



Brazilian glass industry review

According to Lucien Belmonte, the Brazilian economy remains a challenge for the glass industry but a gradual improvement has been observed in flat and hollow glass consumption.



Lucien Belmonte, Superintendent at Abividro.

Per capita consumption of glass has grown significantly in Brazil in the last 15 years, increasing from 11.9kg per person in 2000 to 24.4kg in 2015. This is also due to the evolution of the Brazilian economy between 2000 and 2014, which greatly favoured the consumer markets of glass products. During this period, retail sales of glass products and merchandise that uses glass in its production increased, for example in the case of packaging, mirrors and automotive glass. With this movement of investment and consumption, the production of Brazilian industry changed, systematically improving the consumption of glass products.

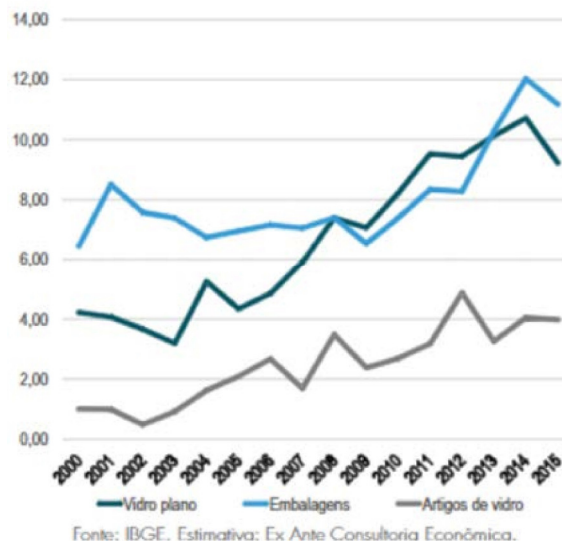
Collectively, the local hollow and flat glasses sector directly employs 13,000 people and generates estimated net sales of R\$10 billion tons. The industry's installed capacity

equates to 4,000,000 tons/year, with some 3,200,000 tons/year produced.

MARKET TRENDS

The construction market is the most sensitive to economic fluctuations and the availability of credit. In the area of commercial real estate, which includes the construction of offices and shopping centres, there has been a significant fall in the number of new projects. The residential sector, which consumes less glass per unit but whose number of buildings is greater, was highlighted with an increase in loans for housing and the sale of construction materials.

The Brazilian automotive sector is the second most important market in terms of glass consumption. It is also very sensitive to economic conditions. Between 2006 and 2012, domestic sales of cars, utilities, trucks and buses virtually doubled (97.2% expansion), from 1928 million units sold in 2006 to 3802 million units in 2012. In 2013 and 2014, due to a fall in the trucks and buses sector, which was provoked by the forced introduction of new environmental regulation, demand stagnated, while remaining at a relatively high level. Subsequently, the fall in domestic demand has been violent. Between 2014 and 2016, domestic sales dropped 41.4%, with a greater reduction in demand for imported vehicles. What helped to maintain the industry's production levels was an expansion of foreign sales. This process was motivated

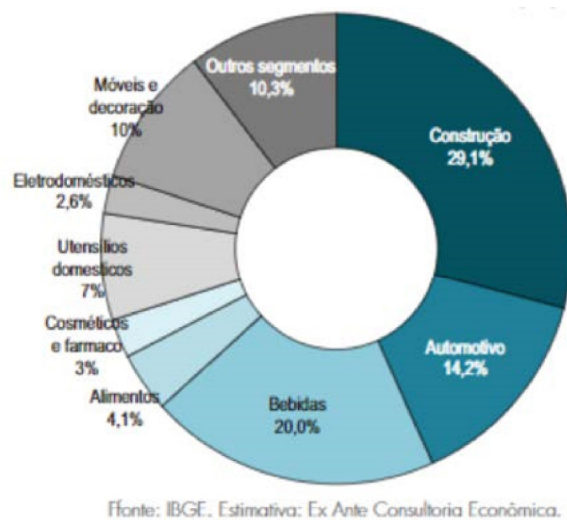


Apparent evolution of glass consumption in Brazil (kg per capita, 2000 to 2015).

by the existence of a large volume of stock in the automakers' yards and above all, by the devaluation of the Real in 2015 and early 2016. The forecast for 2017 is 4% growth compared to 2016.

