SPECIAL SESSION E-12

LAYERED AND FUNCTIONALLY GRADED MATERIALS

Oral Presentations

E-12.1
Processing of Graded and Laminated Materials

E-12.1: IL01 **Structure and Phase Formation in SHS-FGM**
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Self-propagating high-temperature synthesis (SHS), also known as combustion synthesis is one of the most prospective methods for production functionally graded materials (FGM). The advantages of SHS include short time of reaction and product formation, which allow retaining pre-determined concentration gradient in the synthesized material. In the present work, the following challenges remaining in the field of FGM production by SHS are discussed. First, main features of combustion of multilayer samples are considered from the viewpoint of mutual influence of the combustible and inert layers. Second, evolution of the concentration gradients (profiles) during the combustion is outlined and different methods for controlling this process, such as mechanical pre-activation of the reactants are examined. Third, processes of the product phase and microstructure formation in multilayer SHS-materials are described. The problem of creating very thin gradient samples and coatings by SHS is also discussed. The consideration includes data of high-speed video recording, time-resolved X-ray diffraction, SEM, EPMA and other experimental techniques.

E-12.1: IL02 **Laminated and Functionally Graded Ceramics by Electrophoretic Deposition**
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Electrophoresis is the effect that when an electric field is applied to a suspension of a powder in a liquid, the powder particles move under influence of this field. Frequently the powder particles also deposit at one of the electrodes. The form of the electrode determines the form of the deposit, hence shaping is possible. The current insights into the science and technology of electrophoretic deposition (EPD) will be summarised. EPD is well suited for shaping layered microstructures (laminates), by simply changing repeatedly between two or more suspensions during deposition. Laminates consisting of silicon carbide layers and crack deflecting graphite interlayers have been produced. The effects of composite and porous interlayers in these laminates has been studied. Another area of advanced ceramics where the use of EPD makes sense are functionally graded materials (FGM) in which one tries to combine in one component high hardness and high toughness. EPD allows the formation of FGM by depositing from a powder suspension to which a second suspension is continuously added during the process. Examples will be shown of graded WC-Co and graded alumina-zirconia composites with an engineered gradient. The FGM concept can also be used to increase the strength of ceramic components by introducing compressive residual stresses in the outer surface.. This concept was applied to the design and EPD processing of functionally graded alumina and zirconia based femoral components for biomedical applications.. The gradient profiles were designed to obtain a maximum compressive surface stress and minimum tensile stress in the core of the component to increase the strength compared to pure alumina components. The feasibility of this concept has been demonstrated.

E-12.1: IL03 **Developments of Laminated and Graded Materials in LSCPM**
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Developments on laminated and graded materials (LGMs) in LSCPM are reviewed. The bulk FGM systems of ceramic-ceramic, metal-ceramic combinations, and Coating FGM systems are summarized. Some representative research results are involved design, processing, and evaluation. Research on materials design covers tailoring of composition, structure optimization, interfaces design etc.. Several approaches aimed at preparing laminated and graded materials have been summarized, such as powder metallurgy, high-temperature synthesis, plasma spray coating, spark plasma sintering and UHPC combined graded sintering etc..

E-12.1: L04 **Fabrication of Functionally Graded SiAlON Ceramics**
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Functionally graded SiAlON ceramics (FG-SiAlONs) were successfully prepared by tape casting and lamination. Non-aqueous SiAlON slurries with five different alpha to beta-SiAlON ratios, (85a:15b, 70a:30b, 55a:45b, 40a:60b and 25a:75b) were prepared by 66 MEK/34 EtOH (vol.%) mixture. Phase and microstructure analyses incorporation with hardness measurements clearly show that the FG-SiAlONs, prepared by tape casting, exhibit continuous and gradual change in composition and hardness. Thus, the tape casting approach is a viable method to produce FG-SiAlONs with precisely controlled composition, and subsequently properties, as a function of position.

E-12.1: IL05 **Processing and Microstructure of Ceramic-metal Graded Composites**
M.P. Dariel* and N. Frage, Department of Materials Engineering, Ben-Gurion University of the Nagev, Beer-Sheva, Israel

The generation of graded ceramic-composites is one of the key issues that the FGM concept was intended to address. This issue is of relevance to a wide range of applications ranging from thermal barriers to advanced armor materials and thermoelectric devices. A great deal of work was done and many original solutions have been put forward based on the design of a material system in which a one dimensional continuous or segmented transition takes place from a mostly metallic towards a ceramic side. One approach for generating a ceramic-metal composite consists of infiltrating a porous ceramic preform by a molten metal. An initial porosity gradient after infiltration becomes a gradient of the ceramic-to-metal ratio and gives rise to a gradient of physical and/or mechanical properties. The solutions are based on the properties of the particular system under consideration, such as particle size and composition. The commonly used 'constructionist' approach, namely powder layer stacking is often plagued by deformation effects. The stability of the ceramic component over a range of compositions provides additional degrees of freedom that allow the design and implementation of deformation-free graded composites. Several such attempts will be described and discussed.

E-12.1: IL06 **Laminated Composites for Multifunctional Applications**
Jürgen G. Heinrich, Clausthal University of Technology, Clausthal-Zellerfeld, Germany

Near net shaped ceramic components with tailored microstructures and properties can be manufactured amongst others by tape casting followed by lamination or by layerwise slurry deposition (LSD). These processes, wich are suitable for both, mass production and rapid prototyping, will be described on the examples of silicon nitride components for mechanically loaded applications and on hydroxyapatite bone substitute implants. Unstructured tapes can be laminated by common thermal compression. Complex structured tapes can be joined by using preceramic polymers as lamination aids. When binder burn out is bothering organic free powders or slurries can be processed by LSD. This laser supported technology allows manufacturing of complex shaped parts without using any organic additive. This work discusses on the example of laminated silicon nitride tapes the influence of processing

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ABSTRACTS

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