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Foreword

Explosive growth in fundamental research, development and processing of advanced materials and nanotechnologies is impacting almost every existing industrial sector worldwide. Ideally, advanced materials and nanoscience are seen as providing a stepping-stone to technical advancements that positively impact many engineering disciplines, economy, existing industries and society in general. All across the scientific community researchers are launching ambitious nano-related research programs and activities, with advanced materials and nanoscience becoming a significant path for innovations, sparking the birth of a new generation of material systems.

Continuing and promising advances in nanoscience as well as in novel processing technologies fuel the hope of future economic growth. Although these are still largely scientific but this enabling science, useful when it is adapted to enhance existing technologies, creating a nucleus for maintaining an environment in which cutting edge research is translated into new generation of materials.

With all the above in mind we initiated this special issue on the 'Nanoengineered Composites and Ceramic Laminates'. The articles in this issue have been selected to reflect a diversity of research interests and achievements both in nanobased composite materials using nanofibers, nanoparticles, nanotubes, nanocolumns, etc. as well as in advanced processing of ceramic based laminated composites focused on key mechanical property requirements for future applications.

The first part of this issue deals with nanoengineered composites. All the articles are selected to cover

- Key basic science issues underlying these materials.
- Challenges and opportunities for new applications of these materials.
- Mechanisms for collaborative interdisciplinary research involving the basic and applied sciences that will promote new developments in, and a clearer understanding of nanomaterials.

The second part of this issue is devoted to laminate composites intertwined with novel processing ideas. The laminate ceramics are the class of engineering materials with excellent mechanical properties, such as strength, hardness and wear resistance. Recently a lot of work was performed to improve the brittleness of the laminate ceramics by designing the residual stresses that contribute to the significant increase of fracture toughness of the layered composites. The articles aim to identify

- Fundamental science problems underlying these ceramics.
- New criteria for material's design.
- Novel application for the tough ceramics laminates.

The articles for this issue have been received to reflect the current state-of-the-art in these fields. A broad diversity of research interests and achievements are presented by the authors from various countries around the world including USA, China, Russia, Korea, Hungary, Japan, Australia, Italy, Germany, Spain, Slovakia, Ukraine, and United Kingdom thereby making this special issue a truly international effort.

1. Part A. Nanoengineered composites

Paper 1. Carbon Nanotube and Nanofibre Smart Materials by Mark J. Schulz et al. (USA). The paper discusses the development of smart nanocomposite materials that can sense, actuate, detect damage, generate power, and carry load. The need for better control over nanotube synthesis and improved conductive polymers is also discussed.

Paper 2. Preparation, Structure, and Properties of Nano-Cr_2N Reinforced Al_2O_3Composites by Lian Gao et al. (China). Dense Al_2O_3–Cr_2N composites with high bending strength were successfully prepared for the first time. The bending strength of the prepared composites has been greatly improved and both the fracture toughness and the hardness of the composites increased.

Paper 3. Study on Crystallization Ability, Thermal Stability and Mechanical Properties of PET/MMT Nanocomposites by Yimin Wang et al. (China). Main technical and scientific interests are focused on the preparation and characterization of chemical fibers and fiber reinforced composites, especially on the high performance fiber and technical fiber for the reinforcement of polymer materials for different applications.

Paper 4. Synthesis and Electrical Properties of Aligned ZnO Nanocolumn by Sang Sub Kim (Korea). This paper studies the growth and application of ZnO-based nanostructures including nanorods, nanowires and nanoneedles synthesized by metalorganic chemical vapor deposition.

Paper 5. New Magnetic Materials Based Cobalt and Iron-Containing Nanoparticles by G.Yu. Yurkov (Russia). This work demonstrates that it is possible to create new magnetic composite material based on metal-containing nanoparticles stabilized on the surface of polytetrafluoroethylene nanogranules.

Paper 6. Development of CNT/Si_3N_4Composites with Improved Mechanical and Electrical Properties by Csaba Balazsi (Hungary). In this work, electrically conductive silicon nitride ceramics are realized by carbon nanotube, carbon black

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and graphite additions. The carbon addition may drastically change the electric properties of composites. Insulator and conductor silicon nitrides with low resistance were developed depending on the type and concentration of carbon addition.

Paper 7. A Critical Review on Nanotube and Nanotube/Nanoclay Related Polymer Composite Materials by Kin Tak Lau (China). In this paper, a critical review on recent research related to nanotube/polymer composites is given. Newly adopted coiled nanotubes used to enhance the interfacial bonding strength of nanocomposites are also discussed. Moreover, the growth of nanotubes from nanoclay substrates to form exfoliated nanotube/nanoclay polymer composites is also introduced in detail.

