A Special Section on Nanostructured Ceramic Oxides: Challenges and Opportunities

Developing advanced functional materials and devices with controlled features on the nanometer scale is at the core of R&D innovation. Unique electronic, optical, magnetic, as well as chemical properties of nano-scale materials are making these materials attractive for the new generation of devices. There is ample evidence which suggests fundamentally new behavior in nanomaterials that cannot be predicted by simple scaling laws. Semiconducting nanoclusters display interesting optical, electronic, and chemical properties, making them potential candidates for sensing, catalysis, and optoelectronic devices. Also, while conductivity enhancement by several orders of magnitude is seen in some nanocrystalline oxides, improved chemical and photo-chemical activity is evident in other nanostructured oxides due to enhanced surface area. However, the widespread utilization of nanostructured materials is often complicated by the conflicting demands for precise control of superfine features and large-scale production.

The trend towards miniaturization in the electronic and semiconductor industry has placed a demand on technologies and processes which can not only approach the scale of interest, but do so in an efficient manner. Since the discovery of the integrated circuit (IC), the number of devices per square inch has doubled annually. This has led to the development of patterning techniques such as e-beam lithography, ion-beam lithography, and dip-pen nano-lithography, which have enabled feature definition in the nanometer scale with good pattern fidelity. These processes, however, require expensive equipment and skilled technicians. Also, it is a challenge to scale-up to cover large surfaces in short time frames; these drawbacks sometimes limit their commercial viability.

This special section focuses on the fabrication of nano-structures of ceramic oxides using non-lithographic approaches. Due to their exceptional properties, the ceramic oxide nanostructures are ideal platforms for a variety of applications such as catalysis, sensors (gas, bio-, chemical, etc.), electronic and energy device applications, antimicrobial functions, environmental, biomedical, transportation, chemical manufacturing applications, and more. The fabrication methods covered in this special section represent recent innovations in nano-processing which integrates cutting edge expertise and resources in ceramic processing, non-lithographic approaches in micro- and nano-fabrications, microscopy, and other advanced characterization techniques.


Papers in this special section can be broadly classified into two groups; some focus on exotic synthesis and fabrication processes of nano-materials and nanostructures while others deal with their applications. The review by Choi and Lee presents a novel approach for the formation of various self-assembled structures such as hollow and hierarchical nanostructures using amino acid-assisted reaction. In another paper, Haq and Azad present a comprehensive description regarding the experimental strategy for making various pure and coated
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systems of monodispersed metal basic carbonate/metal oxide particles of important ceramics by using a urea-based homogeneous precipitation process. While these fall under the so-called wet-chemical synthesis category, the review by Ansari and Akbar focuses on a simple process that can be classified under surface modification techniques. They describe a process for the creation of self-assembled ceramic nano-islands by a strain assisted solid-state dissolution-precipitation process. Finally, the paper by Roselin, Selvin, Annesh, and Bououdina discusses the fabrication of hierarchical silicalite-1 possessing three generations of micro-, meso-, and macro-porosities through a dual-template approach using tetrapropylammonium hydroxide (TPAOH) and styrene butadiene rubber (SBR) latex particles as micropore and macropore templates, respectively.

On the application side, papers range from novel design of devices to measuring their performances. The article by Sundararajan and Azad focuses on the development of robust sulfur tolerant catalysts by selecting a non-traditional nanoscale ceramic support and recognizing its synergistic role towards improved on-stream performance in conjunction with the actively operating intermetallic cooperative phenomena among the noble metals present in them. In another paper, Andio, Beach, Morris, and Akbar discuss deposition of metal oxides with hierarchical nanostructures produced by hydrothermal and solvothermal synthesis methods. Furthermore, there are several papers focused on sensing applications. Gouma’s article reviews the effect of polymorphism on gas specificity and the importance of nanoscale processing for stabilizing the desirable oxide phases while introducing a gas-polymer-pseudomorph selection library for building the next generation of gas sensing systems with inherent selectivity. The paper by Matsubara, Shin, Izu, Nishibori, and Itoh presents gas sensing based on In$_2$O$_3$ nanoparticle thin films hybridized to an organic component with various types of functional groups which has promise for realizing gas selectivity.

Kale’s paper concerns a mixed potential sensor for the detection of CO gas where hydrothermally synthesised nanostructured tin doped indium oxide (ITO) is employed as a sensing material. In another paper, Xiaojun, Ooi Kiang, and Man Siu focus on the development of metal oxide based immunosensors using a BST sensing platform. Finally, the article by Wang, Lu, and Lai reviews the pyroelectric fundamentals for thermal infrared detection and the state-of-the-art on oxide-based pyroelectric materials for their application in dielectric bolometers.

We are grateful to the authors for their contributions and cooperation in adhering to the timetable. The fact that they were invited to write on selected topics is a clear recognition of their reputation in the area. As is often the case, scientific writing does not associate financial rewards. The greatest reward is, perhaps, being able to inspire young minds through our insights; the authors will be greatly appreciated for sharing their knowledge. The reviewers are particularly acknowledged for their time in critiquing these papers. Special acknowledgement goes to Professor Ahmad Umar, Editor-in-Chief of Science of Advanced Materials, for his vision, guidance, and cooperation throughout the process of this publication. Finally, we acknowledge the Editorial Office at the American Scientific Publishers for making this idea a reality.

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