Research centre ensures glass industry is booming in Brazil

Edgar Dutra Zanotto and Hellmut Eckert* discuss the recently opened Center for Research, Technology and Education in Vitreous Materials (CeRTEV), in São Paulo, Brazil.

Glass products are part of a multibillion national and international market. The sector is dominated by large global companies, but there are also thousands of small and medium-sized glass producers.

The overall flat glass market is estimated to be €51 billion, and in 2009, Europe, North America & Mexico, and China accounted for 70% of world float/sheet glass demand. In the same year, South America consumed only 4% of the flat glass produced worldwide.

However, this is changing, as Brazil becomes an international industrial player. Since 2007 several float glass companies have built new plants in the country, and the installed capacity will soon rise from 3kton/day to almost 8kton/day, increasing the demand for engineering solutions and qualified human resources in this particular area.

Besides windows, classical established glass applications comprise containers, light bulbs, kitchenware, labware, mirrors and lenses for optical devices, fibres for reinforcement and optical communication and ceramic tiles.

In addition, oxide glasses and glass-ceramics (GCs) can be found in other less obvious applications, such as dental materials; bioactive materials for bone substitution and skin healing; interfacial material for abrasive wheels and electronic devices; engineered proppants for stuffing hydro-fractured oil wells; high-strength touch screens and thin films for sensors.

The success of these high-tech industries is based on the multitude of opportunities for tailoring the physical properties of glass to the particular application considered. Therefore, the development of glass and glass-ceramic compositions and technologies is an enormously active area for R&D.

An indicationdea of the scientific and commercial importance of glass-ceramics comes from a search on Free-patents Online. About 2,400 granted or filed US patents appear with the keywords 'glass-ceramic' in the abstract.

There are also about 1,500 European and 2,700 Japanese patents. We also performed a parallel search of the patent literature using the Derwent Innovations Index (Thomson Reuters Scientific). This search covered patents granted between 1963 and 2013 using the keywords (glass* or amorphous or vitreous or non-crystalline) in the patent titles. This search resulted in about 370,000 patents issued worldwide [1]. These are impressive numbers for a single field within all the numerous materials classes and types.

CeRTEV

The Center for Research, Technology and Education in Vitreous Materials (CeRTEV) began its operations in July 2013 with generous funding by FAPESP (The São Paulo State Research Foundation in Brazil).

Following a two year competition process that initially had 90 proposals, FAPESP awarded funds to a total of 17 new research centres in various strategic research areas deemed particularly important for the Brazilian economy, and supported by research expertise at the applicant institutions.

CeRTEV is an 11-year, US$22 million (excluding salaries) effort with funding at about US$2 million per year for five years, after which FAPESP will evaluate the programme before authorising funding for the next six years.

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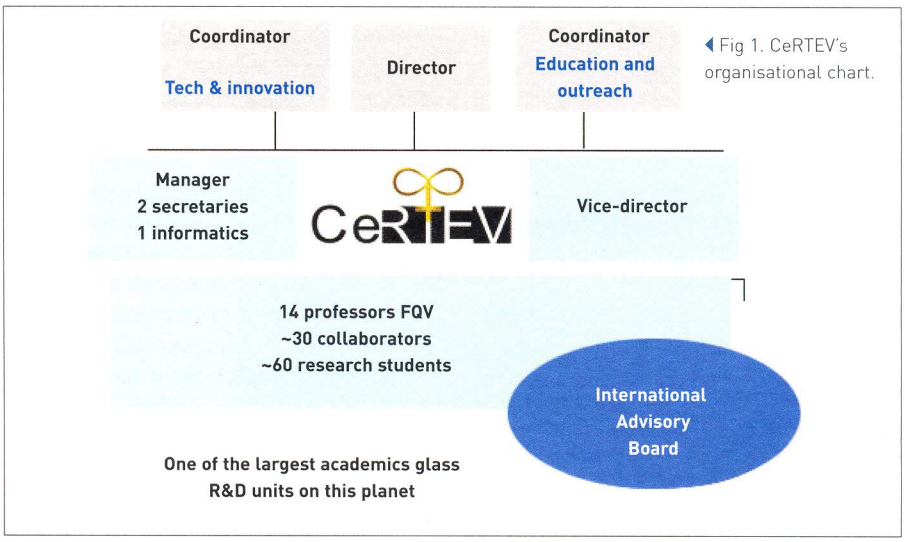

Fig 1. CeRTEV's organisational chart.

