

## **GREAT MOMENTS IN CERAMIC HISTORY: AN OVERVIEW OF THE HISTORY OF WORLD CERAMICS**

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### **ABSTRACT**

This investigation presents an overview of the history of world ceramics from an art historical and object-oriented viewpoint, focusing on what might be considered “great moments” in ceramic history from early Neolithic cultures up through the 20<sup>th</sup> century. Images of ceramic objects from China, Africa, the Ancient Americas, Greece, the Islamic world, Japan, Korea, and the United States will be just a portion of the visuals presented. The results of this visual investigation of great moments, both technically and aesthetically, will be a profound awareness of the void that would exist if ceramics had not been a continuous enhancing cultural thread in our burial rituals, our ancient cooking vessels, our tools, our art objects, the very structure of our homes, offices, cars, medical discoveries, and electronic equipment. The conclusion is acknowledgment of the positive impact of ceramics on our lives.

### **KEYWORDS**

Ceramic art, ceramic history, material culture.

## **CERAMIC MINERAL DEVELOPMENT POTENTIAL IN NEW SOUTH WALES, AUSTRALIA**

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### **ABSTRACT**

New South Wales is endowed with extensive resources of a wide variety of industrial minerals, which have applications in the ceramic and refractory industries. These commodities include zircon, silica, structural clay, magnesite, topaz, zirconia/rare earths, kaolin, feldspathic materials, olivine, limestone, and pyrophyllite. The State offers good opportunities for the development of known resources and for further discoveries.

New South Wales also offers a variety of opportunities for producing value-added ceramic materials by further processing of many of the industrial minerals currently produced or known to occur within the State. These opportunities include the production of silicon metal, silicon carbide, fused silica, zirconia, rare metals and rare earth oxides, fused mullite and ceramic mullite fibres.

The State's potential for the mining and value-added processing of ceramic raw materials is further enhanced by a number of other competitive advantages, including its well-developed infrastructure, competitive transport costs and low cost energy.

### **KEYWORDS**

Raw materials, industrial minerals, development potential, investment opportunities, value added minerals processing, competitive advantages.

## **MECHANOCHEMICAL SYNTHESIS OF NANO ZIRCONIA POWDERS**

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### **ABSTRACT**

This paper presents an overview of three different mechanochemical reaction systems developed for the synthesis of ultrafine zirconia powders from  $ZrCl_4$ . The reaction mechanism is shown to depend on the oxide exchange reagent used. Reaction of  $ZrCl_4$  with LiOH and  $Mg(OH)_2$  occurs during milling whereas reaction with  $Li_2O$  requires subsequent heat treatment. Extensions to these basic reaction systems which allow the synthesis of stabilised zirconia powders are also reported. Preliminary densification studies show that ultrafine powders synthesised by mechanochemical processing possess enhanced sinterability.

### **KEYWORDS**

Mechanochemical, zirconia, nanocrystalline, and ultrafine.

## **CARBON NANOTUBES AS ADVANCED MATERIALS**

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### **ABSTRACT**

Materials that pack in the form of small carbon rod shaped nanotubes are of technological interest since they can exhibit unusual properties. In our laboratory we have made efforts to synthesise these materials from sources other than graphite, and in particular coal, because it is a cheap resource. We are also addressing the outstanding problem of forming a uniform product in which all nanotubes have the same internal diameters and stereochemistry. In this paper we have reviewed work with respect to the physical properties of carbon nanotubes. Nanotubes have the potential in a number of areas including electronics, hydrogen storage and as new materials of hitherto unknown strength and lightness.

### **KEYWORDS**

Carbon nanotubes, properties, hydrogen storage, steel, batteries, electronics, coal, void space.

## NOVEL CERAMICS FOR BIOMEDICAL APPLICATIONS

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### ABSTRACT

It was found in a simulated body fluid (SBF) that functional groups such as Si-OH, Ti-OH, Zr-OH, Ta-OH, Nb-OH, COOH and PO<sub>4</sub>H<sub>2</sub> are effective for the apatite nucleation. On the basis of these findings, it was shown that NaOH- and heat-treated titanium, its alloys and tantalum, a H<sub>3</sub>PO<sub>4</sub>-treated zirconia ceramics and CaO, SiO<sub>2</sub> glass-treated poly(ethylene terephthalate) form the bonelike apatite on their surfaces in SBF. Among them, NaOH- and heat-treated titanium, its alloys and tantalum were confirmed to form the apatite on their surfaces *in vivo* and bond to living bone through the apatite layer. Y<sub>2</sub>O<sub>3</sub>-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> glass microspheres were early shown to be effective for *in situ* radiotherapy of cancers. Recently, pure Y<sub>2</sub>O<sub>3</sub> and YPO<sub>4</sub> polycrystalline microspheres with high chemical durabilities were successfully prepared by high-frequency plasma method. They are expected to be more effective for the radiotherapy.

