8th Pacific RIM Conference on Ceramic and Glass Technology

Sponsored by the American Ceramic Society

Glass Manufacturing Industry Council

International Commission on Glass

TNO Science & Industry

Improving Strength in Industrial Glass

"The Future of Glass Strength – A Society Changing Symposium"

Thursday June 4, 2009

8:00 a.m. to 5:00 p.m.

Hyatt Regency

Vancouver BC Canada

Presentations

8:20 -9:00 a.m.

David Hartman and Peter McGinnis, Owens-Corning Fiberglass: Development of High Strength Fiberglass Compositions and their Applications to Address Current Global Issues

9:00 – 9:40 a.m.

Emilio Spinosa, Owens-Illinois, Inc.: Issues and Opportunities in the Development of High Strength Glass Containers

10:00 – 10:40 a.m.

Adam Ellison, Corning, Incorporated: Post-forming Methods to Increase the Strength of Glass

10:40 – 11:20 a.m.

Carlo Pantano, Pennsylvania State University: Role of Coatings and Other Surface Treatments in the Strength of Glass

11:20 – 12:00 p.m.

Bulent Yoldas and Refika Budakoglu, Sisecam: The Improvement of Fracture Toughness of Glass by Surface-Modifying Coating

12:00 – 1:20 p.m.

Lunch

1:00 – 1:20 p.m. (overlaps with last 20 minutes of lunch)

Mark Doyle, World Kitchen: FILM – Commercial Applications Yielding Strong Glass Tableware

1:20 – 2:00 p.m.

Tanguy Rouxel, University of Rennes: Indentation Damage and Residual Strength of Glass

2:00 – 2:40 p.m.

Frederic Lechenault, University of Montpellier: Nano-Scale Fatigue and Failure Process in Glass

2:40 – 3:20 p.m.

Alastair Cormack, Alfred University: Modeling Glass Failure and the Strength of Oxide Glasses

3:25 – 3:40 p.m.

Mark Doyle, World Kitchen: FILM – Commercial Applications Yielding Strong Glass Tableware

Part I – The Future of Glass Strength – An Industry Changing Symposium

8:15 – 8:20 a.m. **Introduction/Welcome**

Michael Greenman, Executive Director GMIC

On behalf of the Glass Manufacturing Industry Council, International Commission on Glass, and TNO Science & Industry I'd like to welcome you to "Improving Strength in Industrial Glass "The Future of Glass Strength – A Society Changing Symposium"

8:20 – 9:00 a.m. **Development of High Strength Fiberglass Compositions and their Application to Address Current Global Issues**

David Hartman, and Peter McGinnis, Owens Corning Fiberglass

About the Speakers

David Hartman is a Senior Research Associate for the Composite Solutions Business, OCV Reinforcements of Owens Corning, has served with material and design expertise in the development, specification and qualification of glass and carbon fiber products with manufacturers and end users of composite materials in the transportation, construction, armor, aerospace, marine, and wind energy market segments. Hartman received a M.S. Degree in Chemical and Plastics Engineering from the Georgia Institute of Technology. He is well published in the technical literature and holds 21 patents. He has served several industrial and university advisory boards including CERF, UOM-R, MIT House-n, BRITE EURAM, Georgia Institute of Technology, PTFE, and the National Composites Center.

Peter McGinnis is currently the R&D Leader of the High Performance Reinforcements organization within Owens Corning. Pete graduated from Alfred University in 1994 with a PhD in Glass Science and immediately joined Owens Corning at their Science and Technology Center in Granville, OH. He previously served as the Global Leader of Batch and Glass Technology from 2002 to 2008 and has led several glass development efforts including recent R-glass and S-glass innovations.

9:00 – 9:40 a.m. **Issues and Opportunities in the Development of High Strength Glass Containers**

Emilio Spinosa,, Owens –Illinois, Inc.

About the Speaker

Emilio Spinosa is a Senior Glass Technologist for O-I's recently formed, Product Innovation Department. He holds a Bachelor of Ceramic Engineering and a Master of Science in Ceramic

Engineering from the The Ohio State University. Mr. Spinosa has spent his entire, professional career in the glass industry, and has worked for Corning, Inc., Battelle, Ferro, GAF (fiber glass), and O-I. In his is current assignment, he is responsible for product innovation from the perspective of glass composition. O-I's Product Innovation Department Charter includes the development of enhanced strength characteristics of glass containers.

9:40 – 10:00 a.m. **Break**

10:00 – 10:40 a.m. **Post-forming Methods to Increase the Strength of Glass**

Adam Ellison, Corning, Incorporated

10:40 – 11:20 a.m. **Role of Coatings and Other Surface Treatment in the Strength of Glass**

Carlo Pantano, Pennsylvania State University

About the Speaker

Carlo Pantano is Director of the Penn State Materials Research Institute, which administers interdisciplinary materials research across the campus. He is a Distinguished Professor of Materials Science and Engineering, teaches courses on glass and surface analysis, and performs research on glass, surfaces and coatings. He is also Co- Director of the NSF International Materials Institute on "New Functionality in Glasses", which brings contact with glass researchers throughout the U.S. and overseas. Glass research activities include surface chemistry and organo-functionalization of glass; nanostructured thin films and coatings; glass-polymer adhesion; glass-blowing and related outreach programs for K-12 and the public. He has over 245 journal publications and 6 book chapters. He holds patents for a microporous sol/gel coating for capillary gas chromatography, and substrates for DNA/Protein arrays. He was named an Outstanding Teacher in 1983, he won the Wilson Award for Excellence in Research in 1996 and was named the Corning Faculty Fellow from 1990-2000. He is a Fellow of the American Ceramic Society (ACerS) and of the AVS. He is a former Chair of the Glass and Optical Materials Division of the ACerS, and a former US Council Representative for the International Commission on Glass. He was recently elected to membership in the World Academy of Ceramics, and was also awarded the 2005 George W Morey award for outstanding technical contributions to the field of glass science and technology.

