthesis technique. Before EPD of these particles was done, we repeatedly centrifuge the particles, removed the supernatant and resuspended the particles in solution, a process called cleaning. We then repeatedly let this solution air dry and again resuspended the particles, a process called D&R. Finally, EPD is conducted in the solution on silicon substrates and solely DC electric fields. We varied the number of cleanings and D&Rs and compared the resulting films and current profiles for the EPD. The films are analyzed using a scanning electron microscope and atomic force microscope. Future investigations will explore the mechanism behind 2D superlattice formation.

ASSEMBLING OF ZNO NANOFILMS WITHIN ORGANISED THICK FILMS

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Interest in ZnO-based structures has recently increased due to their great potential for a wide range of applications, including chemical sensors, transparent semiconductors or high speed, highly integrated, low power and low cost electronic and optoelectronic devices. Different techniques have been studied to grow ZnO thin films, such as magnetron and rf magnetron sputtering, metal-organic chemical-vapor deposition, and pulsed laser deposition among many others. Electrophoretic deposition (EPD) is gaining increasing interest as a processing technique due to its versatility to obtain complex structures in the nanoscale, as well as due to its high potential for scaling up to large volumes. Actually, EPD might become an alternative to the evaporative coating processes to tailor ceramic nanostructures and nanoparticles assembly.

Effectiveness of EPD and ordering of the nanostructure have been related to main suspension parameters, especially to those related to the suspension's stability, i.e. stable and well monodisperse suspensions are a necessary requirement. On the other hand, conductivity, current density, directionality and intensity of the electric field, as well as deposition time, play a determinant role in the particles assembly success, rate and behaviour. Based on the different polarity of the suspension media, organised and dense thick films have been prepared by EPD using two solvent-dispersant systems: hexane and water-PEI. The resulting nanostructured films have been characterised by HR-TEM, AFM, FE-SEM and different spectroscopic techniques.

EPD OF METAL OXIDE NANOPARTICLES FROM POLYOL-BASED COLLOIDAL SUSPENSIONS

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Microwave-assisted synthesis of nanoparticles in polyols is a well-established technique for the production of colloidal suspensions. In this technique, metal precursors are dispersed in polyols, and nanoparticles are then synthesised by microwave-heating the mixture. Microwave-assisted synthesis of nanoparticles in polyols produces suspensions of extremely fine particles (~10 nm), characterized by exceptional colloidal stability. Furthermore, flexible functionalization of the particles' surface can be performed, allowing the fine-tuning of key colloidal parameters, like zeta potential and particle size distribution. Both the exceptional colloidal stability of such suspensions and the outstanding physico-chemical properties of nanosized metallic and oxidic materials render polyol-based suspensions very attractive systems for EPD applications. Despite the abovementioned properties, in most cases EPD from polyol-based suspensions did not appear to be straightforward, even though high values of the zeta potential were measured and no sedimentation of the particles was observed to take place over several months. Since such high stability was to some extent preserved after adding controlled amounts of solvents to the suspensions, modifications of the composition by dilution were attempted, which in some cases led to successful EPD. This empirical observations, besides leading to successful EPD from some polyol-based suspensions, may provide some insights on the fundamental mechanisms through which the two main steps of EPD, i.e. mass transport and coagulation, take place in these systems. In this presentation, we report about the practical results of EPD trials from some of these system and the possible explanations of either success or failure in achieving the formation of the EPD films.

MECHANICAL PROPERTIES OBTAINED BY NANOINDENTATION OF NANOSTRUCTURED TITANIA-ALUMINA FILMS

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TiO₂-Al₂O₃ nanoparticles were synthesized and deposited on glass substrate using sputtering and electrophoresis combined deposition methods. Optimization of the process resulted in homogeneous nanostructured films. The mechanical properties of TiO₂-Al₂O₃ nanostructured films were obtained by nanoindentation techniques, the experimental procedure to obtain these films, and the characterization are discussed in this work. The nanostructure of the films was analyzed using Scanning Electron Microscopy, Transmission Electron Microscopy and Atomic Force Microscopy; the topography of the films was also analyzed, with Atomic Force Microscopy. The nanoindentation techniques allowed to estimate the nanohardness of the film and also let to derivate the adhesion properties of the film to the Corning glass substrate. A significant nanohardness and good mechanical behavior of the films was demonstrated. Keywords: Mechanical properties, titania-alumina, anatase, sputtering, electrophoretic deposition, nanoindentation.

ELECTROPHORETIC ASSEMBLY OF TiO₂ NANOCRYSTALS IN NON POLAR-SOLVENTS

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The work discussed in this presentation contributes to the production of continuous, freestanding films of densely-packed titanium oxide (TiO₂) nanocrystals, synthesized by solvothermal synthesis and assembled by sacrificial layer electrophoretic deposition (SLED) using non-polar solvents. TiO₂ has attracted significant research interest due to its photochemical activity and optical properties. Colloidal nanocrystals (NCs) have increasingly been employed due to their attractive size-dependent optical properties. Precise control of the morphology and the size of these materials at nanometric scale is of a basic importance to fine-tuning of their physical properties, such as electrical conductivity or magnetic, optical and mechanical characteristics. Hence, to improve the preparation method of nanocrystalline TiO₂ with a narrow size distribution is of great importance.

Electrophoretic deposition (EPD) of particles from colloidal suspensions stands out as a powerful and versatile colloidal process to face inexpensive and mass production of films using low concentrated suspensions. Ceramic NCs can be easily deposited by EPD on any conductive substrate. Furthermore, EPD can facilitate much thinner films than can be produced by other techniques, such as tape casting. Interestingly self-ordering occurs during EPD in monolayers of certain colloidal nanocrystals, which may allow the production of highly ordered 3-D NC structures. To assemble NCs obtaining free-standing films, SLED has been used as a technique to facilitate multilayered NC films with macroscopic lateral dimensions after the sacrificial layer is dissolved.

The electrical parameters of the TiO₂ nanocrystal suspensions were optimized to achieve the necessary NC deflocculated conditions and to produce homogeneous films of nanocrystals by SLED using non-polar solvents. The associated physical properties, current density, potential, electric field and deposition time, were optimized to produce homogeneous self supporting films.

ZN BASED STRUCTURES THROUGH HOMOGENEOUS PACKING AND SEEDING OF ZNO NANOPARTICLES BY EPD

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Electrophoretic deposition is a very useful technique to obtain complex structures in the nanoscale, films, laminates or micropatterned arrays, with controlled thickness and morphology. The main parameters that determine the effectiveness of EPD are those related to the suspension stability, i.e. stable and well dispersed suspensions are a necessary requirement. On the other hand current density, directionality and intensity of the electric field as well as the deposition time, among others, play a determinant role in the obtaining of homogeneous and reproducible deposits. In the present contribution all these parameters have been studied and optimized in order to prepare uniform films of ZnO nanoparticles on different substrates. The obtained deposits show a remarkably high packing density of oriented nanoparticles, as inferred from AFM, FE-SEM and different spectroscopic measurements. Drying and sintering processes of the as-deposited films were studied by means of different thermal treatments, and their electrical characterization revealed semiconductor behaviour. Finally the usefulness of these films as seeded templates for further growth of ZnO structures with tailored orientation under hydrothermal conditions was analyzed.

DIRECT NUMERICAL SIMULATIONS OF ELECTROPHORETIC DEPOSITION OF CHARGED COLLOIDAL SUSPENSIONS

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Motivated by applications in the field of functionally graded materials, we perform large-scale numerical simulations of the electrophoretic deposition of suspensions of charged colloids in an electrolyte. A simulation method is developed to model the full deposition process, that captures linear electrophoresis, dipolar interactions, van-der-Waals forces, steric interactions, Brownian motion, as well as electric and hydrodynamic interactions with the electrodes. Using a fast algorithm, suspensions of up to 5,000 particles are simulated, and results are reported for the final deposit microstructure as a function of effective electric Peclet number, particle size and concentration. The simulation results demonstrate that regular crystalline colloidal assemblies are obtained at low field strengths and volume fractions, while more random structures with frequent defects are formed at high Peclet numbers and volume fractions, in agreement with recent deposition experiments.

FUNDAMENTALS OF ELECTROPHORETIC INFILTRATION FOR COMPOSITE MATERIAL FABRICATION

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In this study we numerically model particle flow-fields through simple porous materials and experimentally verify the models with controlled geometry microfluidic chips milled from poly(methyl methacrylate) (PMMA). The objective of this work is to better understand fabrication of composites from porous substrates using electrophoretic deposition. We will explore the influence of pore and particle surface charge on electrophoretic infiltration and make recommendations for composite materials design. We will also explore the influence of electrical double layer (EDL) thickness, particularly for the case of overlapped particle EDLs. Overlapped EDLs are prevalent at the high particle concentrations required for fast material fabrication. Further, we will define an infiltration efficiency based on nondimensional parameters relating particle size to pore size, electric double layer thickness (Debye length) to pore size, and van der Waals forces to electrostatic repulsion.

EPD OF PHOSPHORS FOR DISPLAY AND SOLID STATE LIGHTING TECHNOLOGIES

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Electrophoretic deposition (EPD) has been used as a phosphor screening procedure for a variety of information displays and more recently, solid state lighting. EPD is well suited to deposit the fine (nanometer to micrometer diameter) phosphor particles needed for high resolution displays. The fundamentals of the EPD process in a standard isopropanol bath are characterized by the dissociation behavior of nitrate salts in isopropanol, measurement of the effects of pH and nitrate salt concentration on the zeta potential of the particles, and processing conditions with modeling of the deposition rates. Methods to fabricate full-color screens and the optical performance of the phosphor films will be reviewed. Recent results on the EPD of nanophosphors for solid state lighting applications will be discussed.

MACRO- AND MICROSCALE FABRICATION BY FIELD ASSISTED NANOPARTICLE ASSEMBLY – THE CHALLENGING PATH FROM SCIENCE TO ENGINEERING

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While electrokinetic phenomena of nanoparticles have been extensively examined in terms of rheological behaviour, colloidal stability as well as intrinsic colloidal behaviour of suspensions, electrokinetic shaping of ceramic nanoparticles associated with non-equilibrium surface phenomena to solve any problems in the physics and chemistry of interfaces and tailoring of green body formation in the nanoscale have hardly been examined so far. This matter of fact is all the more amazing because among colloidal shaping techniques electrokinetic shaping methodologies cope with electrokinetic nature of nanoparticles suspended in aqueous and non-aqueous dispersion media. Since non linear electrokinetic shaping phenomena of nanoparticles reveal an enormous potential of tailoring green body structures and characteristics down to the nanoscale general fundamental aspects, experimental techniques and numerical analysis of non linear electrokinetic shaping techniques will be reviewed. Three different techniques of field assisted nanoparticle assembly will be discussed in detail: Electrophoretic processing of lateral functional coatings related to the specific requirements of fuel cell related materials applications, submerged writing methodology of colloidal ceramic matters onto substrates under the influence of external electrical fields (field assisted impinging jet deposition) and field assisted assembly of microstructures in lithographic templates. The mechanics of particle deposition and patterning is theoretically applied to a mathematical and numerical convection-diffusion-migration model. Specific requirements on electrokinetic nanoparticle characteristics, suitable field-assisted AC and DC parameters and efficient methodologies and analytics of process control were concluded in order to better match the needs of technology in terms of the scalability, control and precision of EPD derived processing techniques.