For the glass packaging business, the food and beverage industries in Brazil are the most important markets in terms of consumption. Unlike construction and automotive, these markets are more resistant to short-term economic fluctuations. Between 2006 and 2014, food and beverage retail sales grew by 54.4%, equivalent to an average growth rate of 5.6% per year.

Other very important industries in terms of consumption are those for perfumery, cosmetics and pharmaceutical products. Between 2006 and 2014, sales grew by 124.2%, which is equivalent to an average



Distribution of apparent consumption of glass by demand in R\$ million, 2015.

Float glass	Hollow glass	Technical glass	Suppliers
AGC	Nadir Figueiredo	Owens Corning	Fosbel
Cebrace	O-I		Manuchar
Guardian	Schott Pharmaceuticals		Mineracao Jundu
Pilkington	Sobral Invicta		Rhodia Solvay
Saint-Gobain Glass	Verallia		SCS
Schott Flat Glass	Verescence		
UBV	Vidraría Anchieta		
Vivix	Vidroporto		

Members of Associação Técnica Brasileira das Indústrias Automáticas de Vidro - Abividro.

	2015-2016	2016-2018
Construction	-14.1%	-11.5%
Automotive	-16.6%	-6.5%
Food and beverages	-4.3%	-2.8%
Pharmaceutical, perfumery and cosmetics	-6.1%	-1.9%
Furniture and household appliances	-9.2%	-7.6%
Domestic glassware	-12.0%	-9.8%

Short-term projections of average variation of % for glass products, from 2015 to 2018.



growth rate of 10.6% per year. This expansion was more than double that observed in the mass of incomes of Brazilian families, which indicates a very high elasticity of demand.

Between 2006 and 2014, sales in the retail trade of furniture and appliances in Brazil grew by 121.6%, which is equivalent to an average growth rate of 10.5% per year.

Despite this seemingly positive scenario, the glass industry has faced a major challenge in recent years, namely dealing with the high and abusive rates of natural gas in the country. The sector is one of the biggest users of natural gas in Brazil and the high price of this fuel has a major impact on the industry's performance, since it represents, on average, 25% of production costs, reaching 35% in some instances.

EMISSIONS/RECYCLING

Significant progress has been made by the glass industry in terms of its contribution to environmental performance in recent times. This includes the use of regenerative furnaces, the replacement of heavy fuel oil by natural gas by every company, continuous improvement in combustion performance and furnace design, the realisation of a permanent reduction in packaging weight and a significant reduction of greenhouse gas emissions.

Also of major importance for the environment, recycling represents one of Abividro's biggest challenges, covering a country of continental dimensions. It is now one of the association's main focuses of attention. Brazil is implementing a federal policy for solid waste and efforts have been made by the glass sector to implement reverse logistics in states and municipalities that are remote from the country's main industrial centres in order to guarantee the return of quality cullet to manufacturers, contributing for a reduction of energy consumption and raw materials extraction. Studies concentrating on the development of lighter packaging designs are also part of an industry project to facilitate reverse logistics of the material. ■



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Brazil's glass tableware expert maintains global strengths

Nadir Figueiredo has been an established player in international household glassware markets for almost 70 years. John Wallis explored the family-owned company's history and present-day priorities with Industrial Director, Morvan dos Santos Ladeira.

Nadir Figueiredo Industria e Comercio S/A is a family-owned glass company, focused on table- and kitchenware. The company was founded in 1912 by brothers Nadir and Morvan Dias Figueiredo, who started a small chandelier maintenance shop, before producing their own chandeliers and lampshades.

It was during the 1930s that the young company acquired its first glass plant and in 1948, Nadir Figueiredo inaugurated the first automated production equipment for glass tableware in Brazil. From that date until now, the company has pioneered many technologies in Brazil, including the country's first opal tableware production operation in the 1970s, electric glass furnaces during the 1980s and the production of its own electronic press and blown machines at the beginning of the last decade.

Nadir acquired the Marinex and Duralex (for South America) brands from Santa Marina in 2011 and two years later, completed the transfer of its operations from nine separate sites (including the original Vila Maria factory) to a single, modern plant located in the state of Sao Paulo.

