

# Symposium FB

## The Belt and Road Initiatives Materials Forum

### “一带一路”材料论坛

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## **FB. The Belt and Road Initiatives Materials Forum**

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**A01-01**

**FB-01(Invited)**

**Advanced Methods for Consolidation of Powder Materials under Pulsed Electromagnetic Treatment**

Evgeny Grigoryev

National Research Nuclear University “Moscow Engineering Physics Institute” (NRNU MEPhI)

Advanced technologies for the production of new materials and, in particular, nanostructured materials, using powder technologies require fundamentally new approaches for the formation and preservation of a given structural-phase state. Precision control of the state of materials in the process of consolidating powders of nanomaterials can be carried out using pulsed electromagnetic fields. The aim of the project is to study the effect of high-voltage and low-voltage pulsed electromagnetic fields in the technologies of powder consolidation. The experimental devices of spark-plasma sintering, flash-sintering, high-voltage consolidation and magnetic-pulse compaction are used in our laboratory for the production of advanced materials from metal powders, ceramic and composite powders. We can produce boron carbide, silicon carbide, uranium nitride, tungsten carbide - cobalt - diamond composites, tungsten heavy alloys, and others by electromagnetic methods of powder consolidation. Investigations into the welding of titanium and stainless steel have shown that application of a short high-voltage electric current pulse and pressure produces stronger welded joints composed of both similar and different metals of considerably different thickness. A combination of a short electric pulse with simultaneous high speed application of mechanical pressure in the weld zone causes high-speed deformation of the contact zone. The process of joint formation itself does not cause any appreciable diffusion during welding. Electric exploding of a tungsten carbide – cobalt material near-by high-speed steel surface forms on it a hardening coating. The essential structure properties of the formed coatings are determined by specifications of contact exploding electrode and the pulse current amplitude and duration. The hardening layers of tungsten carbide and pure nanocrystalline tungsten have been formed upon the surface of high-speed steel as a result of electric exploding. Experimental results to consolidation metal powders, ceramic and composites powders by electromagnetic methods presage fruitful results.

Keywords: Spark-plasma sintering; high-voltage consolidation; magnetic impulse compaction

**FB-02(Invited)**

**Advanced Growth of 2D Transition Metal Dichalcogenide Monolayers and Their Heterostructures**

Lain-Jong Li

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Our recent demonstration in vapor phase growth of TMD monolayers such as MoS<sub>2</sub> and WSe<sub>2</sub> has stimulated the research in growth and applications. These 2D monolayer building blocks can be used to form *p-n* junctions. For example, the heterostructures of 2D materials formed by vertical stacking have been realized via transfer of their exfoliated flakes, where their properties are dominated by the stacking orientation and strength of interlayer coupling. Another very attractive structure is the lateral heterojunction, where the atomically sharp *p-n* junction exhibits diode properties and a large strain exhibits at the junction region which offers tunability in electronic structures. In addition to the symmetry 2D materials, we have also developed a method that can precisely manipulate arrangement of chalcogenide atoms (S and Se) along the vertical direction of TMD. This new strategy

allows us to fabricate a MoSSe Janus structure, where the transition metals are sandwiched by selenium at upmost and sulfur at bottom. Such a Janus 2D monolayer exhibits piezoelectric responses and optical dipole along out-of-plane direction. Meanwhile, a location-selective growth has been developed to directly grow desired TMD layers in a one-pot process, and this new strategy enables the bottom-up fabrication of a CMOS circuit.

Keywords: Transition Metal Dichalcogenide; Monolayers; Heterostructures

### **FB-03**

#### **Analysis of metal magnetic memory signals based on reconstruction algorithm**

Hongmei Li

North University of Nationalities

Metal Magnetic Memory (MMM) technique has been extensively used as a qualitative method to test the position of possible damages in ferromagnetic metal structures, a bottleneck in further development of MMM technique is the quantitative relationship between MMM signal and damage characteristic has not been fully revealed. In this paper, analysis of influences of stress and defect on MMM signals is presented based reconstruction algorithm. Samples of diverse types of structural defects were made and then loaded with stress. The resulting residual deformations and residual leakage magnetic field were measured. Firstly, stress distribution was calculated according to the tested stress - strain curve of the material. The residual magnetization inside the specimen was reconstructed using residual leakage magnetic field signals. The quantitative relationship between stress and stress-induced residual magnetization was then established. Stress-induced residual magnetization was observed along the stress direction, and the intensity of the residual magnetization increased almost linearly with increasing stress. Secondly, the distribution of magnetic charge inside the specimen with defects was reconstructed using residual leakage magnetic field signals, the correlation of magnetic charge distribution with defects was analyzed. The magnetic charge was observed concentrating in the border of defects. A method used to visualize the defects was developed.