ELECTROPHORETIC FABRICATION OF RECHARGEABLE MICRO LITHIUM-ION BATTERY WITH 3D CONFIGURATION

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The need to miniaturize and integrate devices has recently been increasing, and this trend also applies to lithium-ion batteries. Conventionally, micro lithium-ion batteries are constructed in a 2D arrangement by chemical vapor deposition or sputtering, in which thin layers of anode and cathode are stacked via an electrolyte layer. This configuration allows high current density with cycle performance due to fast Li⁺ transport over a short distance between the electrodes. Unfortunately, however, thin film lithium-ion batteries have quite a low capacity that is restricted by the dimensions of cell components, namely small amounts of active materials. In order to improve the cell capacity with keeping good transportability of Li⁺, new electrode architectures should be developed. In our previous study, we focused on a pair of interdigitated comb-type current collectors, which can provide a constant distance between cathode and anode even if their amount on the current collectors is increased. So far, we succeeded to prepare a micro lithium-ion battery by casting sols for cathode and anode onto the current collectors. The prepared micro-battery operated reversibly. However, the sols used in this technique should be dilute, which makes it difficult to obtain thick electrodes for practical applications. Here, we used electrophoretic deposition (EPD) method to prepare thick cathode and anode on the interdigitated current collectors by the direct deposition of particles of active materials. In addition, a wall structure of polymer was formed between the interdigitated current collectors as the support to deposit active material particles selectively onto the target current collector in 3D configuration. The performance of prepared micro lithium-ion battery such as capacity and rate capability was thoroughly evaluated and discussed from the viewpoint of electrode structure.

EPD OF REVERSE MICELLE PALLADIUM OR PLATINUM NANOPARTICLES ONTO INDIUM PHOSPHIDE OR GALLIUM NITRIDE FOR HIGH-RESPONSE HYDROGEN SENSORS

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We investigated properties of nanolayers electrophoretically deposited (EPD) onto semiconductor indium phosphide (InP) or gallium nitride (GaN) single crystals from colloid solutions of metal palladium (Pd) or platinum (Pt) nanoparticles (NPs) in isooctane. Colloids with metal NPs were prepared by reaction of the metal compound with the reducing agent hydrazine in water confined to reverse micelles of surfactant sodium bis-(2-ethylhexyl) Sulfocinate (AOT). EPD from the colloid solution was performed in a cell with two plan-parallel electrodes; one consisted of a polished semiconductor wafer. Chopped DC electric voltage was applied for the time period to deposit isolated metal NPs, only partly covering surface of the wafer. The deposits were image-observed by scanning electron microscopy (SEM) and atomic force microscopy (AFM). Diodes with porous Schottky contacts were made by applying drops of colloidal graphite on the deposited surface and making ohmic contact on the blank side of the wafer. The diodes showed current-voltage characteristics of excellent rectification ratio and barrier height values close to Schottky-Mott limit, which was an evidence of negligible Fermi level pinning. Large increase of current was observed after switching on flow of gas blend hydrogen in nitrogen which returned back after switching over the air flow. Current change ratio about 180000 with 0.025 % and 720000 with 0.1 % hydrogen blend was achieved on GaN diodes polarized by 0.1 V, which corresponded to the detection limit of about 1.5 ppb. Finally, it should be noted that the diodes besides the extremely high sensitivity have been temporally stable and of inexpensive production. Relatively more expensive GaN diodes have potential of functionality at high temperatures up to 900 °C.

The work has been financially supported by EU Program COST, Action MP0805, grant OC10021 afforded by Ministry of Education of the Czech Republic, grant KAN401220801 of Academy of Sciences of the Czech Republic and by grant 102/09/1037 of Czech Science Foundation.

ELECTROPHORETIC DEPOSITION OF POLYARYLETHETHERKETONE (PEEK) FROM A MATCHING DENSITY SOLVENT MIXTURE

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Investigating the electrodeposition properties of PEEK from solvents such as ethanol and acetone presents difficulties due to the higher density of the polymer particles relative to that of the solvent. The settling rate in unagitated baths is too rapid to obtain consistent deposits. Whole-bath agitation aimed at maintaining particle suspension can disturb electrodeposits due to eddies and other turbulent flow effects. To eliminate settling, mixtures of two solvents have been employed, the individual solvents having respectively lower and higher densities than PEEK. The proportions of the mixture are adjusted to be the same density as PEEK so that a colloid-like suspension of PEEK particles is possible. This enables the electrodeposition of PEEK to be studied without any significant gravitation or whole-bath agitation effects. Eliminating mechanical agitation of the suspension enables a study of the influence of target electrode movement alone on the rate and quality of electrodeposition.

DIELECTRIC MULTILAYER THICK FILMS OF BAO-LN₂O₃-TiO₂ (LN = ND, LA) PREPARED BY ELECTROPHORETIC DEPOSITION

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Zheng et al [1-2] reported the fabrication of temperature stable composites based on mixtures of BaLa₄Ti₄O₁₅ ($\epsilon_r = 44$, $Qf_0 = 44,000$) and Ba₄Nd_{9.33}Ti₁₈O₅₄ ($\epsilon_r = 82$, $Qf_0 = 10,000$ GHz). The premise of this work was to establish a range of materials suitable for MW applications in which ϵ_r may be modified by altering the concentration of the end members according to standard mixing rules. This approach gave a range of MW ceramics whose properties were suited for filters and antennas but it was noted that some phases arising from reaction of BNT and BLT were present which increased dielectric loss and made ϵ_r difficult to predict accurately. One determining factor that influenced the extent of reaction between BLT and BNT was the high surface area of contact in a classic 3-3 composite. One approach to minimise the reaction is therefore, to fabricate layered composites using a thick film deposition technique in which the interface between the end members is largely planar. In this work multilayers of BNT and BLT were deposited using EPD. Thick film composites of BNT-BLT on metallic substrate with thickness of $\sim 30\mu\text{m}$, exhibit dielectric permittivity ~ 71 and loss tangent ~ 0.002 , with near zero temperature coefficient of permittivity ($TC\epsilon_r$) $\sim -16\text{ppm}/^\circ\text{C}$. Triple thick layer BLT-BNT-BLT films were also developed and $\sim 38\mu\text{m}$ thick films have dielectric permittivity ~ 60 and loss tangent ~ 0.004 , with temperature coefficient of permittivity ($TC\epsilon_r$) $\sim -350\text{ppm}/^\circ\text{C}$. The high $TC\epsilon_r$ might be due to the composite porosity. The composites exhibit permittivity intermediate between the end members that may be tuned by modifying the ratio between and/or thickness of each layer, thereby tailoring the films for specific MW applications. This approach is considered generic and its application to a wider range of dielectric systems is discussed. References : [1] Hong Zheng , Ian M Reaney , Duncan Muir , Tim Price , David M. Iddles, Journal of the European Ceramic Society 27 (2007) 4479–4487. [2] H. Zheng, I. M. Reaney, D. Muir, T. Price, D. M. Iddles, Jpn. J. Appl. Phys. Part 1, 44, 5A, (2005)3087-3090.

THE ELECTRODEPOSITION OF METAL-MATRIX NANOCOMPOSITES: A PATENT REVIEW

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Nanosized particles, suspended in an electrolyte by agitation and/or the use of a microemulsion can be codeposited with a metal allowing the formation of a metal-matrix nanocomposite. The preparation of metal-matrix nanocomposites coatings by electrodeposition have demonstrated some obvious advantages in terms of simple and low cost setup as well as low temperature processing. This contribution analyze most recent developments described in patents and patent applications in terms of equipment and methods of electrodeposition, coating materials and coating applications. The codeposition of nanosized ceramic particles with metallic ions depends on many process parameters, all of them related to three global factors: the applied current density, the physicochemical characteristics of the electrolyte (including the transport phenomena) and the nature and concentration of particles. Direct current, pulsed direct current and pulsed reverse current have been used. A variety of nanosized particles in different concentrations have been incorporated into metal electrodeposits. These include aluminum dioxide, diamond, silicon carbide, silicon dioxide, zirconium dioxide, titanium dioxide, silicon nitride. The most common codeposited metals have been copper, nickel and their alloys. Recent patents claim electrodeposits of nickel & copper in a nanometric grain size structure increasing the wear resistance of the coatings. In order to keep particles suspended in the electrolyte, physical (by bath agitation) and chemical (by cationic, anionic and non-ionic surfactants) dispersion of particles have been reported. A special interest has been given to the development of wear resistant coatings formed under pulsed current of microemulsions. The existence of microdomains of different polarity within the same, single-phase solution enables both water-soluble and oil-soluble materials to be solubilized, at the same time. Future directions in this field towards a green chemistry are suggested.

INFILTRATION OF 3D FABRIC PREFORM FOR THE FABRICATION OF SiCf/SiC COMPOSITE

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Electrophoretic infiltration (EPI) process was used in combination with polymer infiltration and pyrolysis (PIP) process for the fabrication of SiC-based, ceramic-matrix composites for fusion applications. A stable and well-dispersed aqueous suspension of submicron SiC powder enabled the efficient infiltration and preparation of a SiCf/SiC composite with a relatively high density. The Infiltration was enhanced by the use of wetting agents and vacuum infiltration of the fabric preform with aqueous powder suspension prior to electrophoretic deposition. The electrophoretically infiltrated fiber preform was densified by infiltration with polymer precursor and pyrolysed in argon and crystallized at 1600 °C in vacuum, in order to achieve a pure SiC material which is desirable for fusion application. The effect of infiltration of the intra and interboudle areas in the fabric preform was examined using optical and electron microscopy and mercury intrusion porosimetry.

ELECTROPHORETIC DEPOSITION ON NON-CONDUCTING SUBSTRATES FOR SOLID OXIDE FUEL CELL APPLICATION

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Electrophoretic deposition (EPD) process generally requires electrically conductive substrate for deposition. We demonstrate in this paper that the limitation can be overcome by judiciously controlling the porosity of the substrate. As an example, we have successfully deposited thin layers (5-10 micron) of YSZ on electrically non-conductive NiO-YSZ mixed substrate prepared either by tapecasting or dry pressing, for application in solid oxide fuel cells. The EPD was made possible by using NiO-YSZ substrates of suitable porosity fixed on the front face of a metallic electrode. The interconnected pores in the substrates, when saturated with the solvent used for preparing the EPD suspension, helped in establishing a "conductive path" between the electrode and the particles in suspension. This was confirmed from the fact that no deposition occurred on fully sintered and dense NiO-YSZ substrate, whereas good deposition occurred on porous substrates. Deposition rate was found to increase with increasing substrate porosity up to a certain extent beyond which it reaches constant value. For any applied voltage, there exists a threshold porosity value below which deposition does not occur. The threshold porosity is lower for high applied voltage and vice versa. However, very high porosity and presence of pores larger than the particle size, leads to infiltration of the particles into the pores and consequently to their closure causing drop in deposition rate with increased time of deposition. A single SOFC cell was constructed on the sintered bi-layer (YSZ /NiO-YSZ) by brush painting a porous layer of cathode paste consisting of 50:50 weight ratio of La_{0.8}Sr_{0.2}MnO₃ (LSM) and YSZ followed by sintering at 1200 °C for 2hrs. The single SOFC cell exhibited an open circuit voltage (OCV) of 1.03 V and the peak power density of about 624 mW/cm² at 800 °C when tested using H₂ as fuel and ambient air as oxidant.