Having joined the family-controlled glassmaking business as an 18 year old apprentice, Morvan Ladeira has developed multi-disciplinary experience within Nadir Figueiredo's extensive production operations. In a career spanning almost three decades, he has been an IT apprentice, marketing apprentice, sales administrator, product development co-ordinator, Export Department



Two examples from Nadir Figueiredo's award winning Copo Americano range of glassware.

trader, marketing co-ordinator for HORECA (catering and food services), Marketing Manager for strategic projects and Strategic Planning Manager.

Today, as Industrial Director, he is an influential member of the company's experienced management team. Chief Executive Officer, Patricio Taborda Figueiredo has served as a board member since 2010 and was named CEO in 2014, while Antonio Ivo Dória do Amaral,

Chief Financial Officer, has more than 20 years' experience within the group, becoming a director in 2004. Completing the team is Paulo Figueiredo de Paula e Silva, Commercial Director, who has occupied a number of positions within the company for more than two decades, taking on its commercial leadership in 2008.

KEY ACHIEVEMENTS

According to Morvan Ladeira, among the company's most notable achievements in recent years has been its strong focus on quality control and continuous quality improvement, initiated in 1992 and responsible in part for the company's subsequent successful transformation. In addition, he cites the importance of a decision to develop its own technologies for furnaces, presses and press and blow machines, giving the glassmaker closer control of its processes and allowing the re-introduction of opal glass production to Latin America in 2011. "Another milestone for Nadir Figueiredo was its acquisition of Santa Marina and its brands (Marinex and Duralex for South America) in 2011" he suggests.

Nadir Figueiredo is the market leader in Brazil for retail and food service household glassware, accounting for approximately 3% of global industry sales, based on >



The Suzano factory produces high quality soda-lime glass, as well as an opal composition, with a total annual capacity in excess of 800 million pieces.

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turnover. Since 2013, the Suzano site has produced high quality soda-lime glass, as well as an opal composition. The factory features capacity to produce pressed, press and blow, IS and spun products, with a total annual capacity in excess of 800 million pieces.

Recent investment highlights have included the commissioning of a new opal glass electric furnace in 2011 and the completion of phase two at the Suzano plant two years later, including the start-up of a second furnace with a capacity of 285 tonnes/day. The opal glass electric furnace was increased in size by 50% in 2016 and in the same year, a major repair of Furnace No 1 coincided with a melting capacity increase to 225 tonnes/day.

INVESTING IN PEOPLE

"In Nadir Figueiredo's culture, the company is only as strong as its people" says Morvan Ladeira. "It is the pillar from which the company develops our human resource activities." These initiatives include work safety and health programmes, operational development courses and leadership tuition, as well as academic development courses, each of which is tailored to the activities and needs of employees.

The Suzano plant is an important employer in the region, with a workforce of more than 2000 people. "We have a strong policy of hiring the family members of our employees, increasing the bond between the company and its community" Mr Morvan explains. "Such is Nadir Figueiredo's commitment to the community that it is actively involved in developing courses in glass production for a local public school."

A low index of work-related accidents is maintained at Suzano thanks to the longstanding concern for work safety of former company President, Jorge Figueiredo. He was largely responsible for pioneering work safety-related practices in Brazil. Nadir Figueiredo offers health plans for all employees and their families, as well as basic medical care at the plant.

The glassmaker has maintained ISO 9000 quality management standards since 1996 and is currently updating its compliance to the 2015 revision. Environmental issues are also considered important by the management team, including the integration of catalytic emission control systems during the 1980s, long before such equipment became mandatory in Brazil. Subsequently, Nadir Figueiredo



The Marinex Seleta series of ovenware is sold in a diversity of sizes to satisfy the needs of every household.

has improved its facilities and procedures further, in response to concerns about their impact on the local environment. In addition, the company is a keen supporter of national glass association ABIVIDRO and its recycling programme initiatives.

CUSTOMER FOCUS

Key to the establishment and maintenance of good customer relationships are the delivery of high service levels, attention to customisation requirements, low to zero quality claims and zero logistical errors. "Nowadays with instant communication, response times are even more critical" says Morvan Ladeira. And to differentiate itself from competitive suppliers, Nadir focuses on delivering the best total value for clients, an approach that includes maintaining a complete range of products, with optimal quality, excellent service and fast deliveries.