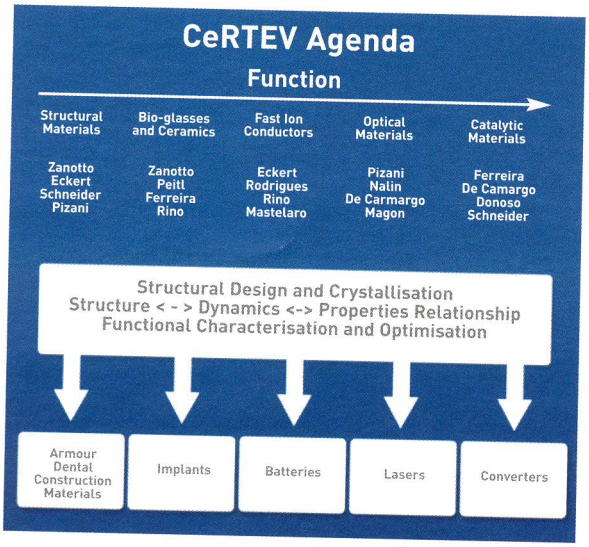

Fig 2. CeRTEV functions.

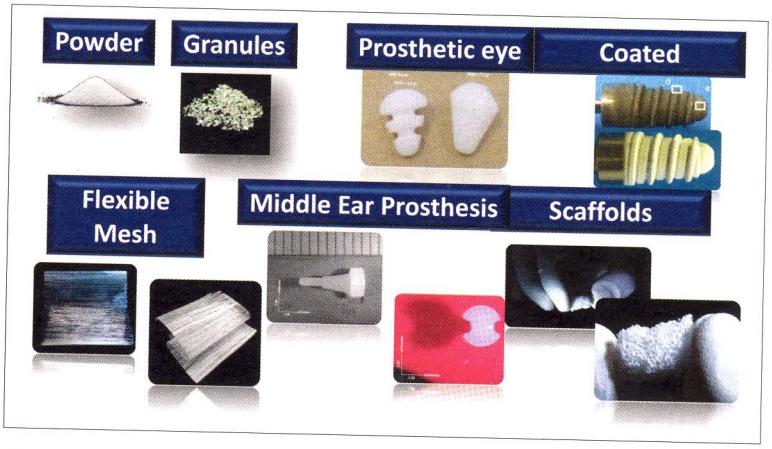

Fig 3. Objects developed from bio-active glasses and glass-ceramics currently under study and development at CeRTEV.

The centre brings together an interdisciplinary team of 14 faculty members advising 60 research students and post-docs from two state universities (USP and UNESP) and the Federal University of São Carlos (***Fig 1***).

It includes a mix of young faculty and some of the world experts in vitreous materials and structural characterisation techniques such as nuclear magnetic resonance, Raman spectroscopy, and extended X-ray absorption fine structure (EXAFS) spectroscopy. All the research labs are located within a 30km distance of each other.

CeRTEV's activities will focus on multidisciplinary, relevant glass science, useful technology and efficient education and outreach. It aims to research and develop or improve active glasses and glass-ceramics, presenting application-relevant functionalities, such as high mechanical strength, ionicconductivity, biological, optical or catalytic activity, and/or combinations of these properties.

A fundamental understanding of these properties will be sought on the basis of the structural organisation of these materials on different length scales.

CeRTEV will apply NMR, EPR, EXAFS and vibrational spectroscopies to characterise the local and medium-range order, as well as the full resolution range of optical and electron microscopies, XRD and microanalyses for elucidating nano- and microstructures.

This comprehensive experimental approach will be complemented by molecular dynamics simulations. With these tools at hand, CeRTEV will seek a fundamental understanding of glass sintering and crystallisation in terms of the mechanisms, thermodynamics and kinetics of viscous flow, nucleation, and crystal growth, enabling us to exercise control of these processes by developing appropriate formation and thermal treatment protocols.

In a concerted effort, the participating laboratories will jointly investigate a number of important benchmark systems, which are deemed particularly promising for applications either as structural reinforcement materials (e.g., glass-ceramics for armour, architecture and constructions, as well as dental implants), bio-active glasses and glass-ceramics, optical materials (eg laser glasses and other photonic devices), materials for electrochemical energy storage devices (electrolytes, high-temperature seals), and catalytically active systems (***Fig 2***).