ELECTROPHORETIC DEPOSITION OF BIOMOLECULES: FUNDAMENTALS AND APPLICATIONS

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Recent developments have shown that biosensors can be used to selectively detect molecules, pathogens or elements with a sensitivity which often surpasses that of traditional sensors. Yet despite their advantages availability of such sensors is limited due to a lack of production techniques which are capable of reproducibly mass producing these systems.

One of the critical factors in the production of these sensors is the need to avoid denaturation of the molecules by for instance pH changes or electrochemical reactions. Hence, although it is often used to study and manipulate these molecules, DC-electrophoresis can not be used to deposit such molecules. However alternating current electrophoretic deposition (AC-EPD) does not suffer from these side effects. In this paper the first results obtained in the deposition of enzymes by AC-EPD and the fundamentals aspects governing this technique are summarized

ALTERNATING CURRENT ELECTROPHORETIC DEPOSITION (AC-EPD) OF LIVING CELLS

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The recent development of the alternating current electrophoretic deposition (AC-EPD) technique has rendered it possible to deposit material from aqueous suspensions while preventing the electrochemical reactions associated with the application of high voltages on such systems. This does not only allow for more economical and ecological processes but also opens up electrophoretic deposition as a processing technique to a whole range of materials sensitive to either electrochemical reactions or non-aqueous solvents. Living cells can be considered as one class of such materials. In this paper the deposition of two types of bacteria, the Gram-positive *Staphylococcus aureus* and Gram-negative *Escherichia coli*, and one type of yeast cells, *Saccharomyces cerevisiae*, is demonstrated.

DESIGN OF EXPERIMENT (DOE) APPROACH FOR THE ELECTROPHORETIC DEPOSITION OF PEEK COATINGS

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PEEK is a polymer which exhibits good biocompatibility and stability, which makes it an attractive material for use as coating in medical implants. Electrophoretic deposition is a convenient process to produce PEEK coatings on metallic substrates from ethanolic suspensions of PEEK microparticles. To find the best processing parameters for optimal and homogeneous PEEK coatings, a design of experiment (DOE) approach has been developed. For this purpose, the electrode distance was kept constant and the three parameters voltage, time and suspension concentration were varied. DOE method represents a very efficient way to optimize the processing parameters and to understand in more detail the influence of the different parameters on PEEK coating quality. The deposition rate per area was considered the so-called output of the system which is strongly influenced by the processing parameters. By statistical analysis, it is possible to ascertain which parameter has the highest influence on the deposition rate, and which parameter combination gives the highest deposition rates at the least variance. In addition, the effect of processing parameters on strength of adhesion to substrate, extent of microcracking upon drying and formation of edge effects, which define the overall quality of the deposits, must be considered. By carrying this optimization study, the "best" processing parameters for PEEK coatings on stainless steel substrates were found. The optimized samples were heat treated to densify the layer and to improve the adherence to the surface. The implications of the results for the further development of the EPD technique to fabricate homogeneous PEEK coatings for orthopedic implants of complex shape, including bone tissue porous scaffolds, will be discussed.

ANTIBACTERIAL PROPERTIES OF NANOSTRUCTURED TITANIA-CERIA FILMS ON E-COLI

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TiO₂-CeO₂ nanoparticles were synthesized and deposited on glass substrate using sputtering and electrophoresis combined deposition methods. Optimization of the process resulted in homogeneous nanostructured films. The photocatalytic activity of TiO₂-CeO₂ nanostructured films to eliminate *Escherichia coli* using only visible light irradiation was probed, the experimental procedure to obtain these films, and the characterization are discussed in this work. The nanostructure of the films was analyzed using Scanning Electron Microscopy, Transmission Electron Microscopy and Atomic Force Microscopy; the topography of the films was also analyzed with Atomic Force Microscopy. Microbiological test was used to study the photocatalytic activity of the films and their antibacterial activities against the *Escherichia. coli* bacterium cultures, in order to know the reduction of *E. coli* colonies. A significant bactericidal effect under visible light irradiation was demonstrated. Keywords: Biocide activity, photocatalytic activity, titania-ceria, anatase, *Escherichia coli*, sputtering, electrophoretic deposition.

ELECTROPHORETIC DEPOSITION OF BIOMEDICAL COATINGS BASED ON CHITOSAN/BIOACTIVE GLASS COMPOSITES

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Electrophoretic deposition (EPD) has previously proved promising in making uniform composite coatings and provides the possibility of co-deposition of organic and inorganic components. In the present research this advantageous technique has been applied to fabrication of composite biomedical coatings.

The need for improved biological adhesion between metallic orthopaedic implants and human tissue requires enhancement of surface properties of these medical devices. In this regard, bioactive glass coatings are well-known candidates which interact with host tissue at cellular level and contribute to the formation of a strong bond with the soft and hard tissue. Composite coatings based on natural biocompatible and biodegradable polysaccharides (chitosan) in addition to a bioactive glass such as 45S5 Bioglass®, have potential use as such orthopaedic coatings.

Initially the kinetics of deposition of chitosan from aqueous solutions and its pH-dependent behavior was studied. Further, coatings of 45S5 Bioglass® were fabricated from aqueous suspensions and the effect of EPD parameters on the deposition rate was investigated. Finally EPD of chitosan/Bioglass® composite coatings on both flat and 3D porous metallic structures were considered. A design of experiment approach based on the Taguchi method was utilized to optimize the deposition rate of the coatings. Obtained results indicate a noticeable increase in the deposition rate of bioactive glass particles in addition to an extended processing window due to the incorporation of chitosan. The mechanism of electrophoretic co-deposition of bioactive glass and chitosan has been elucidated. Additionally EPD technique was applied to incorporate biomacromolecules in the composite films to fabricate novel multifunctional coatings with drug release capability.

STABILITY AND EPD OF CONCENTRATED SUSPENSIONS OF ALUMINA WITH NANOSIZED TITANIA

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Alumina-aluminium titanate (A-AT) composites and laminates have been recently investigated because they can provide improved flaw tolerance and toughness associated to a microcracking mechanism. A-AT composites have been produced by slip casting and reaction sintering of submicron sized alumina and titania powders. This work deals with the preparation of thick self-sustained A-AT films from mixtures of submicron sized alumina and nano sized titania. Suspensions were prepared in water to high solids loadings ranging from 30 to 50 vol.%. The stability of diluted suspensions was studied through zeta potential measurements as a function of pH and deflocculant type and concentration. The stability of the concentrated suspensions as a function of deflocculant content, sonication time and solids loadings was studied from rheological measurements. Self-sustained films were obtained by aqueous EPD using graphite substrates under constant current density conditions. The evolution of mass per unit area with current density and deposition time was recorded. The films were characterized in the green state and after debinding and sintering by density measurements, and electron microscopy observations.

ELECTROPHORETIC DEPOSITION OF POLYETHER ETHER KETONE (PEEK) FROM AN AQUEOUS SUSPENSION

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Polyether ether ketone (PEEK) is a well known thermoplastic polymer used in many engineering applications. In this study, PEEK was deposited onto copper using electrophoretic deposition (EPD) from a suspension containing ~5wt% solids, prepared from diluted aqueous dispersion of VICOTE[®] F817 manufactured by Victrex. Deposition was performed under constant current between 10 and 20mA for 5 - 10s. After drying, films were densified at 410°C for 10 minutes (N₂ atmosphere). The roughness and microstructure of as deposited and heat-treated PEEK layers were observed using light and electron microscopy respectively. The ability to deposit from an aqueous suspension a highly insulating, tough polymer such as PEEK opens up many new avenues of development within device and coating technology.

PREPARATION OF PEROVSKITE-TYPE OXIDE THICK-FILM BY EPD METHOD AND ITS APPLICATION FOR ELECTROCHEMICAL ION-SENSOR DEVICE

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An electrophoretic deposition (EPD) method was applied for the preparation of LaCoO₃ powders (LCO) thick-film on various substrates for electrochemical ion sensor applications. Perovskite-type oxide (LaCoO₃) fine powders were prepared by a polymer precursors (PP) methods at 300–500°C. The electrophoretic deposition was performed in a suspension of anhydrous ethanol being dispersed perovskite-type oxide fine powders with stabilizer (AcAc, PVA, iodine, lactic acid, and tartaric acid). ITO glass, Au attached-alumina, and carbon-felt (cloth) were used for working electrode, as a substrate. A Pt-plate was used for counter electrode. Constant DC voltages of between +10V and +30V were applied anodically for fabricating oxide thick-films. The LaCoO₃ fine powder could be prepared at 380°C when the use of EDA and PEG for organic- and polymer- additives, respectively. The surface area of LCO was ca. 39m²/g. LCO thick-film could be prepared from the steady state suspension with the addition of AcAc or PVA. Thickness of the LaCoO₃ thick-film prepared with PVA by the EPD method was ca. 15 microns at +10V, 3min. The CV measurements revealed that the anodic current of the LaCoO₃ thick-film electrode increased with increasing HPO₄²⁻ concentration. This suggests that an amperometric sensing of HPO₄²⁻ using anodic current is possible by the use of LaCoO₃ thick-film electrode. The current density of the LaCoO₃ film sensor was changed with changing HPO₄²⁻ concentration at +1.00 V vs. SCE. The device showed relatively good amperometric response to H₂PO₄⁻ from 1.0x10⁻⁵M to 1.0x10⁻³M with the 90% response time of ca 2min. The LaCoO₃-based sensor also showed a good selectivity among the examined anions of NO₃⁻, Cl⁻ and SCN⁻.

FABRICATION OF BARIUM FERRITE FILMS WITH A HIGH DEGREE OF MAGNETIC ORIENTATION USING ELECTROPHORETIC DEPOSITION

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Oriented and textured film or bulk samples from different diamagnetic materials can be prepared by electrophoretic deposition (EPD). The orientation of the diamagnetic particles with an anisotropic magnetic susceptibility occurs in a magnetic field of around 10 T. A much lower magnetic field is needed to orient ferrimagnetic barium ferrite (BaF) particles, which possess a high magnetocrystalline anisotropy. However, by applying the magnetic field the magnetic attraction between the BaHF particles in the suspension is strongly increased and an agglomeration occurs. Therefore, other methods must be used to prepare oriented films of BaF. Here we show that, for highly anisotropic particles, the electrophoretic force, the force of gravity and the electrostatic attraction between the electrodes and the particles are responsible for the orientation of these particles during the EPD with a larger plane parallel to the electrodes.

For the EPD the most difficult step is the preparation of a stable suspension from the BaF magnetic particles. In this study the plate-like particles of BaF with diameters from 20 to 350 nm and thicknesses from 3 to 11 nm prepared by a hydrothermal synthesis were used. The magnetic attraction between the particles was negated by a double-layer adsorption of a surfactant called dodecylbenzenesulphonic acid. The zeta-potential of the 1-butanol suspensions was around 100 mV. These suspensions were used for the preparation of oriented films on gold or platinum by EPD.