Keywords: Metal magnetic memory; reconstruction algorithm

### **FB-04(Invited)**

#### **Li-ion conductors for solid state and Li-air batteries**

Li Lu

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Solid state batteries have recently attracted a lot of attentions not only from academics but also from industries. One of the main reasons of attraction is the advantage of use of highly safe solid state electrolyte that replaces traditional organic liquid electrolyte. Replacement of highly flammable organic liquid electrolyte by solid and stable electrolyte leads to increased safety and at the same time expand voltage potential window from 0 to 4.5V to up to about 8V due to wide operating potential range of the solid electrolyte. Studies also note that use of solid electrolyte can significantly expand battery operation temperature range. Therefore, solid state battery is the future energy storage device. Solid electrolyte or Li-ion conductor is a key and also an essential component in the batteries. The solid electrolytes can be categorized into following types: oxide, glassy, sulfate, and polymer and its composites. Different types of solid electrolytes show different advantages in different aspects. Based on safety concern, oxide-based electrolytes such as garnet-structured, nasicon-structured and lisicon-structured materials have demonstrated pretty good stability in ambient condition with reasonably high ionic conductivity of about  $10^{-4} \sim 10^{-3}$  S/cm. Some of them can be potentially used in all-solid-state batteries and Li-air batteries.<sup>1,2</sup> This presentation will report our recent development of solid state electrolyte for Li-air batteries and for all-solid-state

batteries.

Keywords: Lithium Ion batteries; solid electrolyte; ion conductor

#### **FB-05(Invited)**

##### **Some research progresses in electromagnetic nondestructive evaluation of plastic deformation in materials of nuclear power plants**

Zhenmao Chen

Xi'an Jiaotong University

Plastic deformation and residual stress play important role in the safety of key structural components in nuclear power plants. The aim of this research is to evaluate feasibility of different electromagnetic Non-Destructive Evaluation (NDE) methods for quantitatively evaluation of plastic deformation in typical carbon steel and stainless steel used in nuclear power plants. The efficiency of the typical ENDE methods is compared through experiments and analyses.

The major contents of this review are as follows: 1) Backgrounds and fabrication of test-pieces with different scale of plastic deformation; 2) Establishment of experimental setups of typical electromagnetic NDE methods, i.e., magnetic Barkhausen noise, magnetic incremental permeability, magnetic flux leakage method, pulsed eddy current testing and eddy current testing for plastic deformation evaluation; 3) Experiments of plastic deformation measurements using different NDE methods and investigation on correlations of the plastic deformation and the signals of different NDE methods to clarify the feasibility of the ENDE methods for evaluation of plastic deformation for both ferromagnetic and paramagnetic materials; 4) Observation and discussions on the microstructure changed due to plastic deformation, and extraction of a suitable NDE strategy for evaluation of plastic strain in typical material of nuclear power plants.

Keywords: Plastic deformation evaluation; electromagnetic non-destructive evaluation methods; nuclear power plant

#### **FB-06**

##### **Facile and simple fabrication of WO<sub>3</sub> with different crystal structure for photocatalysis**

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Tungsten trioxide (WO<sub>3</sub>) has attracted immense attention as an n-type semiconductor material for photocatalysis because of its visible light response (bandgap energy,  $E_g = 2.6 \sim 2.8$  eV). In addition, WO<sub>3</sub> has a variety of crystal structures including monoclinic, hexagonal and cubic phases, and thus different crystal structured WO<sub>3</sub> exhibit different photocatalytic properties.

Here we report that different crystal structured WO<sub>3</sub> were prepared by in-situ synthesis utilizing hydrothermal technology, in which the WO<sub>3</sub> with different crystal structures were synthesized by adjusting the pH values of reaction system only. This approach is simpler than those ones reported previously due to avoiding the complicated calcination process.

The UV-visible diffuse reflectance spectra (DRS) exhibited that different crystal structured WO<sub>3</sub> exhibited different absorption edges also. The strong correlation between the crystal structure and band gap of WO<sub>3</sub> is of wide interest, the  $E_g$  values of different WO<sub>3</sub> phases decrease in the order monoclinic > hexagonal > cubic. The photocatalysis activity of cubic phase WO<sub>3</sub> was higher than those hexagonal and monoclinic ones due to the narrower band gap of cubic phase WO<sub>3</sub> can utilize the visible light more efficiently.

Keywords: Tungsten trioxide; crystal structure; photocatalysis

**FB-07****Influence Factors on the Sintering Properties of Silicon Carbide**

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Sintering is one of the most important procedure to produce silicon carbide ceramic. This paper from the perspective of industrial production to discuss influence factors on the sintering properties of silicon carbide from four aspects: powder of raw material, product formula, density of green body and sintering curves. The results were as follows: 1) Cost of sintering silicon carbide ceramic is economical when the particle size is in the range of 0.6-0.7 micron. 2) The density of sintered body can reach 3.15 g/cm<sup>3</sup> (98% T.D.) at 2150°C, when carbon and boron carbide content is 3wt% and 1wt%. 3) With the pressure increase in dry pressing process, density of green body and sintered body rise. When the pressure reaches 1.8 t/cm<sup>3</sup>, green body density reaches 1.86 g/cm<sup>3</sup> and sintered density reaches 3.15 g/cm<sup>3</sup>, then with the pressure and green body density increase, the sintered density remains unchanged. 4) When the heating rate during 1600°C to 1900°C is 1.5°C per minute, and the heating rate during 1900°C to 2100°C is 0.5°C per minute, the samples' vickers hardness can reach 2877±200, three-point bending strength can reach 534±52 MPa.