### KEYWORDS

Bioactive material, bonelike apatite, simulated body fluid, titanium, tantalum, zirconia, apatite-polymer composites, radiotherapy.

## **DECOMPOSITION OF DUAL HYDROXYAPATITE/FLUORAPATITE COATINGS ON METAL SUBSTRATES**

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### **ABSTRACT**

In order to prevent the formation of tricalcium phosphate (TCP), a relatively weak and rapidly biodegradable biomaterial, during sintering of hydroxyapatite (Hap) onto metal substrates, a novel two-layer coating was applied. This was achieved by pre-coating the substrate with either Hap or fluorapatite (Fap) which preserved the purity of the Hap top coating. However, Fap is more stable thermally than Hap. By using Fap the formation of TCP was totally prevented through out the coatings at a sintering temperature of 1050°C at which a relatively dense Hap outer coating was produced.

### **KEYWORDS**

Decomposition, hydroxyapatite, fluorapatite, electrophoresis, double layer, and coating.

## **SYNTHESIS OF HYDROXYAPATITE IN THE PRESENCE OF BIOLOGICALLY SIGNIFICANT MOLECULES**

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### **ABSTRACT**

In bone mineralization non-collagenous phosphoproteins containing polycarboxylate sequences are thought to control crystal nucleation and to subsequently modify crystal growth. Invertebrate calcified tissues may also contain significant amounts of phosphoserine and/or acidic amino acid residues together with chitin (a polysaccharide). The present study investigated the effect of synthetic phosphorylated compounds as well as monomeric/polymeric carboxylic acid compounds on the formation of hydroxyapatite under conditions of physiological pH, temperature and ionic strength. Poly-L-sodium aspartate was found to have the greatest inhibitory effect; only octacalcium phosphate (a known precursor of hydroxyapatite) could be detected in the presence of this polymer. Resultant minerals showed a variety of aggregation states. In addition, a series of experiments were performed to induce the formation of HAp on biogenic substrates, such as chitin and its derivatives, chitosan, reconstituted chitin and phosphorylated chitin. Granular aggregates of hydroxyapatite could be induced to form directly on phosphorylated chitin surfaces, but not on other biogenically-derived substrates.

### **KEYWORDS**

Hydroxyapatite, octacalcium phosphate, biomineralization, laser Raman spectroscopy, Fourier transform infrared spectroscopy.

## **HYDROXYAPATITE WITH CONTROLLED POROUS STRUCTURE AND ITS POLYMER-INFILTRATED COMPOSITES**

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### **ABSTRACT**

A basic approach to control both the microstructure and the pore characteristics of hydroxyapatite is proposed. Porous hydroxyapatite bodies were prepared from starting powders with different morphology using either pressureless-sintering or capsule-free HIPing sintering at various temperatures. The porosity characteristics (i.e., the fraction of open porosity and pore size distribution) and the size of hydroxyapatite matrix grains were evaluated. Pore volume and size distribution greatly depended on both sintering temperature and sintering method. Infiltration of polymeric secondary phase into porous hydroxyapatite, obtained through the present procedures, was also attempted and, as a result, various types of hybrid hydroxyapatite/polymer composites could be designed.

### **KEYWORDS**

Porous hydroxyapatite, pressureless-sintering, HIPing process, pore characteristics, microstructure, polymer infiltration.

## **TOUGHENING MECHANISMS IN CERAMICS STUDIED BY *IN SITU* MICROPROBE PIEZOSPECTROSCOPY**

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### **ABSTRACT**

The experimental recognition of appreciable toughening by extrinsic mechanisms (particularly crack-wake bridging and transformation toughening) in engineering ceramics stimulates the development of new methods of microscopic stress analysis to verify and extend theoretical micromechanics. This paper focuses on two piezospectroscopic techniques, fluorescence and Raman spectroscopy (henceforth referred to as piezospectroscopy), which can provide, upon employing a microprobe spectrometer device, microscopic stress information in ceramic materials. Microscopic stress fields which develop both ahead and behind the advancing crack tip can be analyzed *in situ*, using the microprobe piezospectroscopic device. Emphasis is placed on rationalizing the interaction between the stress fields locally developed during fracture and the pre-existing (residual) stress fields. Microscopic *in situ* maps of local stress are straightforward in providing new insight in the ceramic physics of fracture. This enables one to classify the proposed toughening mechanisms according to their actual effectiveness, thus clarifying their relative roles and limitations on ceramic fracture.

