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Much more than simple glass

Researchers at the Federal University of São Carlos produce vitreous material that can be used in telescopes, high-tech ovens and artificial bones

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When the question is research into the development of special types of glass and related materials, Brazil has an excellent reason to celebrate . Over the last few years, a research team from the Vitreous Material Laboratory (LaMaV) of the Materials Engineering Department of São Carlos (UFSCar) have produced important contributions into the research of glass ceramics, a sophisticated material that has its origin in glass and that could be used in the manufacture of artificial bones and teeth, substrates of laptops hard discs, very large telescopes mirrors, luxurious floors, transparent pots resistant to thermal shocks and glass hot plates in modern electric ovens, in place of the traditional gas burners.

These glass ceramic materials came about more than forty years ago. They are produced starting from the controlled crystallization of vitreous materials. The controlled crystallization is a phenomenon that occurs when the glass, containing a nucleus dissolving agent (titanium oxide, phosphorus oxide ,zirconium oxide, silver, gold etc.), is submitted to a temperature that varies between 500 and 1,100 Celsius degrees (Co). As a result of this process, it transforms itself into a new material, adopting differentiated characteristics. "Glass ceramic materials are smooth and much more resistant than those of glass.

Furthermore, they can have low electrical conductivity and thermal dilation close to zero", explains the materials engineer Edgar Dutra Zanotto, coordinator of the LaMaV and who is responsible for the development of new products. The advantages of these qualities are that these materials work as electrical insulators, a necessary characteristic for the substrates of hard discs, for example, and can be used in situations where the glass dilation material damages to the correct functioning of the equipment, as it is the case of telescopes or oven plates.

The most recent of the inventions of the UFSCar laboratory - whose patent is being registered - is glass ceramic that has the appearance of marble or granite and is more resistant than these materials. It can be used in the manufacture of various products that are included in a house: floors, tiles and lavatories. For the time being, the LaMaV masters the technology for small parts manufacturing , measuring between 15 x 15 centimeters, but they are developing others that are larger. Throughout the world, only the Japanese company Nippon Electric Glass is manufacturing and marketing a similar product, at a price of approximately US$ 500 per square meter, but with a chemical composition totally different from the studies of the LaMaV. "We still

don't know how much our product will cost. The price will be defined during the production phase, but most certainly it will be a lot cheaper", explains the coordinator of the LaMaV.

In another line of study by the UFSCar researchers, the objective is to develop glass ceramic parts that could substitute human bones. The first example of a bio glass- ceramic was created in the middle of the 90s in a partnership with the University of Florida in the United States. It is material used in the manufacture of artificial teeth and small bones of the ear, such as the hammer, the stirrup and the anvil. As a powder, it can be used to recompose cavities in teeth. At the end of the last decade, the patent was licensed to the company American Biomaterials in the United States. "During the patenting process, due to our innocence, we were identified only as the inventors of the product and not as the owners - those that are the retainers of the rights over the patent - which is of the University of Florida", explains Zanotto. "We never received a penny of the royalties", laments the researcher.

Two years ago the scientists at the LaMaV concluded the development of yet another glass-ceramic, this time starting from the leftovers of the steel furnace, a by-product in the metallurgy industry with a high level of silica and metallic oxides. The study was carried out in partnership with the Research and Development Center of Usiminas (A major Brazilian steel mill), located in the town of Ipatinga (MG). At the Usiminas company around 125,000 tons of leftovers from the blast furnace , including this by-product, are produced per month, representing a serious environmental problem. "The production of glass-ceramics from metallurgical leftovers would free the environment of part of these industrial residues and would permit the substitution, often with advantages, of natural rocks and other primary raw materials", says Zanotto. Thanks to its agreeable visual aspect, this new glass-ceramic could be used as a flooring, a wall covering and in the decoration of different environments. The LaMaV researchersarewaiting to shortly begin studies on the manufacturing of products on a pilot scale.

Advances on the frontiers

The creation of these new materials reveals the importance of the research carried out by Zanotto and his team. "Our laboratory has twenty five years of experience and a well defined work philosophy", says the researcher. "We believe that it will be possible to carry out basic research of a high level and to apply similar methods in the development of technology. We want to advance on the frontiers of knowledge and innovate in the sector of glasses and related materials." To achieve these goals, the LaMaV has established close cooperation with industry. No less than eighteen Research and Development (R&D) projects have been carried out over the last twenty years in conjunction with various companies, among them Pirelli, Usiminas, Companhia Baiana de Pesquisas Minerais (CBPM) and Alcoa.

All of this technological production, in the opinion of Zanotto, is rooted in the field of fundamental science in research based on the understanding of the crystallization phenomenon . "Glasses are materials that have relatively highenergy at the atomic level due to its disordered molecular structure and tend to self-crystallize spontaneously, without control, during its manufacture or use, losing its transparency, fracturing or breaking", Zanotto points out. "Crystalline materials, on the other hand, such as glass ceramics, whose molecular structure is organized, has the least possible energy level, and consequently are thermodynamically stable." This phenomenon, when spontaneous, can be a source of serious problems. However, if the crystallization is carried out in a controlled manner, it is possible to develop new polycrystalline materials such as the glass-ceramics.

