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Multidisciplinary Center for Development of Ceramic Materials

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MULTIDISCIPLINARY CENTER FOR DEVELOPMENT OF CERAMIC MATERIALS

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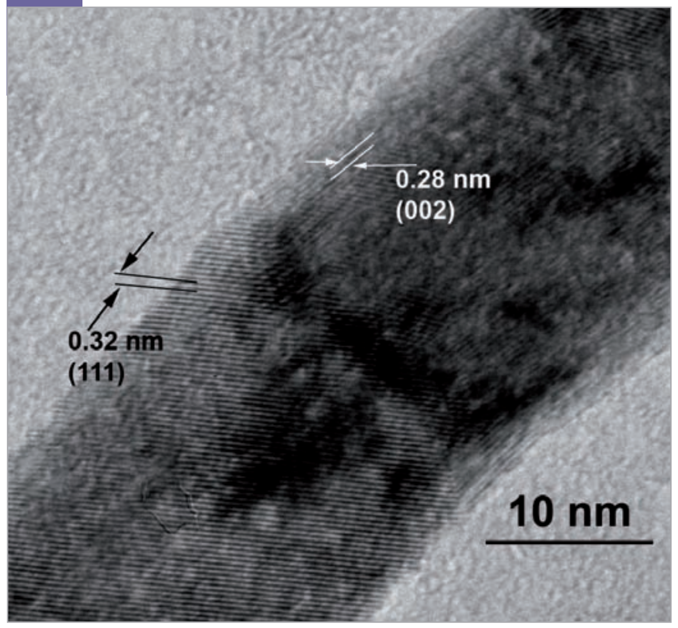

Synthesis of nanocrystalline ceramics: HRTEM image of CeO_2 nanobelts obtained by the oriented attachment (OA) mechanism

The Multidisciplinary Center for Development of Ceramic Materials was proposed by researchers of Paulista State University (Unesp), Federal University of São Carlos (UFSCar), University of São Paulo (USP) and Institute for Energetic and Nuclear Researches (IPEN). The activities of the proposed Center are totally focused on the enhancement of interdisciplinary and multidisciplinary research. The Center was constituted with the multifold mission of encouraging basic and applied research – so that new knowledge can be constantly generated – and promoting a systematic transfer of this knowledge for technological applications and educational purposes. This continuous process spreads knowledge, enlightens the society through instruction, and feeds back the cycle with more demands, that are ultimately satisfied with innovative approaches. To achieve these goals, the Center elects the industry and the schools of all levels as qualified partners for the task.

Our mission is to become formally estabilished as a reference center for ceramics research and development. For this, the Center consolidates an existing infrastructure and improves it to host, as a single and unique institution in science, engineering and education, basic and applied research, technology transfer and diffusion of knowledge. By hosting and encouraging interdisciplinary collaborations, the Center opens new means for research, both on campus and outside universities. The Center provides an intellectual atmosphere and physical means for scientists from different departments and institutions to meet and work together. Theoreticians and experimentalists, mathematicians, physicists, chemists and engineers will have the opportunity to discuss and argue in such a way that the ideas of each area of research will influence one another collectively, and thus new research themes will emerge.

MAIN RESEARCH TOPICS

Catalysis
Thin films
Nanotechnology
Theorical chemistry
Voltage-dependent resistors
Cosmetics
Luminescent materials
Ceramic pigments
Sensors
Art ceramics
Refractories

SUMMARY OF RESULTS TO DATE AND PERSPECTIVES

Innovations: highlights Refractory
The innovations developed by the metallurgical sector with the CSN company consisted in advanced refractories that can be applied in order to assure high metal quality from economical and ecological aspects. During services, not only must refractories tolerate high temperature but also withstand stress (thermal and / or mechanical), as well as exhibit resistance to combined attack by liquids such as molten metals, slags and fluxes.

Catalyst Materials
The innovation contracted by Petrobras (Brazilian Petroleum Company) is the development of a new catalyst material based on Al_2O_3-ZrO_2 system. Basically, the innovation consists of modifying the Al_2O_3 surface by using a nanolayer of zirconia and analyzing the influence of the ZrO_2 layer on hydrogenation reactions. Figure 1 shows HRTEM image of the alumina with a ZrO_2 layer.

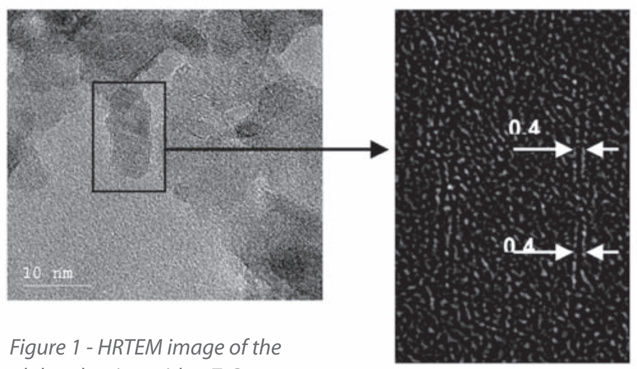

Figure 1 - HRTEM image of the alpha alumina with a ZrO_2 layer (HRTEM=High Resolution Transmission Electron Microscopy)

Development of automotive temperature sensors
Different kinds of perovskite-based NTC temperature sensors have been developed by the MCDCM which were synthesized by mixing, pressing and sintering Ni, Cu, Mn, and Co oxides aiming to apply such compositions as automotive temperature sensors. Some compositions have also been synthesized by a modified polymeric precursor technique. The electrical characterization was carried out by dc methods. An experimental sequence for producing large quantities of each composition was evaluated for the scaling up of the thermistor production by Metalúrgica Iguaçu Ltda. Therefore, the challenge posed by local industries looking for Brazilian-made temperature sensors for application in the automotive industry has been overcome: four out of six thermistors with behaviors similar to those exhibited by commercial thermistors have been successfully developed.