Research and technology

As with the other 16 centres, CeRTEV focuses on two 'actions': Research and technology. These both support industry, and education and outreach to generate sustainability.

The main idea behind the research and technology agenda is to develop the genome of different glasses, from the recognised structure to special thermal treatments, which may or may not result in crystallisation, and then to develop microstructures to achieve certain properties for applications.

This has been planned with the explicit goal of generating new technologies and patents, all the way to new products and production processes ('science to business approach').

Promising new technologies are expected in five main fields of application: 1) strong GCs for armour and dental implants; 2) bioactive materials for bone and tissue restoration; 3) energy storage and conversion systems; 4) photonic devices; and 5) catalysts for converting biomass into fuels and chemicals.

In all these fields we will vigorously pursue transferring fundamental and applied research activities to the productive sector, by establishing cooperation agreements and licensing of on-demand technologies commissioned by industry, and nucleating spin-off companies from the group activities.

We will also extensively promote innovation and technology transfer via the responsible university channels. ***Fig 3*** highlights some of the objects based on bio-active glasses and glass ceramics currently under study and development at CeRTEV.

In collaboration with industry partners, the technological core of our group will also establish infrastructure for the production of prototypes, on a scale beyond the laboratory, bringing our activities closer to the productive sector, e.g one melting furnace for larger glass volumes than the conventional lab scale (some kilogrammes instead of grammes); one disc mill that can be continuously operated, for a high output of glass powders; and a lab spray dryer for conditioning powders into granules with suitable properties for a fine ceramic processing.

Furthermore, to ensure efficient cooperation between academic and industrial laboratories, it is crucial to increase the exposure of our students and postdoctoral fellows to the R&D environment in the industrial sector, significantly beyond the current practice in national postgraduate programmes.

To this end, we will establish a new

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fellowship programme with the explicit purpose of enabling students to conduct part of their master and doctoral projects in the laboratories of industrial partners.

Educational agenda

The educational and outreach agenda will create sustainability of this effort.

It is of utmost importance to attract talented students to this research area and to train them to become accomplished glass and ceramic scientists. Outreach channels beyond the traditional education done at the university have to be established.

In collaboration with the Paulo Souza Educational Center of the State of São Paulo, CeRTEV will develop and offer training courses for middle and high school graduates seeking a career as professionals in the glass industry.

We also consider it essential to increase public awareness of the enormous technological role of glass and glass-ceramics in modern society.

Thus, the CeRTEV outreach concept includes various effective measures of dissemination, promoting both the importance of glass and glass-ceramics as strategic materials, as well as emphasising the main underlying scientific concepts of this research field, such as the structure of solids and liquids, experimental techniques, and electrical, optical, biological, chemical and mechanical properties.

Targeted audiences include the general public, high school students and teachers, university undergraduate and graduate students, university professors and industrial researchers.

Besides public presentations, school visits and receptions at the universities, and the development of physical demonstration kits and various web-based activities, CeRTEV plans to assemble a museum devoted to object processes related to glass science, manufacturing and applications.

All of the 17 São Paulo research centres are expected to have a strong international impact. In fact, FAPESP used international review panels to evaluate the 90 proposals to avoid conflicts of interest within Brazil.

CeRTEV's research progress as well as the realisation of its technological and education/outreach objectives will be monitored by an International Advisory Board consisting of professionals active in glass research in industry and academia.

Over the next 11 years CeRTEV aims to expand its international collaboration network.

International exchanges of students, postdocs and faculty will be an integral part of this endeavour, in a similar manner as currently practiced by the IMI-NFG programme at Lehigh University and Pennsylvania State University.

Considering the volume and duration of the award, CeRTEV is likely to be one of the current largest and longest timeframe academic research efforts dedicated to glass science.

It will seek to make an impact on glass research in Brazil and worldwide for the coming decade and beyond and would be grateful to receive insights, suggestions and feedback.

CeRTEV looks forward to interacting with the international glass community in the years to come. ■

1 - John C. Mauro and Edgar D. Zanotto - Two Centuries of Glass Research: Historical Trends, Current Status, and Grand Challenges for the Future - Int. J. Applied Glass Science, May (2014) submitted.

***Director Certev and Universidade Federal de São Carlos, São Paulo, Brazil www.certev.ufscar.br**