The deposition was made with vertical and horizontal positions of the electrodes in order to study the influence of the above-mentioned forces on the orientation of the particles. The effects of the applied voltages on the particles' orientation and the thicknesses of the deposits were studied. To increase the thickness and the orientation of the deposit, EPD with a step voltage was applied, where the voltage was increased by a step of 10 V and different holding times were used during the steps. The increase of the film's density during the sintering of as-deposited and isostatically pressed deposits was studied. The orientation was calculated from the X-ray diffraction pattern and observed from the magnetic properties that were measured parallel and perpendicular with respect to the substrate surface. The deposits with the highest orientation of 94 % were prepared in the horizontal position on the lower electrode.

HYBRID SUPERCAPACITOR SYSTEMS VIA EPD

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Supercapacitor has gained huge attention in the recent years due to its ability to provide much higher power density and longer cycle life when compared to lithium batteries. This advantages have attracted considerable interest especially in the field of portable energy storage and for electrical vehicles. In the effort to enhance the performance, electrode materials of the supercapacitor are one of the major research focuses. Among them, nanostructure oxides show promising properties, however, it is reckoned that the performance can be further improved if the electrical properties can be enhanced via a hybrid material system approach. The present work looks at the processing of hybrid systems via the EPD process. It is reckoned that the superior processing flexibility of EPD facilitates the formation of desired network configurations that will promote the performance of the supercapacitor.

GROWTH OF TITANIA MESOPOROUS COATINGS INDUCED BY ELECTROPHORESIS

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Titanium dioxide is a semiconductor material employed in many industrial applications due to their physical, chemical and optical properties. Several researchers have reported that TiO₂ crystallised as anatase phase is the most effective and suitable catalyst for photocatalytic reaction of organic pollutants. Particularly, the preparation of mesoporous thin films by incorporating pore generating agents has become a dynamic field of study in order to obtain coatings with high surface area. Those films promote contact between pollutant and catalyst, favouring pollutant degradation. Among disposable methodologies to synthesize mesoporous TiO₂ coatings, physical deposition techniques combined with sol-gel chemistry lead to successful results. In those processes, the controlled evaporation of volatile solvent allows the condensation of the inorganic species around surfactant micelles and their self-assembly. In this work, a new approach has been tested based on the electrically induced assembly of organic/inorganic structures. The interaction of organic/inorganic surfaces, through the formation of neutral paths, in titania sols with the addition of non-ionic surfactants has been checked. The formation of micelles during the process has been related to synthesis parameters and deposition time. Concretely, this study describes the preparation of titania sols by alkoxide routes using titanium isopropoxide (TISP) with and without the presence of a pore-generating agent, Pluronic F-127 (F127), and varying the molar ratios TISP/H₂O and TISP/F127. Synthesis conditions have been optimised considering stability, evolution of the zeta potential and particle size as a function of aging time. Coatings were deposited by dipping and Electrophoretic Deposition (EPD) on AISI 304 substrates. The structure arrangement generated during the process within the sol or at the working electrode surroundings has been study and described as a function of synthesis conditions. Homogeneous coatings were obtained up to current densities of 0.13 mA/cm². Deposited mass of 1 mg/cm² and maximum thickness of 1 μm were obtained.

MULTI-WALLED CARBON NANOTUBE AND HEXAMETHYLENE DIISOCYANATE COMPOSITE COATING ON COPPER SUBSTRATE BY ELECTROPHORETIC DEPOSITION

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The applicability of a very simple and novel technique known as electrophoretic deposition (EPD) based on colloidal deposition process to fabricate uniform and strong thin composite coatings on copper substrate has been presented. Based on optimized process parameters, the coatings of thickness around 150 microns at constant applied voltage condition 30V and deposition time 3 minutes were obtained with an excellent microstructure. The thickness of the coatings was controlled by changing voltage and deposition time. The adhesive strength of the CNT/polymeric resin thin composite coatings was assessed qualitatively by peel test using adhesive tape and was found to be excellent. The bonding strength to the substrate is significantly improved with resin hardner compared with the coatings only with CNTs and Gum Arabic as dispersant. The process is environment benign since system is aqueous based and dispersant used is also natural polysaccharide produced by Acacia trees. Possible mechanism for strong adhesive composite coatings of MWCNT and HDI with substrate material is also proposed. Scanning electron microscopy (SEM), Transmission electron microscopy (TEM) and Raman spectroscopy were employed to characterize the CNTs and composite coatings.

ELECTROPHORETIC DEPOSITION ON NON CONDUCTING SUBSTRATES: A NEW APPROACH AND DEVICE APPLICATION DEMONSTRATION

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Through the use of a sacrificial graphite layer, this work reports a new method of performing electrophoretic deposition (EPD) of films on non-conducting substrates, overcoming the historical restricting requirement for EPD of a conducting substrate. EPD is a simple, fast and inexpensive deposition technique for obtaining thin and thick layers. One of the advantages of EPD over the other techniques is the ability to coat complex geometries, which allows easy materials deposition onto substrates of various shapes, what is currently important for nanoscale and 3-D geometries of electronic devices. The fabrication process by EPD includes the formation of charged suspensions that under an electric field are attracted and deposited onto a conductive and oppositely charged electrode and a final thermal annealing. EPD requires the substrate to be conducting or coated with a conducting electrode. In principle, it is not possible to carry out EPD on non-conducting substrates. This is a limitation of the technique and, particularly limiting for the production of microelectronic circuitry. As a proof of concept, the new method was applied to the development of dielectric films on insulating alumina substrates. The study showed that the key parameter to be controlled is the thickness of the sacrificial graphite layer - this is expected to be a general result for the application of the processing method. This leads to the potential use of the EPD process method in a far wider range of applications, such as deposition on insulating substrates for fuel cells and biotech devices. Furthermore, in conjunction with work reported elsewhere, the development of the specific barium titanate based films microwave dielectric system opens up a technology platform for a range of high Q (low loss) devices. More specifically, BNT layers were achieved with dielectric constant of 146 and Q of 1161 at 10 GHz. These can now be integrated with tunable dielectrics and dielectrics on metal substrates to provide a platform for devices in the front-end of communication systems and in cellular base stations.

EXAMPLES OF EPD PROCESS APPLICATIONS IN THE ELECTRONIC INDUSTRY AND THEIR CHARACTERISTICS

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Electrophoretic deposition is a technology that offers unique possibilities. The electronic industry has used these to their advantage in many ways. Within Philips EPD as a coating technology for powders has been in use since the early days. Early examples are the application of electron emitter material on cathode ray devices or the uniform deposition of insulating ceramic powders on heaters for the same. Electrophoretic deposition, as opposed to for example spray coating, is a technology known for its efficient use of material. Thickness and uniformity of the applied layer can be controlled precisely and the packing density of the layers is high. Despite these wonderful abilities, when it comes to applying a coating on a substrate however EPD is not the natural choice. Spray-, dip- or spin coating can in many cases be used as well. Running and maintaining an EPD process at high volume requires in depth process understanding and strict process control. But with the right tools and process layout EPD can in some cases outperform the other technologies. The geometry of the substrate to be coated determines to some extent the design and setup of the EPD process. As these substrates can be flat surfaces, wires, caps, pins, cylinders or other irregular shapes with holes or cavities. When the coated surface is part of a sub-assembly, complete submersion of it into the EPD suspension is not always possible. Special precautions are needed when the suspension is based on a flammable medium, like an alcohol. This lecture presentation will visit some EPD application processes and highlight their characteristics as well as address some of the challenges associated with them.

THE ROLE OF TRIETHANOLAMINE IN THE ELECTROPHORETIC DEPOSITION OF DIELECTRIC THICK FILMS

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The electrophoretic deposition (EPD) technique has attracted great interest as a method for the preparation of thick films. As a simple and cost effective process, besides allowing products of different geometries to be processed, EPD have been widely used for the fabrication of high-performance functional thick/thin films. To ensure the quality of the green deposited layer the stability of the suspension is an essential parameter in the EPD process. And the influence of the type and concentration of additives plays a crucial role in the suspension stability. In this work TiTe₃O₈ thick films were fabricated on Si substrates by EPD. Ethanol, propanol and acetone were used as suspension media. A high quality of the suspension that results in a high quality of the green films was obtained for acetone based suspension additivated with Triethanolamine (TEA). Films sintered at 700 °C for 5 h exhibit uniform and dense microstructure with a dielectric permittivity of ~60 and dielectric loss (tan δ) of ~0.007, measured at 100KHz and a temperature coefficient of permittivity of +75ppm/°C. The role of TEA is discussed based on the evaluation of the Zeta potential, conductivity and far infra-red spectroscopy of the suspensions.

CHARACTERIZATION OF A CERAMIC POWDER SURFACE BY CONTACT ANGLE MEASUREMENTS AND INFRARED SPECTROSCOPY

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The surface chemistry of a suspended particle greatly affects its behavior during electrophoretic deposition. The type and amount of surface groups determines whether the particles can be charged by interaction with the solvent. Furthermore it is suspected that the surface chemistry plays a prominent role in the mechanisms governing the actual deposition of the particles.

In the present work the surface chemistry of as-received and surface modified alumina powder is characterized by means of contact angle measurements and Diffuse Reflectance Infrared Fourier Transform spectroscopy. The wetting is measured using a modified Washburn method which yields quantitative contact angle values. The acid-base and dispersive surface energy components are calculated from these values using the surface tension component theory. Infrared spectroscopy was used to compare the surface groups of the treated and untreated powders and confirm the trends in surface properties as calculated from the contact angles.

AC ELECTROPHORESIS, A NEW TECHNIQUE FOR DEPOSITION OF CERAMIC NANOPARTICLES; INTRODUCTION, APPLICATION AND MECHANISM

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In this paper, AC electrophoresis is introduced as an effective method for nanoparticle sorting, manipulation and device fabrication. In this method ceramic nanoparticles, suspended in non-aqueous medium, are moved by effect of applied electric field. In same time, a flow may induce in the liquid and this fluid flow can affect movement of the suspended particles. Final deposition pattern of particles highly depends on the applied frequency. Sensor fabrication, particle separation, micropatterning and chain formation of nanoparticles are some applications of applying AC electric fields at low frequencies below 10 KHz. Here, some mechanisms are suggested to explain the effect of frequency on deposition pattern. These mechanisms help us to develop this technique and to find new applications. Here in this report, direct video observation and also numerical simulation is used to clarify the active mechanisms.

Posters

4th International Conference on Electrophoretic Deposition: Fundamentals and Applications

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CasaMagna Marriott Hotel, Puerto Vallarta, Mexico



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31. INFLUENCE OF DOLAPIX AS A DISPERSANT IN DEPOSITION PATTERN FOR FAST FABRICATION OF ELECTRONIC DEVICE BY USING LOW FREQUENCY ALTERNATIVE CURRENT ELECTROPHORETIC DEPOSITION (LFACEPD)
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AQUEOUS EPD OF BIMODAL TITANIUM OXIDE SUSPENSIONS

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Titanium oxide is one of the most common ceramic materials due to the wide number of applications in different fields, such as pigment in paints, photocatalyst, antibactericide coatings, etc. In some cases, the incorporation of nanosized particles serves to enhance the behavioural properties. This work deals with the preparation of thick coatings of titania on stainless steel substrates. Submicronic and nanometric powders of titania have been used separately and together to increase the coating performance. The stability of the suspensions was studied in terms of zeta potential as a function of both pH and polyelectrolyte concentration. Constant voltage tests were carried out for EPD using suspensions with different solids contents ranging from 25 to 100 g/l with and without deflocculants. In order to reduce the sintering temperature, the effect of mixing the ceramic particles with a frit was also evaluated.