Via its various brands, including Nadir, Marinex, Duralex (in South America and the Caribbean), Sempre ovenware and Colorex, the glassmaker serves all retail sectors and is the main supplier for the professional food service sector in Brazil and other countries. In addition, Nadir Figueiredo has a B2B commercial unit, focused on glass packaging for the food market, as well as promotional items.

The company offers a strong portfolio of its own designs, as well as third party designs ranging from one-piece stemware, tumblers, plates and dishes to beer mugs and cups in clear, coloured, decorated glass and opal dinnerware, as well as complete ovenware ranges. Recent significant developments have included the Barone stemware range, which

delivers enhanced quality levels for one-piece stemware, Marinex Seleta ovenware and the Duralex Opaline range.

A constant pipeline of product development is maintained, the company using leading international and national houseware fairs to launch its latest designs. Important customers include Walmart, Carrefour, Casino group, Lojas Americanas, GIFl, Family Dollar, Makro, Sodimac and Dollarama. Active clients are maintained in 70 different countries, with close to 10% of production destined for export.

FUTURE CHALLENGES

According to Mr Morvan, greater commercial openness and increased competition in traditional Nadir markets have been observed in the past decade. He believes that one of the main challenges faced is to cater for changing tastes in the face of increasing competition, both from other glass suppliers and increasingly from other materials, while at the same time encouraging tougher regulatory policies.

"Our main opportunity is to advance technologies in order to face these challenges" Morvan Ladeira confirms. "Nadir will continue to develop its market offerings and strengthen its position as a worldwide market leader. And in line with our corporate culture, we will continue to develop in-house technologies to support our strategic goals." ■



The Barone stemware range delivers enhanced quality levels for one-piece stemware.

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Vitreous materials research focus

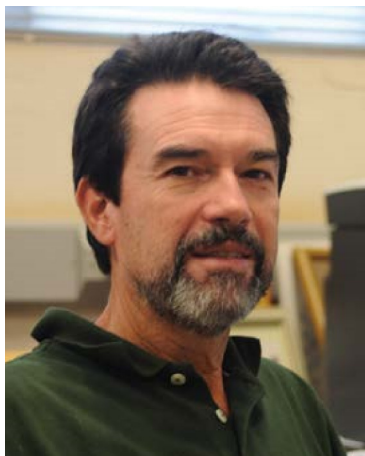
Hellmut Eckert and Edgar D Zanotto discuss the history and present-day activities of the Sao Carlos Center of Research, Technology and Education in Vitreous Materials (CeRTEV) in Brazil. This multi-disciplinary centre unites the research groups of 14 professors in physics, chemistry and engineering.



Hellmut Eckert.

Four years ago, the Sao Carlos Center of Research, Technology and Education in Vitreous Materials (CeRTEV) was created with funds from the Sao Paulo Foundation (Fapesp) as part of the State's comprehensive CEPID programme. This multi-disciplinary centre unites the research groups of 14 professors in physics, chemistry and engineering at the Federal University of Sao Carlos (UFSCar), the University of Sao Paulo (USP) (both located in Sao Carlos) and the Sao Paulo State University (UNESP), located at Araraquara, 35km from Sao Carlos. They advise approximately 60 students and post-doctoral researchers and are embedded in a large Brazilian and international network of collaborations. Altogether, the centre, led by director Edgar D Zanotto is one of the largest academic 'glass' research teams on the planet.

CeRTEV's mission is to promote scientific, technological and economic progress in the area of glasses and glass-ceramics in the State of Sao Paulo and Brazil. The three pillars of this holistic effort are: State-of-the-art fundamental and applied research; development and promotion of new technology; and educational outreach to professionals, students and the



Edgar D Zanotto.

general public. Its aim is to include Brazil in the ranking of the world's top 10 glass research and technology countries and to foster the economic development and growth of the productive glass sector in Brazil.

CeRTEV reports on a yearly schedule to its main sponsor (Fapesp) and to an International Advisory Board (IAB), consisting of 22 international leaders in glass science and industry. Valuable recommendations from the IAB have been added regularly to the scientific agenda and about half of all board members have become collaborators in the meantime. In 2015, CeRTEV obtained excellent marks in an interim evaluation conducted by an international group of referees appointed by Fapesp.