Paper 8. Coiled Carbon Nanotubes: Synthesis and Their Potential Applications in Advanced Composite Structures by Kin Tak Lau (China). This paper reviews the synthesis of the coiled nanotubes and their potential applications in advanced composites. The coiled nanotubes indeed are ideal reinforcements for composite and polymer-based materials. These reinforcements can provide moderate strength improvement as well as enhance the fracture toughness of the composites without substantially increasing the weight and damaging the nanotubes' structures.

2. Part B. Ceramic laminates

Paper 1. Layer Orientation Effects on the R-curve Behavior of Multilayered Alumina–Zirconia Composites by R.J. Moon et al. (Australia). The paper presented studies of *R*-curve behavior of multilayered alumina–zirconia composites. The effect of the relative layer orientation with respect to the crack-tip front through the composite on the resulting *R*-curves was measured and the findings of the influence of the layer orientation on the crack growth resistance behavior are discussed. In situ optical observations of the crack front intersecting a multilayered structure at a skewed angle were performed which allowed evaluating the *R*-curve behavior both in laminates and monolith samples.

Paper 2. Si_3N_4–TiN based Micro-Laminates with Rising R-curve Behaviour by G. Blugan et al. (Germany). Si_3N_4–TiN laminates with rising *R*-curve behavior are further presented by design of the thermal residual stresses in the separate layers. Using the proposed design the significant increase in the apparent fracture toughness is been achieved which will result in increase reliability of the laminates. The Si_3N_4–TiN laminates have been manufactured by tape casting and hot pressing and tested in four point bending after introducing the V notch in the bending bar to evaluate the fracture toughness. The discussion on the toughening mechanisms of the developed laminates is proposed.

Paper 3. Microstructural Design, Characterization and Indentation Responses of Layer-Graded Alumina/Aluminum-Titanate Composites by Skala et al. (Australia). Design and indentation responses of alumina–aluminium-titanate composites together with their structural characterization are presented in the paper. The infiltration route was used to fabricate of the composites with homogeneous layers of alumina and heterogeneous layers of alumina/aluminium-titanates. Hardness and elastic modulus, as well as residual stain were studied using the indentation response of developed laminates. The microscale plasticity has been reported during the deformation of laminates which can be connected to grain debonding, grain sliding, microcracking, grain bridging or grain push-outs. There is a significant capability of the presented laminates to absorb energy, which can be influenced by the existence of residual strains.

Paper 4. Design and Production of Ceramic Laminates with High Mechanical Reliability by V.M. Sglavo and M. Bertoldi (Italy). Authors discussed their research on the design and manufacturing of ceramic laminates with high mechanical reliability. The novel procedure for designing reliable ceramic laminates was proposed. As a basis for the proposed design a fracture mechanics approach was used which allowed defining the stacking sequence, thickness and composition of different layers using the requested strength and the defect size distribution. The specific and well-defined residual stress profile is generated upon cooling after sintering of the laminates because of the mismatch of the thermal expansion coefficients between different layers. The proposed approached was verified on two model layered systems—alumina–zirconia and alumina mullite laminates. Mechanical performance of the laminates are discussed in terms of the generated residual stress profile and compared to parent monolith ceramics.

Paper 5. Crack Propagation Paths in Layered, Graded Composites by M.T. Tilbrook et al. (Australia). The paper is focused on the structural integrity and crack propagation behavior in layered graded structures. The study examined the influence of crack position on the crack propagation trajectory in layered, graded alumina–epoxy composites. The composites were produced by infiltration of layered porous alumina bodies. Both experimental and modeling work was done to predict crack-tip stress fields and crack propagation paths. The effect of elastic property gradient, microstructural heterogeneity and toughness anisotropy at interfaces are considered and the structural reliability of layered structures are discussed.

Paper 6. Processing of Al_2O_3/Y-TZP Laminates from Water Based Cast Tapes by A.J. Sanchez-Herencia, J. Gurauskis, and C. Baudin (Spain). The manufacturing of alumina–zirconia laminates is reported in the work of Sanchez-Herencia, Gurauskis, and Baudin. The laminates have been studied on their capability to improve the mechanical performance of the composites and initiate mechanisms, such as crack deflection, bifurcation, surface strengthening and threshold strength, which are responsible for the increase of the mechanical properties. The fabrication of layered ceramics has been done by stacking water based cast tapes at room temperature and low pressures. The sintering conditions of the laminates have been optimized by adjusting the green density of the tapes to avoid differential sintering and the associated cracks. Both monolith and layered ceramics free of cracks have been fabricated using the developed technique.