Keywords: silicon carbide; pressureless sintering; sintering properties

**FB-08(Invited)****Additive Manufacturing of Ceramics - unique process for printing 3 D shapes**

Wolfgang Boecker

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This process is based on the well-established inkjet printer technology and has found rising interest in processing of ceramics using a three-dimensional multilayer approach. Originally starting on a laboratory scale it has by now entered the production scale. Compared to standard processing of ceramics this method offers rapid prototyping and complex shape capabilities not obtainable with conventional manufacturing routes. Basics of the process will be described and examples of research scale investigations as well as industrial scale production presented. Key advantages of AM are compared to minor shortfalls.

**FB-09(Invited)****Research and Development on Strategic Metals Recycling**

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Strategic metals are the most important basic materials for national defense and economic & social development. Rare earth is an indispensable strategic resource for national defense industry and high-tech. Platinum palladium and other precious metals as a "strategic reserve metal", are "modern industrial vitamin" and "the first high-tech metals". Copper, aluminum, lead and zinc are the pillars of modern industry, electronic information, transportation, renewable energy and new energy. Strategic metals are not renewable natural resources. Therefore, it is of great strategic significance for the sustainable development of the national economy and society to put the strategy of metal recycling technology into the national key scientific and technological projects.

At present, Chinese strategic metal resources protection crisis is escalating, the contradiction between the shortage of resources and the market demand is increasing. Uncontrolled rough mining has led to the rapid

deterioration of the ecological environment of the mining area. Rare earth reserves is down to the current 23% from 74% in 1970s. China's platinum group metal reserves of less than 400 tons, with an annual output of platinum palladium is only about 3 tons, only the demand of 2.14%, foreign dependency of up to 97.86%. Copper, aluminum, lead, zinc reserves were 27.4%, respectively, 27.1%, 33.7% and 38.2%, of which only the copper reserves of only 30 million tons, can only maintain 6-8 years of mining. Scattered metals gallium, indium, germanium, rhenium due to over exploitation (2013 production of 200 tons, respectively, 380 tons, 100 tons and 25 tons, accounting for the world's 70%, respectively, 50%, and 50%), resulting in rapid decline in geological reserves.

The efficiency of exploitation and utilization of strategic metal mineral resources is low, and the overall recycling rate is less than 10%. The rare earth as an example, as of 2014, Baotou Rare Earth tailings dam in tailings has about 1.97 tons, in which contain thorium, rare earth, niobium and fluorine and other strategic elements calculation, this "rare earth hanging lake" is the world's largest artificial intergrowth rare earth ore, rare earth reserves even more than the United States Wangtingpasi entire mine. At the same time, acid and alkali waste liquid in water pollution and dust pollution and radioactive thorium loss is one of the main sources of mining area and the the Yellow River basin, the deteriorating ecological environment, has been a serious threat to all including humans, animals and plants.

Strategic metals in China's social ownership are growing, increasingly complex components, recycling more and more difficult. If not to accelerate the recycling level of science and technology, it will cause a huge waste of resources and energy and environmental problems. According to statistics, China's rare earth (according to the conversion of social ownership oxides), about 3 million tons of platinum palladium and other precious metal 1000 tons, gallium, indium and germanium rhenium metal scattered about 7000-8000 tons, about 1.2 tons of copper and aluminum of about 4 tons, about 70 million tons of lead and zinc in about 90 million tons. According to the fifteen year life cycle calculation, the average annual scrap strategic metals reached 45 million tons (excluding rare earth). In 2013 the ten major non-ferrous metals recycling has exceeded 10 million 750 thousand tons (recycled copper, tons of recycled aluminum, 5 million 200 thousand tons, recycled lead of 1 million 500 thousand tons, recycled zinc, 1 million 300 thousand tons), the recycling rate was only about 23.9%. Therefore, to improve the strategic metal recycling prospects, is expected to close to the amount of renewable energy consumption in 2030 (about 60 million tons) of the year, in to reduce the exploitation of billions of tons of ore. To improve the level of recycling technology of strategic metals will promote the exploitation and utilization efficiency of strategic metal mineral resources and the promotion of high value utilization of tailings resources. For example, the use of a small number of very low grade rare earth tailings, and co processing of fly ash and slag and other industrial solid waste, new materials manufacturing glass and ceramics with high strength, wear resistance, acid and alkali resistance, can be widely used in petrochemical, metallurgy and other fields.

Strategic metal recycling can not only save non-renewable precious natural resource, but also save energy and protect the natural ecological environment. From the point of long-term development, if we can complete the efficient utilization of various strategic mineral tailing the clean and efficient recycling and the use of various strategic metal containing waste, in the foreseeable future decades, we will have to realize the "non-renewable strategic" metal geology and mineral resources' into the great urban mineral. The realization of this goal, to a large extent, depends on the accumulation of scientific research, technical reserves, industrial planning and the protection of laws, regulations and policies.