### **KEYWORDS**

Toughening mechanisms, Raman spectroscopy, fluorescence spectroscopy, rising R-curves, crack-wake bridging, transformation toughening.

## **COMPUTER MODELING OF MICROMORPHOLOGICAL CHANGE BY PHASE FIELD MODELS: APPLICATIONS TO METALS AND CERAMICS**

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### **ABSTRACT**

This paper presents computer simulations of micromorphological changes in various solids and a comparison between the numerical results and the corresponding experiments. More specifically three different solids and the micromorphological phenomena observed therein will be investigated: first, the precipitation and coarsening of tetragonal in cubic phase in Partially Stabilized Zirconia (PSZ), second, the coarsening and rafting phenomenon of Ni-base superalloys and, third, the phase separation and coarsening in eutectic tin/lead (SnPb) solders. Discrete Fourier transforms are used for the numerical treatment of the thermo-elastic, diffusion and order parameter problems encountered during the modeling of these phenomena. More specifically, the analysis will be based exclusively on continuum theory and starts with a numerical computation of the local stresses and strains in a representative volume element (RVE) of the solid. This information is then used in partial differential equations to study the evolution of local concentrations of the constituents as well as their state of order. Such "extended" phase field equations allow to quantitatively determine the influence and the interaction between classical diffusion of the Fickian type, surface energies according to Cahn and Hilliard, as well as the mechanical stresses and strains that accompany or arise during coarsening and phase separation.

### **KEYWORDS**

Microstructural change, phase field models, diffusion, order parameter, SnPb solder, Zirconia, Ni-base superalloys.

## **A COMPARISON BETWEEN THE SEVNB AND SCF MEASURED R-CURVE BEHAVIOR OF MULTILAYERED ALUMINA-ZIRCONIA COMPOSITES**

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### **ABSTRACT**

The single-edge-V-notched-beam (SEVNB) and the surface-crack-in-flexure (SCF) testing methods were used to measure the short-crack R-curve behavior of multilayered composites. The initiation and extension of short cracks were observed *in situ* via optical microscopy. The resulting R-curves, for both techniques, were similar when evaluating monolithic composites, however, deviations occurred when testing multilayer and/or gradient composites. The SEVNB R-curve measuring technique was more sensitive to changes in the microstructure on the measured apparent fracture toughness as compared to the SCF testing geometry. The differences in the crack geometry between the two measurement techniques were believed to be the cause these deviations. The ability to control the position of the SEVNB V-notch tip within a composite, to initiate small (~15-50  $\mu\text{m}$ ) cracks and extend these cracks subcritically in ~10  $\mu\text{m}$  extensions enables the influence of specific microscopic features on the fracture behavior to be investigated.

### **KEYWORDS**

R-curve, layered-composites, SEVNB, SCF, fracture.

## **FACTORS INFLUENCING THE MICROSTRUCTURAL DEVELOPMENT OF Ca $\alpha$ -SIALON EXHIBITING ELONGATED GRAINS**

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### **ABSTRACT**

Ca  $\alpha$ -sialon is a high hardness material that exhibits *in-situ* growth of elongated grains during pressureless sintering. This potentially gives the material very good fracture toughness. This paper examined the effects of a number of variables on microstructural development during sintering. The effect of composition was investigated by studying seven different compositions. Densification was seen to be hindered in compositions that produced only small quantities of liquid phase during sintering. Elongated  $\alpha$ -sialon was observed in all the compositions. It was in combination with equiaxed  $\alpha$ -sialon in low liquid compositions, but only elongated  $\alpha$ -sialon was present in the liquid rich compositions. The effects of using  $\beta$ -Si<sub>3</sub>N<sub>4</sub> instead of  $\alpha$ -Si<sub>3</sub>N<sub>4</sub> starting powders were also examined. Compositions using only  $\alpha$ -Si<sub>3</sub>N<sub>4</sub> and those that used a 50:50  $\alpha$ : $\beta$  mix displayed similar development during sintering. However, compositions that used only  $\beta$ -Si<sub>3</sub>N<sub>4</sub> were significantly hindered in their densification and displayed inhomogeneous microstructures.

### **KEYWORDS**

Sialon, calcium, microstructure, densification, grain growth, elongated, pressureless.