ELECTROPHORETIC DEPOSITION OF PEEK-TiO₂ COMPOSITE COATINGS ON STAINLESS STEEL

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This work focused on the investigation of the electrophoretic codeposition of polyetheretherketone (PEEK) and TiO₂ nanoparticles to produce novel PEEK-TiO₂ composite coatings. TiO₂ has many potential applications in various industrial and domestic fields including catalysis supports, photovoltaic cells, biomedical coatings as well as water and air purification materials. TiO₂ improves wear resistance, hardness, and other properties such as corrosion resistance as inclusion of polymer coatings. PEEK is thermally stable, has high strength, excellent stiffness and toughness, as well as excellent tribological properties. For this reason PEEK can be seen as a unique polymer for production of relatively high temperature and high wear resistant polymer-ceramic composite coatings. The use of fine inorganic particles as filler of thermoplastic materials to develop new wear-resistant and biocompatible coatings is of great interest. A previous investigation has optimized the EPD of PEEK-alumina composite coatings [1]. In this work electrophoretic deposition (EPD) technique has been successfully used to deposit composite coatings of PEEK and titanium dioxide (TiO₂) on 316L stainless steel substrates. The suspensions of TiO₂ nanoparticles and PEEK microparticles for EPD were prepared in ethanol. Various experiments were performed to find the best processing parameters during the deposition process and the sintering step needed to densify the coating and to eliminate remaining porosity. An understanding of the parameters affecting the EPD of PEEK and TiO₂ on metallic substrate from ethanol suspensions was verified. Finally, the optimum EPD coatings of both sintered and unsintered composite coatings were microstructurally evaluated by scanning electron microscopy (SEM) and the coating-substrate adhesion strength was also characterised.

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ELECTROPHORETIC DEPOSITION OF BIODEGRADABLE POLYESTER COMPOSITE COATINGS WITH BIOACTIVE GLASS NANOPARTICLES

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Even though many different kinds of polymers have been synthesized, their properties characterized, and used in commercial applications, polyesters still constitute one of the most applied class of polymers in the biomedical field. Specifically, biodegradable polyesters such as polylactic acid (PLA) and polycaprolactone (PCL) have been studied and used extensively for biomedical applications due to their proven biocompatibility and predictable degradation in-vitro and in-vivo. Another important biomaterial group is represented by bioactive glasses and ceramics, like hydroxyapatite or Bioglass®, which are attractive materials used in coatings of orthopedic devices. One problem that occurs when coating metallic implants with inorganic materials is the shrinkage during the sintering process which may cause cracks and structural defects in the ceramic coatings. Another problem is related to the high sintering temperatures that can lead to a decomposition of the inorganic material inducing damage of the substrate material. For this reason the codeposition of PLA and PCL with different concentrations of bioactive glass nanoparticles is of interest. Nature often combines inorganic with organic materials like for example in bone to exploit the positive properties of the two different phases. Another reason for embedding nanoparticles in a polymer matrix is the (nano)structuring of the surface that can improve cell adherence. In this work we present the development of nano-bioactive glass/biodegradable polyester composite coatings prepared on stainless steel substrates by EPD in ethanol and dimethyl carbonate (DMC) suspensions. Through the co-deposition of the polymer and the glass particles, the sintering step usually necessary for glass coatings can be avoided. The results show that EPD is a convenient and effective method to obtain biodegradable polyester coatings containing up to 4wt% of nanoscale bioactive glass.

ELECTROPHORETIC DEPOSITION AND DIELECTRIC PROPERTIES OF $\text{Bi}_{1.5}\text{Zn}_{1.0}\text{Nb}_{1.5}\text{O}_7$ THICK FILMS

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Bismuth based pyrochlore ceramics are being considered as a potential candidate material for high frequency capacitors and microwave resonators. Out of the two main phases in the $\text{Bi}-2\text{O}_3\text{-ZnO-Nb}_2\text{O}_5$ system the composition with cubic pyrochlore structure and having the chemical formula $\text{Bi}_{1.5}\text{Zn}_{1.0}\text{Nb}_{1.5}\text{O}_7$ (c-BZN) is getting much attention because of its voltage dependent dielectric characteristics. It is one of the few non ferroelectric material known today exhibiting voltage dependent dielectric permittivity. Because of being non ferroelectric, this material exhibits low loss and high figure of merit in the microwave frequency region. Although there are some reports on the dielectric characteristics of thin films, thick films of this material system is not yet widely explored. In this paper we are reporting the preparation of c- BZN thick films using an electrophoretic deposition (EPD) process on flexible metallic substrates and its electrical properties as function of temperature, frequency and bias field. The relations between the processing conditions and the final properties are established. Cubic bismuth zinc niobate (c-BZN) thick films having the composition $\text{Bi}_{1.5}\text{Zn}_{1.0}\text{Nb}_{1.5}\text{O}_7$ were fabricated on flexible platinum foils by EPD under different processing conditions. The structure and morphologies of the films were analyzed by X-ray diffraction and scanning electron microscopy. Under optimized deposition conditions, well densified c-BZN thick films could be obtained below 1000°C . The dielectric measurements were conducted on metal-insulator-metal capacitors using gold as the top electrode. The dielectric constant of the c-BZN thick film sintered at 850°C and 950°C , measured at an applied frequency of 1MHz were, 134 and 145, respectively. The corresponding values of dissipation factor were 0.004 and 0.0038, respectively. The films were showing a tunability of 2.4 % under an applied bias field of 100KV/cm. The characteristics such as high dielectric constant, low losses, low temperature sinterability and field dependent permittivity of c-BZN thick films suggest a potential application for high power microwave electronics and LTCC worthwhile to be further explored.

MECHANICAL AND TRIBOLOGICAL PROPERTIES OF AL₂O₃-ZrO₂ COMPOSITES PREPARED BY EPD

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Al₂O₃-ZrO₂ composites with various volume fractions of the constituents as well as laminate composites with composition gradient were prepared by EPD. Their microstructure was observed and assessed. Mechanical properties (hardness, fracture toughness) were measured by indentation methods and related to microstructure parameters and residual stresses present. Tribological behavior was studied using pin-on-disk technique at room temperatures in air in conditions of dry sliding. Coefficient of friction and wear rates were measured, the types of wear regimes were observed and damage micromechanisms identified.

DEGRADATION OF THE BACTERIUM E. COLI THROUGH THE FILM OF TiO₂-CeO₂

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Heterogeneous photocatalysis involving TiO₂ has been systematically reviewed at fundamental and applied levels. Commercial worldwide interest in this technology is explicit, but is still in pilot, or lab development, in most cases. The process fundamentals consist in hitting the semiconductor with radiation of energy greater than its band gap energy, generating high energy electron-hole pairs, which initiate the heterogeneous photocatalytic reaction. However, undesirable recombination of electrons and holes, and low efficiency under irradiation in the visible region are the two main drawbacks associated with the use of non-modified TiO₂ [1]. To overcome these limitations, one possible solution consists in doping the TiO₂ semiconductor with d-metal ions/oxides. In particular, cerium oxides have attracted much attention due to the optical and catalytic properties associated to the redox pair Ce³⁺/Ce⁴⁺. The inactivation of pathogenic organisms is of primary importance in the treatment of domestic water supplies and usually accomplished using chemical additives such as chlorine [1]. However, it is generally accepted that this can lead to the generation of low molecular weight chlorinated organic species in solution, some of which are harmful to humans, and some have been shown to provide a nutrient source for the residual bacteria in the potable water [2]. In this paper we study the power photocatalytic degradation in Escherichia Coli of films of TiO₂-CeO₂ nanostructures. A combination of methods was used to obtain the Ce-doped TiO₂ films: sputtering and electrophoretic deposition. In order to obtain a conductive substrate with similar composition to titanium oxide, the sputtering of metallic titanium on glass was proposed, followed by the use of these substrates as electrodes for electrophoretic deposition (EPD) in which the TiO₂-CeO₂ is deposited from a stable colloid suspension by an electric field. [1] E. Barajas-Ledesma, M. L. García-Benjume, I. Espitia Cabrera, A. Bravo-Patiño, M. E. Contreras-García, Biocide Activity of TiO₂ Nanostructured Films., *Journal of NanoResearch* Vol. 9 (2010) pp 17-24 [2] T. Matsunaga, M. Okochi, *Environ. Sci. Technol.* 29 (1995) p 501. [3] L. A. Lawton and P. K. J. Robertson, *Chem. Soc. Rev.* 28 (1999) p 217.

ELECTROPHORETIC DEPOSITION OF BIOGLASSES COATINGS ON Ti12Mo5Ta ALLOY

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Metallic implants used in orthopedic surgery are generally titanium alloys because of their mechanical properties and resistance to corrosion. To improve their osseointegration, they are coated with calcium phosphates as hydroxyapatite. The coatings are obtained by different techniques : plasma spray, electrodeposition or electrophoretic deposition (EPD). Bioglasses are able to establish a direct chemical bond with the bone tissue, due to their physicochemical reactions with the body fluids. Consequently bioglasses are more resorbable and have higher bone bonding ability than hydroxyapatite. In addition the bioactivity rate can be controlled by the bioglass chemical composition [1]. However, among the techniques mentioned above only EPD allows to produce bioglasses coatings.

In this work we used two different bioglasses : a 58S bioglass (SiO₂ 58%, 33% CaO and 9% P₂O₅ : mass percent) prepared by the sol-gel process and a 46S bioglass (SiO₂ 46%, CaO 24%, P₂O₅ 6% and Na₂O 24% : mass percent) prepared by the melting-quenching process. The bioglasses coatings were performed on a new titanium alloy Ti12Mo5Ta [2].

Coatings were obtained from powders suspensions (particles size lower than 20µm) in ethanol, with a weight percentage of 10%. The dispersion process was carried out using magnetic stirring followed by ultrasonic dispersion for 40min. EPD experiments were performed at ambient temperature. Two Ti12Mo5Ta discs of 6mm diameter and 0,5mm thick were used as electrodes with a separation distance of 8,5mm. EPD was carried out by applying a constant voltage of 4V during 10min with a continuous magnetic stirring of the suspension to avoid particles sedimentation.

The bioglasses coatings were studied by MEB-EDXS. The results showed that the coatings are uniform and compact with a good link to the substrate. Quantitative X-Ray elemental maps revealed that bioglasses compositions were not altered by EPD with an homogeneous distribution of all the elements into the coatings.

In conclusion we demonstrate, for the first time to our knowledge, that EPD can be successfully used to obtain bioglasses coatings on Ti12Mo5Ta. This preliminary work has to be completed by studying the effect of a heat treatment on the coatings and by measurements of adhesion strength between coating and substrate : work in progress.

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DEVELOPMENT AND CHARACTERIZATION OF COMPOSITE CERAMIC-POLYMER MEMBRANE

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The miniaturization of electronic components embodied by the present VLSI microelectronics technology has not been accompanied by a similar miniaturization of power sources. We recently presented a three-dimensional, rechargeable Li-ion microbattery (3DMB) that is compatible with microsystem power requirements. The 3DMB cells were fabricated on a perforated silicon substrate which has thousands of high-aspect-ratio holes per square cm, thereby providing more than an order of magnitude increase in surface-area per given footprint (original substrate area). The fabrication of 3DMB cells has encountered complicated technical issues, among them the insertion of an ion-conducting membrane in long (500 μ m-deep) and narrow (50 μ m diameter) channels.