Keywords: Strategic Metals; Recycling; Urban mineral

## **FB-10(Invited)**

### **Combustion Synthesis of SiAlON Ceramics: Achievements and Prospects**

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SiAlONs are solid solutions of silicon nitride with excellent hardness, strength, and wear/corrosion/thermal shock/high-temperature creep resistance. So that SiAlON ceramics are widely used in various engineering applications such as refractory and structural materials for molten metal handling, bearings, cutting tools, fixtures in welding and so on. Moreover, application field of SiAlONs is permanently expanded. Due to their encouraging luminescence properties (high conversion efficiency, low thermal quenching, and high chemical stability) the rare-earth doped SiAlONs have great potential as phosphors for color correction of white LEDs. SiAlONs are also highly promising for developing advanced transparent and biocompatible ceramics.

Combustion synthesis (CS) is a rapidly developing area of R & D oriented on convenient production of high-melting compounds and materials. About two last decades CS of SiAlONs was intensively investigated in many countries including the belt and road ones. The obtained results explain the fundamental macrokinetic regularities of infiltration-assisted combustion and reveal the main mechanisms of structure and phase formation in corresponding reaction systems. CS was found can be successfully used for production of high quality raw powder material for subsequent sintering as well as for direct production of ceramic items in one stage (membrane, catalyst carrier, heat insulation, high-density machinable composites). The aim of the present work is to review the main achievements and to highlight the most attractive directions for research cooperation in future.

Keywords: SiAlON; ceramics; combustion synthesis

## **FB-11**

### **Preparation and Characterization of a novel SrTiO<sub>3</sub>-Ag/AgCl hybrid composite with promoted plasmonic visible light excited photocatalysis**

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One kind of efficient visible light responsive photocatalyst SrTiO<sub>3</sub>-Ag/AgCl hybrid composites were successfully prepared through a two-step method combined in-situ photoreduction. XRD, FESEM, HRTEM, EDS mapping, XPS, N<sub>2</sub>-BET, UV-Vis were applied to characterize their phase structures, morphologies, elements mapping distribution, surface chemical composition and states, specific surface area, light absorption ability, respectively. Transient photocurrent responsive of the as-prepared samples under visible light illumination was measured in a three-electrode system, indicating that SrTiO<sub>3</sub>-Ag/AgCl possessed stronger photocurrent response than SrTiO<sub>3</sub> and Ag/AgCl, thus lower recombination rate of photogenerated electrons and holes. SrTiO<sub>3</sub>-Ag/AgCl hybrid composites were served as photocatalysts to decompose MO, RhB and phenol aqueous solutions under the illumination of visible light and exhibited a promoted photocatalytic activity compared to SrTiO<sub>3</sub> and Ag/AgCl. A possible photocatalytic mechanism was proposed, which was associated with the synergistic effect of surface plasmonic resonance of Ag<sup>0</sup> photoreduced from AgCl and decreased recombination rate of photogenerated carriers through transferring electrons from the surface of Ag<sup>0</sup> to SrTiO<sub>3</sub>. Moreover, photodegradation reaction processes of MO, RhB and phenol on SrTiO<sub>3</sub>-Ag/AgCl are in accordance with the pseudo-first-order kinetic rules and the reaction rate constants are approximately 10 times as high as that on Ag/AgCl. High photodegradation efficiencies and features were remained after successive four recycling experiments, indicating that the as-prepared SrTiO<sub>3</sub>-Ag/AgCl is stable and durable.

Keywords: visible light; plasmonic resonance; SrTiO<sub>3</sub>-Ag/AgCl hybrid composite; photodegradation

## **FB-12**

## **A facile synthesis of magnetic mesoporous silica microspheres and their performances for immobilization of lipase**

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The lipases have been employed widely in the kinetic resolution of secondary alcohols with high activity and enantioselectivity<sup>1-3</sup>, however, research on the application of lipases to the resolution of  $\alpha$ -halo carboxylic acids and their esters, as an important herbicides and pesticides, was seldom focused on. From our previous work, it demonstrated that the mesoporous silica supported lipase could efficiently resolve the secondary alcohols<sup>[4]</sup>. Herein, magnetic mesoporous silica spheres (MMSS) with mesopore size ( $\sim 6.7$  nm), large surface area ( $515 \text{ m}^2 \text{ g}^{-1}$ ) and high saturated magnetization ( $8.7 \text{ emu g}^{-1}$ ), were successfully synthesized and then utilized to immobilize lipase from *Candida Cylindracea* (CCL). The resulting biocatalysts (CCL/MMSS) were first employed for hydrolytic resolution of methyl 2-bromopropionate (2-BMP) in aqueous buffer/organic co-solvent, as a result, 96.2% enantiomeric excess ( $ee_s$ ) of methyl (S)-2-bromopropionate with 18% yield was obtained. The MMSS facilitated the separation of CCL/MMSS from reaction system for the repetition. The 83.2% of its initial activity was remained after the CCL/MMSS was repeated for eight cycles.