RESEARCH AGENDA AND PROGRESS

The 14 groups have consolidated a coherent research agenda, developing glasses and glass-ceramics with important functionalities, such as high mechanical strength, electrical conductivity, biological, optical or catalytic activity and/or combinations of these properties. Work is being carried out in five core areas: Structural materials for architecture and construction, armour, as well as


dental restoration; bioactive glasses and glass-ceramics for bone and cartilage healing and growth; ion-conducting materials for applications in modern battery technologies; photonic glasses and glass-ceramics for lasers and optical sensors; and catalytically-active systems. These areas reflect the enormous importance of glassy materials in meeting future societies' needs for improved safety, health, communication, energy management and environmental protection, as modern society has entered the 'glass age'.

As technology developments and fundamental scientific insights are truly inseparable in this field, a few directions and highlights of CeRTEV's research programme are highlighted here. In its research effort on structural materials, the organisation has uncovered the mechanistic principles for the toughening process in lithium disilicate glass-ceramic - crack deflection, crack bowing and trapping and crack bridging. Theoretical models for the elastic modulus, crystal fracture toughness and crystallised volume fraction have been developed and successfully tested to explain the increased fracture toughness with increased crystallised volume fraction for the full range of crystallisation in glass-ceramics of this composition. Using spectroscopic methods, researchers are currently trying to understand mechanical properties on the basis of structure and dynamics on different scales of length and time.

Research at CeRTEV on bioactive glasses focuses on the continuing improvement of osteoconductive and osteoinductive materials for stimulating bone healing and growth, by developing and testing innovative bioactive formulations and composites, such as Biosilicate for applications in bone repair and dental restoration. Recent histopathological, cytotoxicity and genotoxicity analyses have confirmed that Biosilicate scaffolds possess excellent biocompatibility. Researchers are further continuing to explore compositional effects on various aspects of bioactivity performance, by substituting calcium with magnesium or strontium and by developing boron-containing bioactive glasses.

Glass-ceramics based on lithium titanium (or germanium) phosphate compositions featuring highly mobile alkaline ions have shown significant promise for applications as solid electrolytes in high energy storage devices. CeRTEV researchers are trying to better understand the composition/structure/performance relationships in these systems. Modern solid-state NMR techniques have provided valuable insight to the influence of the crystalline fraction on the ionic mobility and electrical conductivity. Investigations are now gradually shifting from lithium towards sodium-based glass-ceramics because sodium features similar electrochemistry as lithium but is much more abundant than the latter.

CeRTEV's activities in the area of photonic glasses and >



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Optical micrograph showing a plethora of lithium metasilicate crystals embedded in the residual matrix of a rare (nucleant-free) glass-ceramic. The bar indicates 100 micrometers.

glass-ceramics are focusing on the development and characterisation of systems doped with luminescent species (transition or rare earth metal ions, metal nanoclusters) for applications in lasers, sensors and other photonic devices. The structural environments of rare earth ion species in fluoride phosphate matrices have been studied by recently developed NMR and EPR approaches, leading to an understanding of their photophysical characteristics regarding the ligand distribution around the rare earth ion species.

Researchers will now proceed to the second step of preparing glass-ceramics, based on rare-earth-doped fluoride nanocrystals embedded in a glassy environment. They also co-dope these glasses with metallic nanoparticles to enhance the luminescent properties via surface plasmon resonance effects.

Another area of active research within CeRTEV is the development of photonic inorganic-organic hybrid materials and nanocomposites. Besides offering the possibility of designing a more favourable chemical environment to improve the photophysical properties of the guest molecules, encapsulation in these solids also protects the emitter molecules, prevents their leakage (especially critical for biological applications) and ultimately leads to more robust and versatile materials.

An entirely new application field

of glass-ceramics is being developed in the fifth topical CeRTEV research area, devoted to catalytically active systems for the conversion of biomass to fuel and fine chemicals. These materials are hierarchically structured, combining mesoporosity (for catalytic conversions) with macroporosity (for facilitating mass transport of highly polymerised substrates). Techniques under development include ceramic foaming based on the use of porogenic agents, selective leaching of phase-separated base glasses and template sol-gel synthesis using molecular precursors.

In pursuing its research agenda, CeRTEV has been reaping the synergetic benefits from results obtained in these different application areas. It has already developed various excellent glass and glass-ceramic systems, whose technological application potential is being explored together with industry partners.