This work presents the development and characterization of a new composite ceramic-polymer membrane prepared by electrophoretic deposition. 2D- and conformal 3D-films were deposited on nickel, gold, and different cathode and anode materials. The EPD process follows a simple linear relationship between time and mass of the deposit for the tested ranges of values of the relevant parameters. The ionic resistance of the porous composite ZrO₂-based membrane filled by LiPF₆:(EC/DEC) liquid electrolyte is comparable to that of commercial separators. The effect of the composition of the EPD suspension and operating parameters on the morphology, lateral and depth distribution of the membrane components, adhesion of the membrane to the substrate, its ionic conductivity and the electrochemical performance of Li-ion cells will be addressed.

ELECTROPHORETIC DEPOSITION OF YBA₂CU₃O_{7-X} ON METALLIC SUBSTRATES: INFLUENCE OF THE SHAPE OF THE ELECTRODES

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Magnetic shielding using YBCO superconductors can easily be made by using the electrophoretic deposition (EPD) technique to coat any kind of metallic substrates. However this kind of application sometimes requires particular geometries (edges, holes, ...) in combination with planar surfaces. In order to produce as homogeneous as possible coatings, it is necessary to know the influence of the shape of the electrodes on the homogeneity of the generated electric field.

The influence of the shape of nickel electrodes (planar electrodes with same or different sizes, wires, tips, edges and cylindrical electrodes) on the generated electric field has been studied through numerical simulations using the Maxwell 2D software from Ansis Corporation. This software allows computing the repartition of the electric field and then gives a very good approximation of its homogeneity. These results have been confirmed through experiments in an acetone-I₂ bath and the best configuration of the electrodes is then discussed.

ELECTROPHORETIC DEPOSITION OF YBa2Cu3O7-x SUPERCONDUCTING POWDERS ON BUFFERED NICKEL SUBSTRATES

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YBa2Cu3O7-x superconducting ceramic has important low-Jc applications such as magnetic shielding at very low frequencies. This ceramic can easily be deposited onto substrates of various dimensions and shapes by using the electrophoretic deposition technique. This approach allows avoiding the bulk technology, which one requires more raw material and leads to massive and heavy devices.

Tens micrometers thick YBa2Cu3O7-x layers have been deposited onto YSZ buffered nickel substrates by means of the electrophoretic deposition technique, nickel being an interesting substrate material for its ferromagnetic properties but its reactivity with YBCO led us to cover it with a buffer layer to prevent from nickel diffusion occurring during the heat treatment.

Attention has been focused on the preparation of a stable suspension using an adequate solvent and two kinds of powders (not milled and milled commercial powder), this step being the main one for the realization of crack-free and reproducible coatings. Finally an appropriate heat treatment under an oxygen gaz flow has been employed to sinter the coatings and to ensure the good stoichiometry of the final product.

ELECTROPHORETIC DEPOSITION OF CADMIUM SULFIDE NANOPARTICLES: ELECTRIC FIELD AND PARTICLE SIZE EFFECTS

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The present work shows the electric field strength and particle size effects on the formation of nanostructured arrays by electrophoretic deposition of CdS nanoparticles. The CdS nanoparticles with diameters below 6 nm were prepared by a microwave assisted synthesis. These nanoparticles were aged for 1 and 2 weeks at room temperature in order to produce nanoparticles agglomeration with the purpose of increasing the size of the electrophoretic particle. The CdS nanoparticles were deposited on aluminum plates, with 1 cm of distance between them, using a constant applied voltage of 600 and 900 mV during 1 min. The amount of material deposited under a voltage of 900 mV is bigger than that under 600 mV. The nanostructures formed using CdS nanoparticles freshly prepared under 900 mV show a linear localization pattern, which is usually desired for optoelectronic devices. Under a voltage of 600 mV, nanostructures with elongated morphology were obtained. For these elongated nanostructures is observed that bigger size of the electrophoretic particle, higher elongation it shows. This change in the morphology of nanostructures could modify the optoelectronic properties of the deposits obtained.

CADMIUM SULFIDE AND ZINC SULFIDE NANOSTRUCTURES FORMED BY ELECTROPHORETIC DEPOSITION

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CdS and ZnS nanostructures were formed by means of electrophoretic deposition of CdS and ZnS nanoparticles with mean diameter of 5 nm and 20 nm respectively. Nanoparticles were prepared by a microwave assisted synthesis in aqueous dispersion and electrophoretically deposited on aluminum plates. CdS thin films and one-dimensional nanostructures of ZnS were growth on the negative electrode after 24 hours of electrophoretic deposition at direct current voltage. CdS and ZnS nanostructures were characterized by means of SEM and AFM analysis. CdS thin films homogeneity can be tunable varying the applied electric field. Deposition at low electric field produces thin films with particles aggregates, whereas deposition at relative high electric field produces smoothed thin films. Size of one-dimensional nanostructures can be also controlled by the applied electric field. Two different mechanisms are considered for the nanostructures formation: lyosphere distortion and thinning and subsequent dipole-dipole interactions phenomena are proposed as a possible mechanism of the one-dimensional nanostructures, and a mechanism considering pre-deposition interactions of the CdS nanoparticles is proposed for the CdS thin films formation.

A PHYSICOCHEMICAL AND ELECTRICAL STUDY OF PZT (1-X)/X SOL-GEL BASED PRECURSORS

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In this work, several PZT (1-x)/x sol-gel based precursors were synthesized (25/75, 60/40, 80/20 and 95/05) in order to obtain highly stable colloidal dispersions containing size-controlled nanometric organic precursors. Sols aging and stability were studied by monitoring the particle size distribution using Dynamic Light Scattering (DLS) as well as High Resolution Transmission Electron Microscopy (HR-TEM) direct measurements. The synthesis of perfectly crystalline submicron PZT particles arrays was achieved after thermal treatment. Furthermore, in order to characterize the behavior of these systems for future applications involving an electrophoretic deposition (EPD) process, a cyclic voltammetry (CV) study was carried out. In all cases, it was clearly established the dependence of conductivity with reactants concentration as well as an appropriate EPD regime for obtaining high quality PZT thin films.

ELECTROCHEMICAL FUNCTIONALIZATION OF SINGLE-WALLED CARBON NANOTUBES FILMES OBTAINED BY ELECTROPHORETIC DEPOSITION

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Functionalization of single-walled carbon nanotubes (SWCNTs) using electrochemistry is one of the most selective, clean, and nondestructive methods. However, very few electrochemical methods of functionalization and characterizations of SWCNTs have been described so far in the literature. The reason may be due to the problem in maintaining the nanotubes on the electrode surfaces. Bucky papers were usually employed for the electrochemical characterization of SWCNTs; though, their fabrication led to random samples that offered high resistivities for the electrochemical characterizations [1,2]. In this paper, we report an electrode coated with SWCNT thin-film prepared by the electrophoretic deposition (EPD) technique, which has the advantages of short formation time, simple apparatus and suitability for electrochemistry measurements. SWCNTs electrodes are fabricated on indium tin oxide (ITO) glass substrates using a mixture of CNTs and a cationic detergent tetraoctylammonium bromide (TOAB) in tetrahydrofuran (THF) by applying a negative voltage to the ITO glass plate. The functionalization of these nanotubes is then achieved via electrochemical reduction of aryl diazonium salts, in a manner similar to that employed for functionalization of other carbon surfaces [3-6]. A variety of diazonium salts have been used, including those that provide moieties conducive to further elaboration after attachment to the nanotubes. Furthermore a computational approach based on atomistic and mesoscale simulations was employed to assess the affinity of the functionalized carbon nanotubes for different conductive polymers such as polypyrrole, polyaniline, polythiophene.

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Acknowledgements This work was supported by CNCSIS-UEFISCSU, project PN II-RU number 15/15.08.2010, code TE_153.

FABRICATION OF POLYANILINE/CARBON NANOTUBES COMPOSITES USING CARBON NANOTUBES FILMS OBTAINED BY ELECTROPHORETIC DEPOSITION

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The composites of carbon nanotubes (CNTs) and conducting polymers combine the large pseudocapacitance of the conducting polymers with the fast charging/discharging double-layer capacitance and excellent mechanical properties of the CNTs. One of the challenges is to approach the problem of manipulating CNTs to produce a particular arrangement needed for a given application. In this study, single-walled carbon nanotubes (SWCNT) thin films have been obtained by electrophoretic deposition technique on indium tin oxide (ITO) glass substrates using a mixture of SWCNTs and tetraoctylammonium bromide (TOAB) in tetrahydrofuran (THF). The polyaniline (PANI)/SWCNTs composite modified electrode was then fabricated by galvanostatic electropolymerization of aniline on SWCNTs-modified ITO electrode. We report a facile electrochemical method to obtain PANI/SWCNTs composite electrodes by combining the electroreduction of diazonium salts and electropolymerization of conductive polymers. In a first step, the CNTs are covalently functionalized with diphenyl amine through the electrochemical reduction of the 4-aminodiphenylamine diazonium salt in order to provide anchors for the polymer. The aniline oxidation remains possible on this grafted layer and PANI can easily be deposited on the diphenyl amine-modified electrodes. The electrochemically deposited composites exhibit excellent electrochemical charge storage properties making them promising electrode materials for high power supercapacitors.

Another important challenge concerns the improvement of mechanical properties of the composites PANI/SWCNTs. In order to predict the effect of SWCNTs on reinforced PANI composites a computational method based on molecular mechanics and dynamics simulations was employed. Computational bulk models of PANI and PANI/SWCNTs were implemented with different compositions and were investigated concerning mechanical properties. The results clearly confirmed that SWCNTs have beneficial effect on mechanical integrity and the Young's moduli values range from 0.80 GPa in the case of pure PANI to 1.37-3.6 GPa in the case of PANI-SWCNTs composite systems.

Acknowledgements

Authors recognise financial support from the European Social Fund through POSDRU/89/1.5/S/54785 project: "Postdoctoral Program for Advanced Research in the field of nanomaterials"

A STUDY OF YTTRIA STABILIZED ZIRCONIA PARTICLES' BEHAVIORS IN ALCOHOLIC SOLVENTS FOR ELECTROPHORETIC DEPOSITION APPLICATIONS

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In this study, some parameters which have been believed had effective roles on electrophoretic deposition (EPD) were explored for the alcoholic suspensions of yttria stabilized zirconia (YSZ). For such purpose, electrophoretic mobility (EPM), stability and conductivity of suspensions with different iodine concentrations (0 to 0.8g/L) and different aging time (a few hours after suspension preparation to 7 days) were evaluated. It was revealed that YSZ powder has a catalytic effect for the solvents – iodine reactions and the conductivity of suspensions can increase by passing of the time. However, except of ethanol suspensions, the EPM of the suspensions particles was only a little improved by applying iodine as a dispersant. Moreover, utilizing iodine did not enhance the suspensions stability and even, in some cases, it can destroy it.