Keywords: magnetic mesoporous silica microspheres; immobilization of lipase; hydrolytic resolution; enantiomeric excess

### **FB-13(Invited)**

#### **Oxide layer growth stress studied by deflexion analysis on a Zr-based metallic glass alloy during oxidation**

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Zirconium based bulk metallic glass (BMG) alloys can be candidates for mechanical component applications because of their good forming ability, excellent strength, and better physical and chemical properties comparing with traditional Zr-based crystalline alloys. For some applications at high temperature a good oxidation resistance is necessary. It's important to study oxidation behaviour of those alloys. During oxidation process, very few information has been obtained, in-situ, until now about the growth stresses of oxide layer, but oxide growth stresses can influence largely the residual stress and the component integrity after oxidation.

In the present study, the deflexion tests during oxidation at high temperature (573 K) have performed on a  $\text{Zr}_{55}\text{Cu}_{30}\text{Al}_{10}\text{Ni}_5$  BMG alloy and the associated oxide growth stress has been analyzed based on in-situ curvature measurements. The curvature can be induced by thermal stresses from thermal expansion differences between the oxide and the alloy, or by volumetric stresses from growth of new oxide films or from phase transformations. The dissymmetry of each sample was provided by the formation of a 2mm thick protective Zirconia layer on one major face of the deflection sample before deflexion test. The dimensions of the deflection samples are around length,  $L = 40$  mm, width,  $l = 8$  mm and thickness,  $e = 0.15$  mm.

XRD method has been used determine residual stress level in Zirconia oxide layer after oxidation. The stress difference between growth stress and residual stress indicates the contribution of thermomechanical stress dues to thermal expansion difference between the oxide and the alloy. The contribution of thermal stress and the growth stress in final residual stress evolution has been discussed based on experimental and bibliographic studies.

Keywords: metallic glass alloy; oxidation; growth stress; residual stress; deflexion measurement; XRD stress analysis; thermomechanical stress



**FB-14(Invited)****Peculiar synergetic effect of MoS<sub>2</sub> Quantum dots and graphene on Metal-Organic Frameworks for Photocatalytic Hydrogen Evolution**

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Special enhanced synergetic effect of MoS<sub>2</sub> quantum dots (MoS<sub>2</sub> QDs) and graphene on metal-organic frameworks for photocatalytic hydrogen evolution is obtained here. The rate of H<sub>2</sub> evolution reach 2.07 mmol h<sup>-1</sup> g<sup>-1</sup> over the EY-sensitized 5 wt% MoS<sub>2</sub> QDs/UiO-66-NH<sub>2</sub>/G irradiated under visible light irradiation ( $\lambda \geq 420$  nm) in 3 h, and the apparent quantum efficiency (AQE) is 40.5% at 430 nm. The synergistic effect between MoS<sub>2</sub> QDs and graphene together with UiO-66-NH<sub>2</sub> is corroborated by photo-luminescence spectra, electro-chemical and photo-electro-chemical experiments, which demonstrated that the charge separation and the electrons transfer are more efficient with the aid of the MoS<sub>2</sub> QDs and graphene. MoS<sub>2</sub> QDs might be a promising alternative to replace noble-metal as co-catalyst for design new type of catalysts in photocatalysis proton reduction.

Keywords: MoS<sub>2</sub> QDs; metal-organic frameworks; Graphene; Photocatalytic hydrogen evolution

**FB-15****Effect of water vapor on the oxidation of Fe-17Cr stainless steel at high temperature**

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The purpose of this work was to investigate the influence of water vapor on ferritic stainless steel at high temperature, which is proposed to be used as interconnector in the planar solid oxide fuel cells (SOFCs). The oxidation experiment has been conducted at 700° C, 800° C and 900° C for 12h-96h by thermal gravimetric analysis (TGA) system under different humidity. The oxide surface morphology, cross-section microstructure and the chemical composition of the oxide scale were studied after oxidation, and the residual stresses distribution of the oxide scale were determined at room temperature. It has been found that the oxide scale composed of an inner Cr<sub>2</sub>O<sub>3</sub> layer and an outer Mn<sub>1.5</sub>Cr<sub>1.5</sub>O<sub>4</sub> spinel layer, the residual stresses in both oxide layers are compressive and the growth stresses plays an important role. The competition of the stresses generation and relaxation during oxidation and cooling affects the residual stresses level. The evolution of residual stresses in the two layers is different according to the oxidation temperature, and the stresses in the two layers are interactional.

Keywords: Solid oxide fuel cells (SOFCs); Water vapor; Oxidation; High temperature; Residual stresses; X ray diffraction

**FB-16****Effect of functional additives on the performance of internal combustion engine lube base oil**

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In order to improve the quality of oil and prolong the life of oil products, some additives are added into the base oil. The purpose of this experiment is to explore the effect of functional additives on lubricating oil of internal combustion engine and optimum dosage, four kinds of functional additives were added in the base oil with a certain mass fraction gradient: detergent, dispersant, antioxidant and rust inhibitor.