Eyes on the furnace

As it is common in the history of science, the glass-ceramic materials were discovered by accident. At the end of the 50s, the North American researcher Donald Stookey, from the Corning Glass company, had been conducting research with photo-chromatic glass, that which darkens under light - since it possesses dispersed minute silver crystals -, when he realized that he had left, through forgetfulness, a pair of glass lenses overnight in a hot furnace. These lenses had become opaque, completely crystallized since they had been transformed into another material, much more resistant, which he ended up naming as glass ceramics. In this fortuitous case, the silver had acted as a nuclei agent.

From then on, dozens of companies and laboratories spread over the whole planet have been studying new compounds and forms of production of these materials, which have proved to be useful in diverse applications. The lenses of the Gemini telescopes (Chile and Hawaii, USA) are made of glass ceramics, as well as the surface of modern electric ovens that don't have a flame or fire, only circles where the pans or the food itself can be placed. Ovens of this type are already being manufactured by the companies Bosch, Siemens and Jungin in the town of Blumenau (SC), which import the glass ceramic material.

The big leap

Besides the creation of innovative materials, the UFSCar scientists are also researching a new process for the production of glass-ceramics, known as sintering with controlled crystallization. To sinter signifies bringing together various particles for heating. In this case, the formation of the glass-ceramic does not need nuclei agents as happens in the traditional process of obtaining this material. The sintering by controlled crystallization, therefore, does not demand the addition of a new substance to act as a catalyst.

Particles of impurities and defects present in the surface of the glass itself, take on the role of nuclei agents. Zanotto explaines: "We observed that in controlled crystallization the process of the transformation of the glass begins on the surface and we concluded that here there exist particles and errors whose effect is similar to those of nuclei agents", Zanotto tells. Starting from this conclusion, the LaMaV researchers ground up the glass so that the resultant powder would contain these superficial particles. "This was the big leap in our research".

It might appear to be simple, but in practice it is very difficult. The researchers took seven years to unveil the secrets of sintering with this type of crystallization, named competing. The sintering must occur at the start of the process and only at the end must the crystallization begin. "We have a thematic project, with complex computerized simulations, attempting to understand and to control the competition between sintering and crystallization", says Zanotto. According to him, sintering competing with crystallization is a alternative process for the manufacture of glass ceramics, and in certain cases, could be quicker and cheaper.

With the results of the studies produced by the LaMaV's team, the laboratory has turned itself into one of the most esteemed worldwide research centers into sintering for the production of vitreous material. Only a few other groups have managed to reach the level of results obtained by the UFSCar researchers: for example, a team from the BAM laboratory of Berlin in Germany, a group linked to the Academy of Sciences in Bulgaria, and the Japanese company Nippon

Electric Glass. "All of these research groups have made, parallel to ourselves, important discoveries towards the phenomenon of sintering and controlled crystallization", explains the researcher.

Outstanding performance

In order to have an idea about the relevance of the research carried out by Zanotto and his team, it is enough to know that over the last twenty years the group has earned more than a dozen national and international awards and has presented, by invitation, around fifty five lectures at the most important congresses in this area. "A sample of the importance and repercussions of the developed research for our team is the fact that, over the last two years, on twelve occasions, we were invited to deliver plenary lectures in important events", says Zanotto.

Besides the LaMaV, other national research groups have also been outstanding in the development of new materials and new technologies associated with glass. The force of Brazilian research can be evaluated by the publication of scientific papers in international scientific magazines. During the last six years, approximately 5% of all scientific papers published in the*Journal of Non-Crystalline Solids* and 2% of those published in the*Physics and Chemistry of Glasses* , the most important scientific magazines of the sector, were signed by Brazilian researchers.

New installations

The performance of the LaMaV, whose team is formed by three professors, two post doctorate students, six doctorate students, two master's students four undergraduates and a technician, will be even stronger after the opening, next month, of new laboratory installation of some 530 square meters (m2). The building, which cost around R$ 300,000, received financing from UFSCar itself along with agreements with outside companies. The resources for the infrastructure came from the Support Program for Centers of Excellence (Pronex) of the National Council for Scientific and Technological Development (CNPq) and through the thematic project*Current Problems about the Crystallization of Glass* financed through FAPESP.

The building has the shape of an oven for glass manufacture and is equipped with the latest generation of equipment. "FAPESP's funding made possible the installation of a new infrastructure for the new laboratory, which is up to international standard, and also the publication of various articles and the presentation of a dozen or more overseas lecture invitations", tells Zanotto. The LaMaV researchers are, consequently, carrying out science and developing technology into new materials that should be the basis of new products with diverse functions, from artificial bones, to laptop hard discs to the sink of a bathroom.

THE PROJECT
Current Problems on the Crystallization of Glass
Modality
Thematic project
Coordinator
Edgar Dutra Zanotto - Materials Engineering Department - UFScar
Investment
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