## **EFFECT OF MINERALIZER ON THE NITRIDATION OF SIALON-BONDED SILICON CARBIDE PRODUCTS**

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### **ABSTRACT**

The effect of a mineralizer, magnesium silicate, on the nitridation of compacts consisting of silicon, clay, silica and silicon carbide was examined in terms of their reaction depth, density, porosity, phase composition and microstructure. It was found that addition of mineralizer slowed down the nitridation significantly. The kinetic process of isothermal nitridation in the presence of magnesium silicate obeys a parabolic rate law. Otherwise it obeys a linear rate law. The results suggest that nitrogen transportation is the limiting step during nitridation when mineralizer is added. The mechanism of nitridation is discussed in terms of phase composition and microstructure.

### **KEYWORDS**

Mineralizer, nitridation, sialon, silicon carbide, refractory.

## **X-RAY PHOTOELECTRON SPECTROSCOPY STUDIES OF SOL-GEL FILMS ON ALUMINUM 2024-T3**

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### **ABSTRACT**

The purpose of this paper is to show how x-ray photoelectron spectroscopy (XPS) can be used to help understand the growth of sol-gel coatings on aluminum 2024-T3. XPS was used to determine the surface composition after cleaning, and after coating with sol-gel. The growth of tetrapropyl zirconate (TPOZ) was studied both as a function of TPOZ concentration and of immersion time. The growth was found to depend on TPOZ concentration, but not on immersion time, for times longer than 1 minute. TPOZ coated coupons were also immersed in hexanoic acid, and the bonding strength of the acid to the coating was examined by sonication. The coating was damaged after sonication, with some of the coating being removed. XPS was also used to examine an aluminum 2024-T3 coupon that had been partially dipped in a solution of (tridecafluoro 1,1,2,2-tetrahydro-octyl) trimethoxysilane (TDFL), but showed a high contact angle with water over the entire coupon. XPS showed the presence of TDFL on the undipped region, and this was due to the way the coupon was rinsed after dipping.

### **KEYWORDS**

X-ray photoelectron spectroscopy, sol-gel, aluminum 2024-T3, contact angle, XPS, TPOZ, TDFL.

## **MODELLING THE LIQUID INFILTRATION KINETICS IN ALUMINA PREFORMS**

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### **ABSTRACT**

Partially sintered alumina preforms were infiltrated with titanium trichloride,  $TiCl_3$  for the purpose of fabricating functionally graded alumina/aluminium titanate composites. Infiltration rates into the alumina are examined experimentally and theoretically for the cases of water and  $TiCl_3$ . The infiltration kinetics is modelled using the Washburn model, resulting in an effective pore radius approximately an order of magnitude smaller than the average pore size determined from SEM experiments and the pore neck size determined from porosimetry. This result is interpreted using Dullien's analysis, which models the porous medium as a single pore with varying diameter resulting in an effective pore size that is smaller than the smallest pore size seen from SEM and the pore neck size. Assuming a two-size single pore model (pore bulge and pore neck), the pore bulge is calculated from a combination of the Washburn model and Dullien's analysis, resulting in good agreement with the pore bulge size estimated from SEM.

### **KEYWORDS**

Modelling, infiltration, kinetics, alumina, porosimetry, functionally graded, SEM.

## **CARBURIZING OF TETRAGONAL ZIRCONIA**

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### **ABSTRACT**

The low-temperature (200°C) environmental degradation in water/steam of tetragonal zirconia polycrystals (TZP) doped with 3mol% yttria was prevented by heat treating the sintered samples in a carbon atmosphere. This heat treatment of the sintered samples resulted in a surface layer that was stabilized by carbon ions, but the bulk was only slightly affected. The effect on phase stability of the introduction of carbon into tetragonal zirconia was compared with another anion, nitrogen. It is found that the sites for carbon and nitrogen in the zirconia lattice are different, even though both promote the stability of TZP in the low temperature environment. Carbon mainly exists in the octahedral interstitial sites in the TZP lattice as pure atoms, rather than forming a Zr-O-C structure similar to the Zr-O-N or Zr-Y-O-N structures after nitrogen is introduced into the TZP lattice. Although the presence of the surface layer decreased the bulk strength of the sintered 2Y-TZP, the strength of surface-carburized samples was maintained when low-temperature environmental annealing was applied.

### **KEYWORDS**

Tetragonal zirconia, carburizing, nitriding, low temperature degradation, hydrothermal treatment, bending strength, phase stability, interstitial sites, anion stabilizers.