The amount of coke was determined by the SH/T0030 test to evaluate detergency. The dispersion coefficient of oil at low temperature and high temperature was measured by low temperature and high temperature spot dispersion test, and to assess the dispersion performance. The kinematic viscosity of the oil was determined

according to GB / T265-1988 by an Ubbelohde viscometer. The oxidation and nitrification values were determined by infrared spectroscopy and use the flash point meter to measure the flash point of the oil by GB / T3536. After data analysis, the effects of the individual sensitivities and the lubricating oil on the internal combustion engine were studied and determine the reasonable dosage range. The results show that with the increase of the amount of detergent and dispersant, the effect of cleaning and dispersing is remarkable, both of them have a good feeling.

The best dosage of T106A detergent is in 1.5%~2.5%. The best dosage of detergent T106A is between 1.5% and 2.5%. The optimum amount of detergent T115B is between 3.0% and 3.5%. The best amount of dispersant T154B is between 3.5% and 4.0%. With the increase of antioxidant T203, the viscosity of oil increased, the oxidation value and nitrification value decreased, it showed a good feeling. The optimum amount of antioxidant T203 is between 1.5% and 2.5%. However, the addition of anti-rust agent T705 will make the oils flash point and viscosity decreased.

Keywords: internal combustion engine oil; functional additives; optimum dosage

## Poster

### FB-P01

#### Formation of K<sub>2</sub>NiF<sub>4</sub> type of R<sub>2</sub>Al<sub>1-x</sub>Si<sub>x</sub>O<sub>3</sub>N<sub>1-x</sub>C<sub>x</sub> solid solution & phase relations in Pr<sub>2</sub>O<sub>3</sub>-SiC-AlN system

WU Laner, PAN Wengao, JIANG Yong, HUANG Zhenkun

North University of Nationalities

As the continuation of discovery the R<sub>2</sub>AlO<sub>3</sub>N(1:1) (R=Nd,Sm)-SiC solid-solutions in our previous work, the present work studied the formation of Pr<sub>2</sub>AlO<sub>3</sub>N with SiC solid-solution and the phase relations in the Pr<sub>2</sub>O<sub>3</sub>-AlN-SiC system. The Pr<sub>2</sub>AlO<sub>3</sub>N ss was confirmed to have K<sub>2</sub>NiF<sub>4</sub>-type structure with Si-C substituted for Al-N in Pr<sub>2</sub>Al<sub>1-x</sub>Si<sub>x</sub>O<sub>3</sub>N<sub>1-x</sub>C<sub>x</sub>, (x=0~0.6). The crystal chemistry of this solid-solution was briefly discussed. The phase relations in the Pr<sub>2</sub>O<sub>3</sub>-AlN-SiC system were determined to have the compatibility of Pr<sub>2</sub>AlO<sub>3</sub>N ss with AlN, SiC or Pr<sub>2</sub>O<sub>3</sub>, respectively. The phase diagram of the R<sub>2</sub>O<sub>3</sub>-AlN-SiC (R=Pr, Nd, Sm) combined system was presented.

Keywords: solid solution; SiC; Pr<sub>2</sub>O<sub>3</sub>; K<sub>2</sub>NiF<sub>4</sub>

### FB-P02

#### Combustion Synthesis of Eu-doped Ca- $\alpha$ -SiAlON Phosphors

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**Objective:**  $\alpha$ -SiAlON are solid solutions based on silicon nitride that appear due to incorporation of metal ions Me<sup>n+</sup> accompanied by partial replacement of Si - N by Al - O (*n*) and Al - N (*m*) links for charge compensation in the elementary cell. Accordingly, their composition is described by the elemental formula Me<sub>*m/n*</sub>Si<sub>12-</sub><sub>(*m+n*)</sub>Al<sub>*m+n*</sub>O<sub>*n*</sub>N<sub>16-*n*</sub>, where *n* is the valence of embedded metal ion. Originally,  $\alpha$ -SiAlONs have been designed as structural materials operating in severe conditions. Recently, much attention was given to Eu-doped  $\alpha$ -SiAlONs because of their encouraging luminescent properties (excitability by blue light, high conversion efficiency, low thermal quenching, high chemical stability), and high potential for color correction of white LEDs. To date, Eu-doped  $\alpha$ -SiAlON phosphors are produced by solid-state reaction at high temperature and high pressure,

carbothermal reduction and nitridation, and gas reduction and nitridation. These methods, however, suffer various drawbacks such as critical synthesis conditions, impurity contamination, and poor crystallization. Consequently, developing new efficient methods for synthesis  $\alpha$ -SiAlON phosphors is a hot subject of research.

**Methods:** In this work,  $\text{Ca}_x\text{Eu}_y\text{Si}_{12-(m+n)}\text{Al}_{m+n}\text{O}_n\text{N}_{16-n}$ , where  $x + y = m/2$ , were selected for investigation.