Paper 7. Oxide Laminated Composites with Aluminum Phosphate ($AlPO_4$) and Alumina Platelets as Crack Deflecting Materials by D.-K. Kim and W.M. Kriven (USA). The paper investigates the mechanical behavior of oxide–oxide laminates developed by the tape casting. Laminated matrix-interphase composites consisting of alumina–$AlPO_4$, mullite–$AlPO_4$, alumina/YAG–$AlPO_4$ composites have been manufactured. Their bending deformation behavior has been studied by bending technique. The 'quasi-elastic' deformation is reported for the developed 50 vol% alumina/50 vol% YAG in situ composite matrix—alumina platelet interphase which would significantly increase the work of fracture of the developed laminates.

Paper 8. Layered Composites with the Self-Diagnostic Ability by P. Sajgalik et al. (Slovak Republic). Authors presented a very interesting approach for the development of layered ceramics composites with self-diagnostic ability. Si_3N_4–sialon/TiN laminates were designed in the way that gradually increasing residual stresses were distributed across the whole sample. The proposed design allowed achieving increased strength and fracture toughness in comparison with monolithic ceramics. Measurements of the electrical resistivity of the conductive sialon/TiN layers enable predicting the formation of the cracks during the loading, which is proposed to be used for self-diagnostic ability of the samples.

Paper 9. SiC/SiC Woven Fabric Laminates: Design, Manufacturing, Mechanical Properties by N. Orlovskaya et al. (USA). The paper is focused on design, manufacturing and fracture toughness study of SiC–$SiC_{woven\ fabric}$ laminates. The laminates were produced by rolling of the SiC tapes stacked together with $SiC_{woven\ fabric}$ layers in a certain proportions and hot pressed at 1150 °C, 30 MPa for 50 min. The apparent fracture toughness has been measured by SEVNB method by placing a notch with a different length in different layers of the composite. The significant increase in the apparent fracture toughness has been achieved in comparison with monolith ceramics. Thus, the highest measured K_{1c} values is reported to be in the range of 7–8 MPa $m^{1/2}$, while the typical fracture toughness values of monolith SiC ceramics are in the range of 2–2.5 MPa $m^{1/2}$. The crack shielding by compressive residual stresses is reported to be a main acting mechanism for significant toughening of SiC–$SiC_{woven\ fabric}$ laminates.

Paper 10. Structure, Nonlinear Stress–Strain State and Strength of Ceramic Multilayered Composites by O.N. Grigoriev et al. (Ukraine). The paper presented the SiC–TiB_2 multilayered ceramic composites designed by different porous and dense layers. In certain cases the porous SiC layers exhibit special arch structures reinforced by prismatic crystals. Such structures possess the relaxation ability and provide the enhanced strength of the SiC–TiB_2 composites. The modeling of the deformation behavior of the laminates has been performed to describe the nonlinear stress–strain dependencies for the quasi-homogeneous laminates.

Paper 11. Deformation Processes and the Effects of Microstructure in Multilayered Ceramics by Y. Long et al. (UK). The deformation behavior of layered thin ceramic films is discussed. The mechanical behavior and structure of TiN/NbN multilayers have been studied by indentation and TEM, respectively. It has been shown that significant increase in hardness (up to 30 GPa) of multilayered nanostructure thin films, reported by different authors, does not occur in every case. An increase of hardness by 5 GPa in comparison with the hardness of individual layers has been observed which is consistent with the hardening due to changes in dislocation line energy.

Paper 12. Numerical Simulation of Thermal Residual Stress in Mo- and FeAl-toughened Al_2O_3 by V.E. Saouma et al. (Italy). The paper is focused on the numerical simulation of thermal residual stresses in Mo- and FeAl-toughened alumina. Alumina based two-phase composites containing either second phase particles with lower (Mo) or higher (FeAl) thermal expansion coefficients were manufactured by cold isostatic pressing followed by the hot pressing. The hot pressing was performed at 1640 °C for Alumina–Mo and 1245 °C for alumina–FeAl composites. The residual stresses have been measured by fluorescence spectroscopy using Raman spectroscopy technique. The finite element model was used to calculate the residual stresses in the composites. The experimental results for measuring of residual stresses well matched with the values obtained by the theoretical calculations.

Paper 13. Laminated Ceramics Structures from Oxide Systems by G. de Portu, L. Micele, G. Pezzotti (Italy). Authors presented their findings on the hybrid laminated ceramics of pure alumina and a two-phase alumina/yttria stabilized zirconia composite. The significant improvement of mechanical and tribological behavior of the developed composites is shown. The in-plane residual stresses within the ceramic layers are responsible for the increase of strength, apparent fracture toughness, contact damage and wear resistance in comparison with the monolith ceramics were no residual stresses exist.

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