AN INVESTIGATION OF YTTRIA STABILIZED ZIRCONIA PARTICLES BEHAVIORS IN KETONE BASED SOLVENTS FOR ELECTROPHORETIC DEPOSITION APPLICATIONS

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In this research, the most important suspension properties which have been considered for electrophoretic deposition (EPD) application were investigated for yttria stabilized zirconia (YSZ) particles in the ketone based solvents namely, acetone, acetylacetone, acetone-ethanol mixture (3:1 by vol.) and acetylacetone-ethanol mixture (1:1 by vol.). For such purpose, electrophoretic mobility (EPM), stability and conductivity of the suspensions containing different amounts of iodine (0 to 0.8g/L) were probed at different aging time (a few hours after suspension preparation to 7 days). Moreover, the conductivity of solvents were examined and compared to conductivity of the suspensions to recognize the effect of powder in the solvents reactions. It was found that except of acetone-ethanol mixture, the powder decreases the ionic strength of the suspensions which contained iodine. For the iodine content acetone-ethanol mixture, powder acts as a buffer to control the ionic strength of the suspensions. Additionally, iodine can improve the particle charging of YSZ particles and in some cases it enhanced the stability of suspensions.

FABRICATION OF HIGH PRECISION ELECTROPLATED DIAMOND TOOLS FOR OPTICAL MANUFACTURE

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The purpose of this work is to introduce a simple method to build high precision diamond tools to fabricate optical flats, depositing a diamond particle mono-layer in a Ni-Co-Mn matrix onto a precision rectified steel substrate. Nickel alloy adherence was achieved by means of an Electroless initial thin Ni-P layer. The homogeneous distribution of abrasive particles over the tool was achieved controlling their suspension, dispersion and precipitation in an aqueous medium. Results show that an enhanced viscosity electrochemical bath with an electronegative dispersant and a suitable mechanical agitation, provide good abrasive particle dispersion on the steel tool's surface (substrate), preventing their agglomeration. Three 14 cm diameter diamond tools were built (flat, 2 microns convex) precipitating abrasive particles of 45, 25, 9 microns on which a Ni-Co-Mn layer was electrochemically grown to a thickness approximately 2/3 of the particle average diameter.

AN AFM STUDY OF NANOPARTICLE ARRANGEMENT WITH DEPOSITION TIME

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In this study, coatings with irregular nanotopography prepared in electro-polished surfaces are characterised. Films deposited by electrophoresis are composed by YSZ particles, 5-8 nm in size and spherical in shape. The growth behaviour of coatings with time, including array morphology, aggregation origin and activity are explored by means of atomic force microscopy (AFM) in its different measurement modes. Arrangement of electrically driven particles at the nanoscale can be assessed through a topography description. Moreover, it can be associated to the electrokinetics behaviour of particles and the agglomeration degree of the suspension. The evaluation of particle junctions and then the quality of particle cohesion within the film can be also discerned by AFM characterization.

NI-BASED FILMS BY ELECTROPHORETIC DEPOSITION OF NICKEL HYDROXIDE NANOFLOWERS AND NANOFILAKES

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Last decade, the nanotechnology boom has resulted in the discovery of a host of forms of nanoparticles/nanoaggregates, such as nanopowders, nanotubes, nanowires, nanoplates, nanoneedles, etc., which have a lot of applications, in particular as catalysts, nanocomposites, nanodevices, chemical sensors or even as possible carriers of isotopes for medical applications. From of them, nanoflowers (flower-like nanoparticles) have been frequently obtained together or in equilibrium with other nanoforms, depending on reaction conditions. Current and possible applications of nanoflowers as optoelectronics devices or sensors, in catalysis, and solar cells cause a definite interest to them. Nickel hydroxide nanoflakes and nanoflowers-like particles have been sonochemically synthesized using water as reaction medium. Different additives, such as synthesis aids and dispersants, have been used to produce and stabilise them. Films obtained by the electrically driven assembly of synthesized particles have been evaluated on the bases of their surface morphology, crystallography and thermal behaviour.

FUNCTIONALIZING TI-SURFACES THROUGH EPD OF HAP/Y2O3 COATINGS

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Innovation of ceramic materials for bone repair and replacement is the basis for the expansion of the number of different applications of ceramic-based implants. Main research lines address new compositions improving functional and structural performances. Nanoparticles will be introduced into implants to enhance their properties. In this work, the insertion of Y2O3 nanoparticles in a hidroxiapatite matrix has been considered to improve the thermal response and further mechanical properties of implants. Homogeneous and well dispersed suspensions of Hidroxiapatite and Y2O3 nanoparticles have been prepared and co-deposited by electrophoresis on Ti substrates. Processing conditions have been adjusted to process tailored coating structures.

EPD AND COMBUSTION SYNTHESIS: TWO POTENTIALLY COMPLEMENTARY TECHNIQUES

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Electrophoretic deposition (EPD) was exploited to deposit sub-micrometric zirconia particles on metallic powders compacts belonging to the systems Ni+Al and Ti+Al. Combustion synthesis of these reactive substrates was ignited in a microwave single-mode applicator, operating at the frequency of 2.45 GHz, in order to obtain in a single step the synthesis of the desired intermetallic phase and the sintering of the deposited ceramic coating. In fact, the excess heat released during the formation of nickel and titanium aluminides by combustion synthesis reactions was exploited not only to self-sustain and self-propagate the reaction front along the substrate, but also to sinter the oxide layer obtained by electrophoretic deposition. The innovative procedure, here proposed, can be considered an interesting strategy in order to obtain, in a single step, high temperature materials or coatings, protected by well-adhered thermal barriers coatings.

CONTROL OF ELECTROPHORETIC DEPOSITION KINETICS FOR PREPARATION OF LAMINATED ALUMINA/ZIRCONIA CERAMIC COMPOSITES

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The electrophoretic deposition is effective method for preparing dense ceramic layers containing low amount of defects. For preparation of laminated structures containing certain level of residual stresses it is necessary to deposit homogenous layers with controlled density and interlayer cohesion. From this point of view it is essential exact control of deposition kinetics influencing final properties of the deposit. The electrophoretic deposition of alumina and zirconia from isopropanolic suspension in the presence of monochloroacetic acid was studied in the constant-current regime. The novel method of deposition kinetics control based on direct weight measurement was developed enabling exact control of deposit weight. It was found that the experimental electrophoretic deposition kinetics deviated from theoretical prediction and disabled prediction of deposit thickness. The change in resistivity of electrolyte during deposition and decrease of effective mass of particles forming deposit was found. Taking into account these changes the electrophoretic deposition kinetics has been successfully predicted based on fundamental physical properties of the suspension. The constant current regime used ensured final layer with constant green density across the deposit. The different levels of electric current during deposition from 250 μ A to 48 mA were used. The green density of deposit depends on the current density and then on the particle velocity during deposition and achieved value from 58% to 61% according to the electric current used. The lower green density of the deposit was, the larger pores were found in the green deposit. The low green density led to low final fired density and subsequently to the low Vickers' hardness changing from 2000 HV5 to 1650 HV5 depending on electric current used. Adopting these findings the microlaminates having various thickness ratios with respect to achieve various residual stress levels consisting alternating layer of alumina and layer of zirconia were prepared.

CONTROLLED DEVELOPMENT OF INTERNAL STRESSES OF ALUMINA-ZIRCONIA LAMINATED STRUCTURES

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The laminated ceramic can provide a flaw tolerant behaviour compare to the monolithic ceramic. Two ways how to ensure flaw tolerant behaviour of layered materials are known. The first is based on production of weak interfaces between layers allowing delamination without catastrophic failure. The disadvantage of this approach is low stiffness and low strength of resulting material. The second way, on the contrary, uses strong bond between layers to develop internal stresses. The development of internal stresses is provided by differences in layer shrinkage during cooling from the sintering temperature. The presence of internal stresses within individual layers can effectively change the crack path or even more to stop the crack propagation. Laminated structures with strong bond between layers can be prepared by various methods including tape casting, slip casting and last but not least by electrophoretic deposition. The electrophoretic deposition is the only one method which is able to create sharp and therefore strong interface in wide range of layer thicknesses. For design of such layered material is necessary to control precisely layer thicknesses during the deposition process. The layer thickness and exact ordering of layers can be modelled and optimised by means of numerical calculations. The necessary input for simulations and modelling is the distribution of internal stresses. Calculations of the internal stresses on the theoretical basis are known but relevance of obtained results is questionable. Furthermore when a phase transformation takes place it is not possible to consider this approach for internal stresses estimation. This contribution demonstrates a way how to determine level of internal stresses based on combined numerical simulation and dilatometric measurements. For this purposes alumina, zirconia monoliths and laminates were prepared. The numerical model of laminated structure was created for FEM simulation. All prepared materials were subjected of various investigations including elastic properties determination.

FABRICATION OF ZNO NANOWIRE ARRAYS BY ELECTROPHORETIC DEPOSITION

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ZnO is a wide bandgap (3,37 eV) n-type semiconductor with photoconductive properties and high excitonic binding energy, which make it potentially useful for the design of photonic devices, such as UV photodetectors, solar cells, laser and optical memories. ZnO nanostructures have also been proposed as suitable nanomaterials for sensors, actuators and nano-enabled synthetic biology [1].

There is an increasing interest in exploring new synthesis and fabrication methods of ZnO nanometer-sized nanowire arrays for these various applications. Many techniques have been developed, among them electrophoretic deposition (EPD), which involves the guided drift and deposition of charged particles in a solution under the influence of a suitable electric field, appears as a promising, fairly swift, low cost process.

In the present work, EPD is used to produce ordered ZnO nanowire arrays embedded in anodic alumina membranes [2]. The ZnO nanoparticle suspension prepared for EPD follows the method by Bahnemann and Hoffmann [3]. Suspensions with different nanoparticle concentrations are prepared by hydrolyzing an alcoholic solution of zinc acetate with NaOH, with a small amount of zinc nitrate added as a binder. This solution is then introduced into the pores of anodic alumina membranes at voltages of 10-100 V. The effect of the process parameters, such as deposition time, voltage and colloidal concentration, on the quality and morphology of the nanowire arrays produced is discussed.

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PEEK-BIOGLASS®-TiO₂ COMPOSITE COATINGS FOR ORTHOPEDIC APPLICATIONS GROWN BY EPD

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Polyetheretherketone (PEEK) is a biocompatible and stable polymer with attractive mechanical properties for a variety of applications, including the biomedical field. Titanium is widely used as material for implants, because it presents good corrosion resistance, mechanical properties and excellent biocompatibility. Since the discovery of Bioglass® by Hench in 1969, this material has been used in medical applications as bone filler material and tissue engineering.

When biocompatibility and bioactivity are combined, the design of composite materials offers an exceptional opportunity for enhancing the final biomaterial obtained as it allows the creation of bioactive films with tailored physical and mechanical properties as in bioactive glass–ceramic- polymer composites coatings. In this research, the combination of PEEK with inorganic particles such as bioactive glass particles and titanium dioxide (TiO₂) nanoparticles is investigated in order to improve the properties of the PEEK coatings.

Electrophoretic deposition was the technique chosen to produce these novel PEEK-Bioglass®) - TiO₂ coatings. The coatings have been successfully deposited on 316L stainless steel substrates by EPD from ethanol suspensions containing titanium oxide nanoparticles, bioactive glass powder (45S5 Bioglass®) and micrometric PEEK particles. As a result, homogeneous composite coatings were produced. The composition of the composite coatings can be varied by changing the concentration ratios of powders in the suspensions.