Combustion synthesis (CS) was realized through the exothermic chemical reaction of powdered mixtures that contain Si, Al, CaO, and  $\text{Eu}_2\text{O}_3$  with high pressure  $\text{N}_2$  gas. Combustion products were characterized by XRD (DRON-3 diffractometer, Cu-K $\alpha$  radiation) and SEM/EDS (S-4800 Hitachi microscope), and chemical analysis. Excitation and emission spectra of synthesized Ca- $\alpha$ -SiAlON:Eu samples were taken at room temperature using a Hitachi F-4600 spectrofluorimeter.

**Results:** Experimentally established were green compositions ensuring maximal extent of conversion, influence of elemental composition on phase composition, crystal structure, and microstructure of synthesized Ca- $\alpha$ -SiAlONs. The excitation spectra exhibit broad maxima peaked around 300 and 400 nm. The emission spectra are broad and position of their peak depends on both  $m/2$  and  $y$ . An increase in  $m/2$  decreases the rigidity of SiAlON lattice, while an increase in  $\text{Eu}^{2+}$  content  $y$  decreases a separation between the  $\text{Eu}^{2+}$  cations. Both factors promote non-radiative deactivation due to intensification of electron-vibrational transitions and energy transfer between the  $\text{Eu}^{2+}$  ions. This must lead to the Stokes shift and a decrease in the intensity of emission bands. For Ca- $\alpha$ -SiAlON:Eu with constant  $x/y$  ratio the fluorescence intensity grows due to an increase in the amount of luminescing Ca- $\alpha$ -SiAlON:Eu within the range of partially stabilized  $\alpha$ -SiAlON ( $0 < m/2 < 0.55$ ) and then gradually comes down within the range of fully stabilized  $\alpha$ -SiAlON ( $0.55 < m/2 < 1.2$ ). For Ca- $\alpha$ -SiAlON:Eu within the range of fully stabilized  $\alpha$ -SiAlON with  $m/2 = 0.6$ , the emission intensity increases proportionally to  $y$  within the range  $0 < y < 0.06$ . At higher concentrations of  $\text{Eu}^{2+}$  ( $y > 0.06$ ), the effect of concentration quenching becomes more pronounced.

**Conclusion:** The luminescent properties of  $\text{Eu}^{2+}$  doped Ca- $\alpha$ -SiAlON phosphors prepared by combustion synthesis has been found to depend on their phase and chemical compositions. The sample with a composition of  $m/2 = 0.6$  and  $y = 0.06$  showed the highest emission intensity.

Keywords: Combustion synthesis;  $\alpha$ -SiAlON; phosphors

### FB-P03

#### Combustion Synthesis and Properties of SiAlON–BN composites

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**Objective:** Solid solutions of  $\beta$ - $\text{Si}_3\text{N}_4$  of general formula  $\beta$ - $\text{Si}_{6-z}\text{Al}_z\text{O}_z\text{N}_{8-z}$  ( $z = 0.0$ – $4.2$ ) are known for their excellent hardness, strength, and wear/corrosion resistance, which explains their wide use in various engineering applications. Hexagonal BN exhibit good dielectric properties combined with high thermal conductivity and corrosion resistance at exceeding low wettability with the melts. Addition of BN to ceramic composites greatly improves their thermal shock resistance, machinability, and to decrease friction. SiAlON–BN composites are highly promising for metallurgical applications such as nozzles and pipes for metal pouring, annular breakers, crucibles, thermocouple casing, etc. In this context, it seemed interesting to apply combustion synthesis to its fabrication in a cost-effective one-stage process.

**Methods:** Synthesis of  $\beta$ - $\text{Si}_{6-z}\text{Al}_z\text{O}_z\text{N}_{8-z}$ –BN composites was based on filtration combustion (FC) of Si–Al–B powder compacts in nitrogen gas. Green mixtures also contained some amount of diluents,  $\beta$ - $\text{Si}_{6-z}\text{Al}_z\text{O}_z\text{N}_{8-z}$  and BN, in order to suppress the dissociation of product and coagulation of Si and Al into inactive agglomerates. Compacts with relative density  $d_{\text{rel}} = 0.62$ – $0.64$  were prepared by CIP at 50 MPa. Combustion was performed at  $P(\text{N}_2)$  up to 150 MPa. Synthesized ceramics were characterized by XRD (DRON-3.0) and SEM (LEO-1436).

Sample densities were determined by hydrostatic weighing. Compression flexural ( $\sigma_f$ ) strength was measured by using an Instron-1195 testing. Thermal shock resistance was determined by measuring critical temperature drop  $\Delta T$  upon quenching in flowing water. Tribological behavior was determined at normal temperature at a gliding velocity of 0.1–2 m/s and a load of 5–30 N by using SiC balls (6 mm in diameter) as a counterbody.

