

Up Close: Ceramics Research at the University of Aveiro

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This article is part of a series focusing on the research capabilities and goals of interdisciplinary laboratories pursuing materials research in universities, industry, and government

The production of ceramics and glass has always been an important industrial activity in Portugal. It wasn't until 1974, however, when the recently created University of Aveiro adopted a resolution to implement a five-year degree lecture course in Ceramics and Glass Engineering, that studies at the university level began in this field.

The reasons behind the establishment of the degree in the University of Aveiro were mainly two: (1) ceramics is one of the leading exporting industries in Portugal and technical staff in the field were recruited among nonceramic engineers; (2) Aveiro is the center of one of the strongest ceramics regions in the country.

It was evident that the nature of the ceramics industry in Portugal had a role to play in the definition of the lecture courses. But the need to prepare the students for the field of new materials was also manifest. It was therefore possible to devise a lecture course giving information on the two fields—traditional and novel ceramic materials—in a way that would enable not only modernization of the existing facilities but also innovation in the fields of new applications.

The integrated approach taken was supported by the close cooperation with Portuguese firms on one hand, and with foreign institutions (the Universities of Leeds and Sheffield) in England, University of Illinois in the United States, and the Institute of Ceramics and Glasses in Madrid, Spain) on the other. This interaction with the Portuguese industrial field and the academic world continues to be highly regarded in the department, and has proven profitable for all parties involved.

Research Activities

This integrated point of view is also manifest in the research carried out in the Department of Ceramics and Glass

Engineering of the University of Aveiro. Investigation programs are under way that deal not only with aspects directly related to traditional ceramics but also to the science and technology of advanced materials. A succinct analysis of current research activities in the Department can identify the following groups:

1. Traditional ceramics. This includes development of new formulations for traditional ceramics and glazes, with the objective of replacing conventional raw materials by others which are cheaper, more abundant, or allow lower firing temperatures. The variables affecting the technological processes involved in the production cycle, such as drying and firing, and their relation to the microstructural characteristics and properties of the final products, are also an object of examination.

2. Refractories. Development of compositions for pot furnace refractories and studies of chemical corrosion by melts are under way together with the investigation of the relevant phase diagrams.

3. Powder preparation. Research is being carried out in the field of preparation of ceramic powders. The methods include precipitation in aqueous and non-aqueous mediums, carbothermic reduction, and hydrolysis of alkoxides. The studies deal with the mechanism of nucleation and growth of particles in suspension and their interaction with the suspending medium, and also with the processes of densification during the various stages of sintering.

4. Ceramics for biotechnology. The preparation of rigid separating membranes for bacterial separation in effluent treatments is the subject of study in this field.

5. Semiconductor and dielectric ceramics. The processing and properties of ceramic materials used in varistors (e.g., ZnO), gas sensors (SnO₂, ZnO, WO₃), ca-

pacitors and transducers (titanates and niobates) are under investigation. The relation between doping materials, microstructure, defect concentration, and the electrical properties of the final products is one of the subjects of this research.

6. Solid oxide fuel cells. The objective of this program is to evaluate solid electrolytes in the preparation of oxygen sensors and solid oxide fuel cells. Deposition techniques are also studied, namely the ones involving suspensions, with the aim of controlling the porosity of thin films formed over electrolyte substrates by regulating the characteristics of the suspensions such as the degree of flocculation.

7. Ceramics with thermomechanical applications. The composition, conformation, sintering, and thermomechanical behavior of silicon carbide and silicon nitride ceramics and composites are being investigated. Conformation techniques involve pressing and slip casting. Sintering is studied in the presence of additives, and the aim is the understanding of the correlation between densification and microstructure and thermomechanical properties. Metal-ceramic bonding is also the subject of research.

8. Transport processes in melts. Volatilization from molten glasses is being studied with the objective of acquiring the information needed for industrial furnace operation. Another field of research is theoretical modeling of the processes related to mass transport in melts.

9. Sol-gel preparation of glasses. The study of sol-gel preparation techniques for special glasses is carried out in an effort to achieve compositions of high mechanical and chemical resistance.

The above investigations are carried out by a staff of 33 researchers, 10 of them being professors, 12 research assistants, and the remainder postgraduate students. Twenty-six fifth-year undergraduates are also involved.