INNOVATION AND KNOWLEDGE TRANSFER

CeRTEV activities are channeled towards the generation of technologies and patents, all the way to new products and production processes (a 'science to business' approach). Thus far, new or improved patentable glass or glass-ceramic materials have been developed for light armours (for use in aircraft, cars and for individuals), tougher monolithic glass-ceramics for dental restoration, macroporous and hierarchically ordered scaffolds, fibres, small monolithic parts and powders with increased osteoinductive activities, combined with the ability for targeted drug delivery for bone and tissue repair.

A three-pronged strategy for technology transfer includes co-operation agreements and licensing of on-demand technologies commissioned by industry, nucleation of spin-off companies and extensive promotion of innovation and technology transfer.

During the past four years, CeRTEV has maintained and expanded its extensive national and international industrial co-operation network. At present, eight such co-operation projects are active, with non-disclosure agreements (NDAs) and material transfer agreements

(MTA) signed and with joint R&D projects being pursued. Despite the gloomy state of Brazil's national economy, several local companies have recently joined the network, providing funding for jointly pursued R&D projects. Industrial partners include Vetra, Nadir Figueiredo, SGD, Rhodia, Alacer Biomedical, Nippon Electric Glass, Nippon Sheet Glass and Ivoclar-Vivadent. To intensify contact with industrial clients, an Industrial Associates Group has been established, composed mainly of members of the Commission on Glass of the Brazilian Ceramic Society (<http://abceram.org.br/membros-da-comissao>).

A further significant highlight in the area of technology transfer has been the creation of the first spin-off company from CeRTEV: VETRA High-Tech Ceramic Products was established in Sao Carlos by three CeRTEV post-docs, based on their doctoral and post-doctoral research achievements. It offers solutions for different market segments by developing glass and glass-ceramic materials that combine individual features, such as biodegradability, bioactivity and bactericidal properties for bio-applications, based on two recently granted international CeRTEV patents. Commercialisation is supported by the two Innovative Research in Small Business (PIPE/FAPESP) grants. They concern applications of a boron-containing >



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bioactive glass formulation called 'F18' (the 18th composition developed in an iterative optimisation process), allowing the fabrication of continuous glass fibre for long periods of time via large-scale processing techniques, such as downdrawing. Besides bioactivity and high reactivity, F18 also presents a remarkable bactericidal effect, a highly desired property. The F18 development opens avenues in tissue engineering and the creation of novel medical devices for clinical applications, including membranes for skin wound regeneration, nerve guide conduits and scaffolds with high porosity. Also, in vivo tests show osteoinductive and osteopromotive activity, making this glass a potential bone grafting material for some clinical applications.

CeRTEV takes pride in its extensive patent application record, with 12 patents in the area of glass synthesis and processing currently under examination. Technology transfer is also being promoted by various industrial workshops and discussion groups and the development of the webpage Wikividros; <https://wikividros.eesc.usp.br/> (under construction), to serve as an open collaboration and discussion platform with partners and clients from industry.

EDUCATION AND OUTREACH

CeRTEV's education and outreach strategies focus on the development of long-term sustainability of glass science and technology in Brazil. At present, the national glass industry faces a serious shortage of qualified technical personnel. This problem arises from a complete lack of technical training courses dedicated to professionals in this area.

Therefore, together with its partner ABIVIDRO, (Brazilian Association of Automated Glass Industry) and the Paulo Souza Center, a Sao Paulo State Government office that now administers 214 technical schools and 59 faculties of technology in 163 municipalities, CeRTEV has developed a full curriculum for a three-semester course. The course includes 450 hours of theoretical training in glass formulation, physical processes, energy management, workplace and environmental safety and entrepreneurship and 850 hours of practical operations. Students can start this specialisation in parallel to the second year of high school or at any time if they have completed high school. The course will be held in the city of Mogi das Cruzes (70km from

the city of Sao Paulo), which is the site of an important Brazilian glass industry, Nadir Figueiredo and which holds one of the technical schools from Paula Souza Center. The course is scheduled to commence in the first semester of 2018. See also <http://www.cps.sp.gov.br/publicacoes/revista/2017/edicao-58-maio-junho.pdf>.