**Results:** Because of high green density, the samples could only be ignited for  $P(N_2) > 30$  MPa. With increasing  $P(N_2)$ , burning velocity  $U$  and combustion temperature  $T$  are seen to gradually attain the values of 0.9–1.6 mm/s and 2400–2600 K, respectively. An increase in  $P(N_2)$  is accompanied by change in a mode of FC. At  $P(N_2) = 30$  MPa, key governing factors are low amount of  $N_2$  in pores and insufficient gas permeability. In these conditions FC proceeds in a mode of unsteady or surface combustion and yields strongly non-uniform and cracked products. For  $P(N_2)$  around 100 MPa, FC becomes frontal and hence most suitable for synthesis of uniform target material. Structure of  $\beta$ - $Si_{6-z}Al_zO_zN_{8-z}$ -BN ceramics is strongly affected by presence of oxide and metal melts within the combustion wave. For BN contents  $< 5$  wt % synthesized composites had non-uniform structure that cannot be eliminated upon variation in green composition. For BN  $> 15$  wt %, volume changes were minimal. Better results are attained for BN = 5–15 wt %, this opens up a way to fabrication of zero defected ceramics with elevated density due to the effect of volume shrinkage. Volume shrinkage was found to grow proportionally to [Al, Si, B] and  $SiO_2$  content of green mixture. Volume shrinkage also depends on sample diameter  $D$ . Its value diminished at some critical values:  $D_{min} \gg 30$  mm and  $D_{max} \gg 70$  mm. Both can be associated with heat losses. The existence of  $D_{max}$  can be explained by difficulties in ensuring heat insulation of large samples from cold walls of SHS reactor. The existence of  $D_{min}$  is conditioned by an increase in the fraction of heat release dissipated into environment.

The flexural strength of synthesized composites was found to obey the well-known expression  $\sigma = \sigma_0 e^{-bP}$  ( $-bP$ ) where  $P$  is porosity,  $b = 4$ , and  $\sigma_0 = 240$  MPa. For composites with BN  $< 15$  wt %, parameters  $D T$  from thermal shock tests are close to those typical of sintered sialons and reaction-bonded  $Si_3N_4$  and slightly below that of hot-pressed  $Si_3N_4$ . For composites with BN  $\geq 20$  wt %, accurate  $D T$  measurements could not be performed exactly. Nevertheless, its residual strength even at  $DT > 800^\circ C$  was higher than that of ceramics with lower BN content by a factor of 1.5. Optimal combination of tribological parameters exhibited the composites containing 10 wt % BN. The friction coefficient of synthesized composites was found to vary within the range 0.3 – 0.7, the lowest values corresponding to composites with BN  $\geq 20$  wt %. But high BN contents negatively affect the wear resistance. Synthesized composites are also readily machinable with WC-based cutting instruments.

**Conclusion:** In combustion synthesis of  $\beta$ - $Si_{6-z}Al_zO_zN_{8-z}$ -BN composites an important role is played by strain-driven volume shrinkage caused by the presence of oxides within the reaction zone and a pressure gradient formed ahead of reaction front. Synthesized ceramics seem promising for fabrication of items operating in conditions of strong thermal shock.

Keywords: Combustion synthesis; filtration combustion; sialons; boron nitride

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**FB-PO01**

**Preparation and Application of Mesopores carbon/sulfur as Cathode Material for Lithium-sulfur Batteries**

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Lithium-sulfur batteries with a high theoretical energy density are regarded as promising energy storage devices for electric vehicles and large-scale electricity storage. Yet their practical applications are still hindered by short cycle life, low efficiency and poor conductivity which are mainly caused by the insulating nature of sulfur

and dissolution of polysulfide. Here, mesopores carbon was obtained by a template method with nano-silica as a hard template and mesopores carbon/sulfur (MPC/S) composite was synthesized via chemical method. In this study, the effects of different carbon sources and different template dosage on the surface and pore size of mesoporous carbon were investigated. Carbon sources, the ratio of carbon sources to the amount of templates were optimized. The relationship between specific surface area, pore size and electrochemical properties of the composites was studied. The pore size of carbon obtained was about 70 nm, and the specific surface was 797.529 m<sup>2</sup>/g. The obtained mesoporous carbon was loose, and the nanometer sulfur with diameter of about 70 nm was uniformly distributed on the surface of mesoporous carbon and in the channel. The rich mesoporous structure of MPC can provide ion transport channel, and accommodated the volume expansion during the cycles, and also improve the dispersion of sulfur in the positive electrode, effectively inhibit the dissolution of lithium sulfide. Because the mesoporous carbon supplied electronic channel for nano-sulfur particles, so the first discharge capacity is 1327 mAh/g, and the impedance decreases after 50 cycles, showing that it has good cycle stability.

Keywords: carbon/sulfur; Lithium-sulfur; Batteries; Cathode Material

## **FB-PO02**

### **Mechanical Properties of Materials Application in Stop Motion Animation**

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The form of stop motion animation is more enriched by emergence of new materials and application of new material manufacturing technology. The research on mechanical properties of new materials can expand the style of stop motion animation, influence the shaping of characters and even the plot development. This paper summarized the characteristics of material selection in stop motion animation production and compared the traditional and emerging animation with their materials application. The result suggested that the mechanical properties of new materials plays an important role in the fabrication of stop motion animation. The advantages of new materials such as fabricable, plasticity and variable translucency will help to broaden the thoughts to the stop motion animation fabrication.