Cooperation with Universities and Research Institutes

It has always been departmental policy to implement scientific cooperation with Portuguese and foreign universities and research institutes. In the beginning, this was a one-way relationship, as staff from the University of Aveiro carried out postgraduate and postdoctoral studies in the then new field of materials with the cooperation of the universities of Sheffield, Leeds, Illinois, and the Institute of Ceramics and Glasses of Madrid. Now this cooperation is more a two-way scheme, with Portuguese researchers taking sabbatical leaves in European, American and Japanese universities, cooperating in joint research projects, and exchanging under-

Ceramics and Glass Research Topics at the University of Aveiro

Powder processing—study of nucleation and growth processes of particles in suspension; preparation of ZnO and ZrO₂ powders from precursors by coprecipitation and sol-gel routes; studies of densification and coalescence during sintering of oxides (ZnO, NiO).

Thermomechanical ceramics—effect of sintering additives on microstructure and thermomechanical properties of SiC, Si₃N₄ and Si₃N₄/SiC composites; influence of composition and microstructure on friction wear of sialons; equilibrium phase relationships in Si₃N₄-oxide-SiC systems; processing of SiC ceramics by slip casting; low temperature sintering of Al₂O₃.

Electrical ceramics—effect of dopants and processing parameters on defect concentration and segregation in semiconductors; processing and properties of ZnO ceramic varistors, resistive gas sensors (ZnO, SnO₂, WO₃), capacitors and transducers (titanates, niobates and tantalates); evaluation of mixed conductors and solid electrolytes for oxygen sensors and fuel cells and of deposition techniques for producing thin films; sintering mechanisms and phase equilibria in Y₂O₃-BaO-Cu oxide superconductors.

Glasses—theoretical treatment of diffusion processes in molten glasses; volatilization in Na₂O-B₂O₃ glasses and its bearing on arc-melting operations; development of glass compositions (SiO₂-ZnO, SiO₂-TiO₂ and SiO₂-Al₂O₃-Li₂O systems) for chemically and mechanically resistant coating prepared by the sol-gel process.

Refractories and Clay Ceramics—development of refractory compositions for glass melting pot furnace linings; study of chemical attack on alumino-silicate and basic refractories by molten salts and slags; determination of equilibrium data pertaining to corrosion processes of basic refractories; development of clay-based ceramic fabrication routes using local raw materials and industrial waste; development of ceramic enamels.

relations.

Another form of cooperation is represented by the development of technical staff by means of short specialized courses in the various fields of the industrial processes.

Funding

A measure of the acceptance of the research carried out in the Department of Ceramics and Glass Engineering can be shown from an analysis of the origin of the funds applied in research. As usual, part of the funds come from the university. A contribution also comes from the Instituto Nacional de Investigação Científica, a national institution which finances selected research topics. Some of the projects currently being pursued are financed by a materials program open to the various Portuguese universities. Having reached a degree of success, the applications originated from the department are being developed normally. In the process, other institutions became involved, namely Portuguese ceramic firms, which are cooperating financially with the department in the development of traditional and new ceramics, reinforcing the collaboration initiated 14 years ago. Applications were also successfully made to the European Economic Community programs, EURAM and Non-Nuclear Energy, in cooperation with other European institutions. Additional funds come from work carried out in the department for industrial firms, requiring consulting, development, or testing activities.

Conclusion

Only 14 years old, the Department of Ceramics and Glass Engineering of the University of Aveiro in Portugal is involved in teaching, development, and research activities in traditional and modern materials, covering a wide range of projects. By implementing relations with Portuguese, European, and American institutions, it has been possible to apply successfully to various national and international programs, guarantee the funding for equipment, and thus keep in touch with novel fields of application of materials. On the other hand, by cooperating with the industry, the department contributes to its technological improvement and to its success.

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graduate and postgraduate students. With the Portuguese entry into the European Common Market, a new set of opportunities has arisen, and the Department of Ceramics and Glass Engineering of the University of Aveiro has become involved in research projects with institutes and universities from England, the Netherlands, Germany, Belgium, Ireland, and France. The department is also trying to further implement the exchange of students, profiting from the European programs available with that objective.

Cooperation with Industry

As the only ceramics university institution in Portugal, the Department of Ceramics and Glass Engineering of the University of Aveiro has special responsibilities in cooperating with the industrial community. The cooperation involves consultancy, development projects, tests and analysis and is mainly, although not exclusively, carried out through the Associação de Apoio à Cerâmica, an association of Portuguese ceramic industrial firms constituted to promote university/industry