Cathodic coatings were obtained applying a voltage between 9 and 30 V and deposition times of 60 to 360 seconds. The deposition of PEEK/Bioglass®/TiO₂ composite on stainless steel confirmed that the carried charge of the PEEK surface at pH < 4.5 is negative during the EPD process; this surface charge of PEEK particles enables the co-deposition on the cathode with Bioglass® and TiO₂. After the EPD process, a heat treatment at 343 °C for 30 min (10 °C min⁻¹) was needed to increase the adhesion substrate-coating.

To analyze the microstructure of the electrophoretic composite coatings, scanning electron microscopy (SEM) and X ray diffraction (XRD) techniques were employed. Tape test analysis showed that the composite coatings exhibited an increase in the adherence to the substrate which was influenced by the presence of Bioglass® and TiO₂ particles.

Further in vitro characterization of the composite coatings is being carried out. EPD can be considered a suitable low cost method to produce PEEK- Bioglass® -TiO₂ composite coatings on metallic substrates, offering the advantages of room temperature fabrication of bioactive coatings for biomedical applications.

ELECTROPHORETIC COATINGS ON CERAMICS

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The electrophoretic deposition (EPD) has a lot of advantages. Thus high deposition rates, the formation of homogeneous compacts with high green density, and deposition of particles with different sizes without separation is possible. The latter is most important for processing of nanopowders. In spite of these advantages in comparison to established processes like slip casting there are only minor activities to utilize EPD for production processes of ceramics. On the other hand EPD is used on an industrial scale (e.g. Miele Company in Germany) for enameling high-end products. Furthermore all laser printers are based on the electrophoretic deposition of toner particles on the photoconductor drum, which are transferred on a paper and thermally fixed. Coatings on ceramics are very important. Nearly on all fine ceramic products glazes are applied for decoration and smoothing the surface. Furthermore, glazes and ceramic coatings are most important as protective coatings for improving chemical durability and mechanical properties like abrasion. As the deposition of charged particles in an electric field needs a conductive electrode as a substrate, the ceramic body has to be coated with a volatile conductive layer, which diminishes during the final firing of the product. For that coatings like graphite or polypyrrole were already investigated. For industrial applications aqueous suspensions would be most favorable. Consequently, the formation of gas bubbles due to the decomposition of water has to be prevented. This can be achieved either by applying pulsed fields utilizing non-linear motion effects (e. g. AC-EPD) or by oxidizing agents, which are used in enameling. In this paper different approaches with volatile layers are compared and first results are presented.

ELECTROPHORETIC DEPOSITION ONTO IONIC LIQUID LAYERS

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Electrophoretic deposition is a promising method for the near net shaping of ceramics if deposit damage during removal from the electrode can be prevented. The latter can be achieved by providing a lubricated interface between electrode and deposit. During application of such a lubricant care must be taken that none of the electrode surface details are lost. Hence thin layers which closely represent the original electrode surface are needed.

In the present work electrophoretic deposition of alumina powder on a thin layer of ionic liquid applied on polymer electrodes is described. After deposition this ionic liquid layer serves as a shear plane during the deposit removal. The resulting deposits exhibit a high surface quality. Furthermore experiments show that the ionic liquid can be used as a means for producing electrodes with areas at which deposition is locally prevented.

THE ROLE OF DEPOSITION PARAMETERS ON THE CHAIN FORMATION BEHAVIOR OF ZNO NANOPARTICLES UNDER THE APPLICATION OF LOW FREQUENCY ELECTRIC FIELDS

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Although nonuniform electric fields have been widely used for separating and characterizing submicrometer bio-particles, their application to manipulate metal oxide nanostructures has gained remarkable attention during the last decade. This category of studies has mainly focused on the fabrication of thick films and gas sensors. In our previous works, we applied low frequency alternating electric fields to deposit ceramic particles within the space between two parallel planar electrodes and investigated the parameters affecting the deposition pattern at 1 Hz. At this frequency, the highly random assembly of the particles within the electrode gap resulted in crack formation across the deposited layer due to ununiformity in the compactness of the deposit. In the present work, the controlled assembly of ZnO nanoparticles into chain-like structures under the application of low frequency nonuniform electric fields was investigated. Depositions were carried out in acetone-based ZnO suspensions on co-planar electrodes with gap width of about 180 micrometers. The particles' alignment along electric field lines to form chains was shown to be dependent on deposition parameters such as electric field strength, applied frequency, time and suspension concentration. As illustrated by Optical Microscopy results, chain formation was obviously observed at 10 kHz where dielectrophoresis force dominates over other mechanisms such as electrophoresis and electric field-induced fluid flow which occur at lower frequencies. The assembly of particles into chains was also observed to be a function of electric field strength. As the electric field strength was increased (an increase in applied root mean square voltage from 5 V to 35 V), the loose assemblies of particles were modified into strong chains perpendicular to the electrodes. Additionally, the number of chains increased as a function of deposition duration so that most gap region was covered. This effect could be important in the sensor fabrication process where an increase in the number of chains would enhance the exposed surface area of the sensing device. The alignment of ZnO nanoparticles along electric field lines into chain-like patterns was also observed to be affected by the population of suspending ceramic particles.

ELECTROCHEMICAL STUDIES ON THE STABILITY AND CORROSION RESISTANCE OF ELECTROPHORETICALLY DEPOSITED HYDROXYAPATITE COATINGS FOR IMPLANT APPLICATIONS

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Stainless steel (SS) is very often used as orthopaedic and dental implant owing to its excellent mechanical characteristics. However, from an electrochemical perspective, SS can be susceptible to corrosion related problem. Therefore, inorganic bioactive coatings on SS surfaces are reported to impart corrosion resistance and enhanced biocompatibility. In this paper, hydroxyapatite (HA) coatings were developed on 316L type SS by an electrophoretic deposition (EPD) technique at various deposition potentials from 10 to 80 V in an acidic aqueous solution. Water was used as solvent because of its biocompatibility and because it allows also the development of multi-components composite coatings, for instance, HA composite coatings combined with polymers, bioactive glass, carbon nanotubes (CNTs), antibiotics and various type of proteins. It is of particular interest the development of HA/bovine serum albumin (BSA) composite coatings on SS by EPD. In addition, the use of water as solvent also offers the advantages with regards to ecology, safety and cost. Homogeneous coatings were obtained at the following EPD parameters: applied constant voltage: 40V, deposition time: 550s and pH: 4. The morphology of the coatings was examined by scanning electron microscopy (SEM) and the phase purity of the coated surface was confirmed by X-Ray diffraction (XRD). The corrosion behaviour of HA coatings on SS in simulated body fluid (SBF) solution was investigated by using electrochemical techniques involving potentiodynamic polarization curves and electrochemical impedance spectroscopy (EIS) measurements.

INFLUENCE OF DOLAPIX AS A DISPERSANT IN DEPOSITION PATTERN FOR FAST FABRICATION OF ELECTRONIC DEVICE BY USING LOW FREQUENCY ALTERNATIVE CURRENT ELECTROPHORETIC DEPOSITION (LFACEPD)

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Influence of Dolapix as a dispersant in deposition pattern for fast fabrication of electronic device by using low frequency alternative current electrophoretic deposition (LFACEPD) J. Esmailzadeh, E. Marzbanrad, B. Raissi Material and Energy Research Center, Tehran, P. Box. 14155-4777, Iran Corresponding Author's E-mail: j_es65@yahoo.com In this paper, the effect of a commercial carbonic acid based polyelectrolyte, Dolapix CE 64, on stabilization of TiO₂ nanoparticles in acetone media is reported. The effect of concentration of polyelectrolyte on the dispersion of TiO₂ nanoparticles has been evaluated by zeta-potential studies, sedimentation, and viscosity measurements. Zeta-potential measurements showed that adsorption of polyelectrolyte on particles surface increased the surface charge indicating strong interaction. Sedimentation tests showed that titania suspensions were stable up to 72 h in acetone media. In order to effectively apply the technique of LFACEPD to process materials, it is essential to produce a stable suspension containing charged particles free to move when an electric field is applied. We used this technique to produce gas sensor in short time (less than 20 seconds). The movie of this deposition is available. For this reason, first, a suspension of TiO₂ (p25-Degussa) in acetone, ultrasonicated for 15 min is prepared. Followed, a variety amount of Dolapix is added to suspension and characterized with the mentioned tests that are brought in above. The most stable of suspension is selected and deposition process by using LFACEPD on alumina comb electrodes is done. The produced device is exposed to reduction gas such as CO and NO. The result of gas sensing properties will propose in full paper. Thus we claim that we can fabricate the gas sensor device at less than 20 minutes with new method.

Engineering Conferences International
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Electrophoretic Deposition IV: Fundamentals and Applications

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10/2/2011 through 10/7/2011

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Engineering Conferences International

Engineering Conferences International (ECI) is a not-for-profit global engineering conferences program that has served the engineering/scientific community since 1962 as successor program to Engineering Foundation Conferences. ECI has received recognition as a 501(c)3 organization by the U.S. Internal Revenue Service and is incorporated in the State of New York as a not-for-profit corporation.

The program has been developed and is overseen by volunteers both on the international Board of Directors and international Conferences Committee. More than 1,400 conferences have taken place to date. The conferences program is administered by a professional staff and the conferences are designed to be self-supporting.

ECI Mission

To serve the engineering/scientific community with international, interdisciplinary, leading edge engineering research conferences

ECI Purposes

The advancement of engineering arts and sciences by providing a forum for the discussion of advances in the field of science and engineering for the good of mankind by identification and administration of international interdisciplinary conferences

To work with engineering, scientific and social science societies and the interested general public to jointly sponsor conferences and to take other actions that will foster complementary programming.

To initiate conferences that will have a significant impact on engineering education, research practice and/or development.

ECI Encouragement of New Conference Topics

The ECI Conferences Committee invites you to suggest topics and leaders for additional conferences and encourages you to submit a proposal for an ECI conference.

Ideally, proposals should be submitted from 18 to 24 months in advance of the conference although the staff can work on a shorter timeline.

The traditional format for an ECI conference is registration Sunday afternoon with technical sessions held each morning and evening through Thursday or Friday noon. Afternoons are used for informal gatherings, poster sessions, field trips, subgroup meetings and relaxation. This format has served well to build important professional networks in many areas.

ECI welcomes proposals for shorter conferences and for conferences which span weekends in order to reduce the number of working days participants are away from their offices.

ECI Works With You

ECI works with conference chairs in two complementary ways. First, an experienced member of the Conferences Committee acts as your technical liaison from the proposal stage through the conference itself. He or she is always available to consult with you on any conference issue.

Second, after your proposal has been approved by the Conferences Committee, the ECI staff will assume responsibility for the administration of the conference.

Your primary responsibilities will be recruiting the organizing committee, developing the technical program and securing third-party funding necessary to support the travel of key speakers.

The responsibilities of ECI's "full service" staff include -- but are not limited to -- the following:

- Recommend, negotiate, contract and make substantial deposits for housing, meals, meeting space, A/V equipment and tours.
- Maintain web sites for the conference and for submission of abstracts.
- Publicize via electronic and print media.
- Administer all finances including grants, contributions and purchase orders. (ECI makes grant funds available as soon as a grant is approved.) There is no need for chairs to set up a conference bank account or file tax returns for their conference.
- Process all applications and registrations.
- Produce bound program/abstracts book.
- Contract for the publication of print or electronic proceedings, if any.
- Provide on-site staff during the conference.

For more information, please contact the ECI Director at Barbara@engconfintl.org