Aside from these highlights, CeRTEV members do their part in developing and presenting workshops in glass science and characterisation within the professional community. These activities include a glass-ceramics internet course taught by Professor Zanotto, in association with the International Materials Institute (IMI), see http://www.lehigh.edu/imi/teched/GlassProcess/Lectures/Lecture15_ZanottoA1.pdf. Finally, most glass classes are now available on youtube: https://www.youtube.com/watch?v=6U0llodQujs&list=PLYkqBrOsu1yCxMLTcb7Y6zwj_smlb5w5x and <https://www.youtube.com/watch?v=AB9H6v3Ctew&list=PLYkqBrOsu1yA2K5wOZjn1WSs8U7BtJ-5>.

In parallel, an aggressive effort has been mounted, promoting the importance of glass and glass-ceramics to the public. As part of UFSCar's ACIEPE initiative (activities for the integration of education, research and extension) the organisation has been able to reach out to approximately 400 students from elementary schools, making classroom presentations and inviting students to its university laboratory. Also, collaboration with the Ouroboros Group for the Dissemination of Science has helped CeRTEV to reach out to hundreds of students with presentations of timely scientific topics (including glass science) at various educational centres within a 500km radius.

The Ouroboros group was also instrumental in developing CeRTEV's Science on Stage initiative of science dissemination through theatre. Since 2014, approximately 10 plays on glass-related and other science topics have been developed and presented to more than 4000 people at various academic and public events. Related to this effort, glass musical instruments have been built to create an orchestra (Vitreous Sounds). The line-up presently includes triangles, bassoons, berimbau, sweet, transverse and pan flutes, as well as carillon, quartz, kalimba and the organ of bowls and is being expanded further. Instruments are tuned with the aid of luthiers, glassmakers and scientists. See <http://g1.globo.com/sp/sao-carlos-regiao/jornal-da-eptv-2edicao/videos/v/ufscar-tem-orquestra-com-instrumentos-feitos-de-vidro-no-laboratorio-de-quimica/5563158/andhttp://g1.globo.com/sp/sao-carlos-regiao/bom-dia-cidade/videos/v/orquestra-de-vidro-da-ufscar-se-apresenta-pela-1a-vez/5517562/>. Music from the glass orchestra also provides the background for about two dozen recently created one minute radio presentations on the topic of glass (Vitreous Minute) broadcast by local radio stations.

Further highlights of CeRTEV's outreach effort include the development of informative and creative printed material and websites. In a two month campaign, three posters, accompanied by an informative website were displayed in the Sao Paulo Metro system. Furthermore, four comic book volumes (2000 issues each) discussing the properties and curiosities associated with 'glass' were produced and widely distributed to students, see <http://www.vidro.ufscar.br/#manga>. Volume one deals with basic properties and the history of glass. Volume two is about glass production and recycling, while volumes three and four introduce optical fibres and bioactive glasses. A fifth volume, entitled 'The Glass Age' is in progress.

Finally, the itinerant Exhibition 'Glass World' can be highlighted, which features experimental demonstrations of

properties and curiosities associated with vitreous materials, including light transmission by optical fibre, glass colouring by doping, acoustic properties, photosensitive and flexible glasses; see <http://g1.globo.com/sp/sao-carlos-regiao/jornal-da-eptv-2edicao/videos/v/ufscar-tem-orquestra-com-instrumentos-feitos-de-vidro-no-laboratorio-de-quimica/5563158/>. The interactive exhibition was presented at numerous major science fairs and other cultural events, reaching out to a total audience of about 30,000 attendees.

CONCLUSIONS

In summary, during the first four years, a coherent, collaborative research programme has been developed, dealing with fundamental research and the development of new technological materials, covering a broad range of important application areas for glasses and glass-ceramics. Collaboration with partners in industry and extensive promotion of CeRTEV's research findings into marketable products is an integral part of the strategy, which also includes increasing the supply of qualified professionals in the productive glass and glass-ceramic sector.

As the creative and highly diversified educational outreach programme has already generated a tremendous amount of interest and positive feedback, the authors are optimistic that CeRTEV will be attracting more talented and skilled individuals to this important area of modern society's technological and economic future. For the seven years to come, the centre will cherish the opportunity of continuing to collaborate with industries in challenging, relevant problems and to lead Brazil's effort in glass science, technology and education.

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