Spin-off Companies
Our students have nucleated two small companies, based on researches developed in our Center. The first one was Kosmo Science and the main purpose of this company is to develop analytical procedures to characterize cosmetic products, as well as the interaction of the cosmetics with hair and skin.

The second company nucleated in our Center was Nanox. The goal of this company is to develop nanostructured coating with functional properties such as bactericide and hard coatings. Figure 2 shows a nanostructured ZrO_2 coating on stainless steel developed by Nanox. This company is also working in the hydrothermal synthesis segment, developing small reactors for laboratories.

New product (Technological Innovation in Small Business - PIPE/FAPESP)
In this group of innovation, our main goal was the development of new products in collaboration with small companies and with the financial support of FAPESP through PIPE projects. An example of innovation was the development of translucent alumina pieces for dentistry applications. This innovation was contracted by Tecnident Ltda., from the dentistry sector that produces dental restoration 100% translucent alumina brackets.

The development of a dental restoration entirely comprised of ceramics, aiming to replace the traditional metal/ceramic dental restoration. This project was very complex and demanded the development of a porous ceramic matrix, and a glass to be infiltrated in the porous matrix. After the glass infiltration, a composite material was formed with excellent mechanical properties. Figure 3 shows an example of a ceramic dental restoration developed along with the EDG Company.

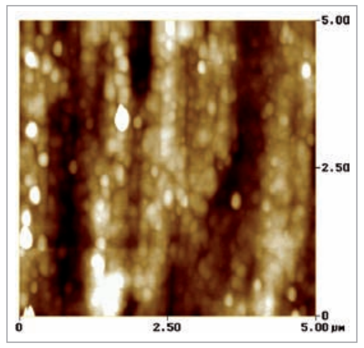

Figure 2 - AFM image of a nanostructured ZrO_2 coating on stainless steel

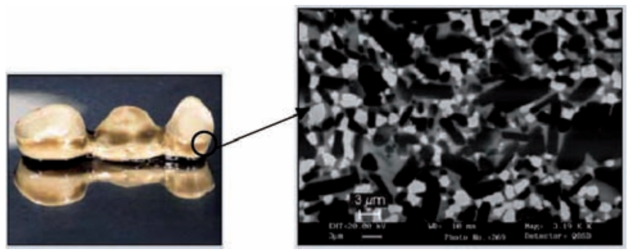

Figure 3 - Example of a ceramic dental restoration developed along with the EDG Company

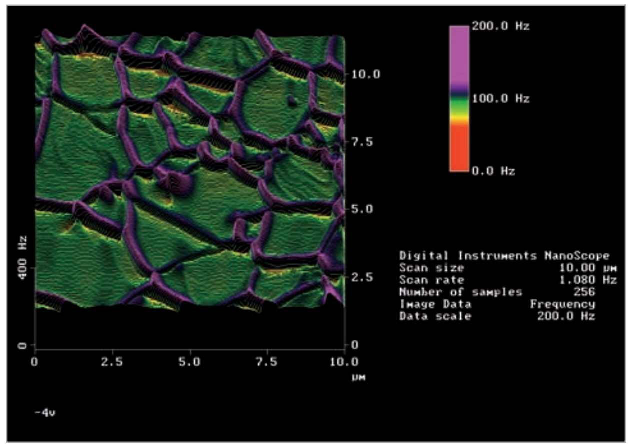

Figure 4 – EFM image of a polycrystalline SnO_2-based varistor

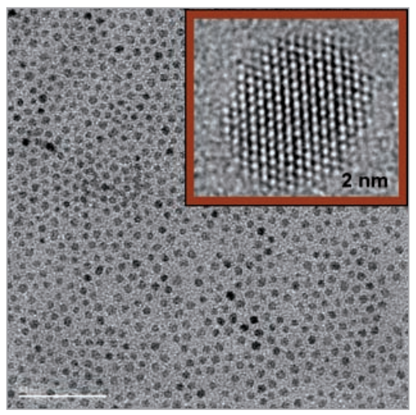

Figure 5 - HRTEM image of ZrO_2 nanocrystal processed by solvothermal process. The inset shows in detail the nanocrystal synthesized at our center

Polycrystalline Semiconductors
Concerning polyrcrystalline ceramic devices, the main development of our center was the SnO_2 based voltage-dependent resistors. We have shown the good electric performance of this device and its superior thermal conductivity and low degradation rate. The development performed by our group shows that the SnO_2-based voltage-dependent resistors presents properties similar or even superior to the ZnO-based voltage-dependent resistors, suggesting that this device is a good candidate for commercial production. An example of the work done on this device is illustrated in Figure 4. This figure shows an Electric Force Microscopy (EFM) image of a SnO_2-based varistor, where it is possible to see the voltage barriers at the grain boundary. In this image, noteworthy is the elevated number of voltage barriers in the grain boundary, which suggests an elevated number of effective barriers.

Synthesis of Nanocrystalline Ceramics
As to the synthesis of nanostructured metal oxides, the main result obtained by the MCDCM was the development of a kinetic model to describe the growth process of nanocrystals in colloidal dispersion, more specifically a statistic model to describe the oriented attachment (OA) mechanism. The OA mechanism originally proposed by Banfield and Penn (*Science.* 1998, **281**, 969) is a process involving the self-organization of adjacent nanocrystals and coalescence. The number of nanostructured materials obtained by the OA process is growing rapidly and has become an attractive form of processing nanomaterials with anisotropic structure. An in-depth understanding of this mechanism allowed for obtaining nanocrystals with controlled morphology, as illustrated in the HRTEM image in Figure 5.