11:20 – 12:00 p.m. **The Improvement of Fracture Toughness of Glass by Surface Modifying Coating**

Bulent Yoldas, consultant, and Refika Budakoglu, Sisecam

About the Speakers

Bulent Yoldas born in Turkey, received his Bachelor of Ceramic Engineering., M.S. and PhD from The Ohio State University. With 30 years of experience in material science and engineering at Owens Illinois, Westinghouse, and PPG. He has conducted the pioneering work in ceramic and glass formation by chemical polymerization. Developed depositing oxide coatings and optical films from sol-gel solutions which are used in photovoltaic and ink jet printing. He taught at Carnegie Mellon University, and was named among the top 100 International Innovators in the first issue of Technology Magazine; recipient of numerous awards. A Fellow of American Ceramic Society. Author of over 50 journal papers and 75 patents.

12:00 – 1:00 p.m. **Lunch**

1:00 – 1:20 p.m. **Film: Commercial Applications Yielding Strong Glass Tableware**
Mike Doyle, World Kitchen, Inc.

About the Speaker

Mark Doyle Nuclear engineer and Master in Industrial Engineering, all from Rensselaer Polytechnic Institute. He had the pleasure of interviewing Admiral Rickover for his job on submarine duty in the navy and after 10 years in the Navy joined Corning Inc. for two years until the division was sold to World Kitchen where he is still working as the chief melting and process engineer after a total of 13 years in the Pressware Plant.

Part II – The Future of Glass Strength – An Industry Changing Symposium

1:20 – 2:00 p.m. **Indentation Damage and Residual Strength of Glass**
Tanguy Rouxel, Rennes University

About the Speaker

Tanguy Rouxel, PhD gained his B. Sc (French DEA) in Mechanics of Materials from the University of Paris XIII, and his Ph.D (French Doctorate) in Ceramic Science from the University of Limoges. After graduating he became a Post-doctoral Fellow in the Government Industrial Research Institute of Nagoya (then the NIRIN, Japan) for one year and a half (1990-1992). Dr. Rouxel then held a position as a CNRS Researcher in the Ecole Nationale Supérieure de Céramiques Industrielles for four years, during which he spent several periods of study leave, in the department of Materials Science at the University of Tokyo, and in the Glasses and Ceramics laboratory in the University of Rennes (France). In 1997, Dr. Rouxel was appointed

Professor at the University of Rennes, where he is presently leading a research laboratory (the LARMAUR) devoted to the study of surface mechanics problems, and flow and fracture in advanced glasses and ceramics.

2:00 – 2:40 p.m. **Nano-Scale Fatigue and Failure Process in Glass**

Frederic Lechenault University of Montpellier

About the Speaker

After obtaining a diploma as an engineer with the National School of the Bridges and Highways (l'Ecole Nationale des Ponts et Chaussées) **Frederic Lechenault** wrote his thesis at the SPEC, within the "Instabilities and Turbulence" Department, under the direction of Olivier Dauchot, from 2004 to 2007. He worked experimentally on the statistical physics of dry granular systems. Specifically, he demonstrated the critical nature of the transition from rigidity in a granular structure by studying the heterogeneity of its dynamics. He subsequently did his post-doctoral work at Raleigh, North Carolina, where he worked with Karen Daniels on the balancing of granular systems and their related intensive parameters, including fracture to fracture interactions. Frederic is currently pursuing further post-doctoral work in France at the SPCSI, CEA Saclay and LCVN, at Montpellier University II, and is working on the mechanisms of glass breakage in corrosive situations. "

2:40 – 3:20 p.m. **Modeling Glass Failure and Strength of Oxide Glasses**

Alastair Cormack, Alfred University

About the Speaker

Alastair N. Cormack is currently Dean of the Kazuo Inamori School of Engineering and Professor of Ceramic Science in the New York State College of Ceramics at Alfred University. Having joined Alfred University in 1985 as an Assistant Professor, he has since served in a variety of administrative offices, most recently as Dean of Engineering since 2003.

Cormack received his undergraduate education from the University of Cambridge and his graduate education from the University College of Wales, Aberystwyth, in Solid State Chemistry. In 1979, he moved to University College London as a Research Associate in the Department of Chemistry.

Cormack is a Fellow of the Royal Society of Chemistry, a Fellow of the American Ceramic Society, a Fellow of the Society of Glass Technology and a Fellow of the Mineralogical Society. He is also a Chartered Chemist and Chartered Scientist in the UK. He is a member of Phi Kappa Phi, Keramos and Tau Beta Pi honor societies.

He has published over 160 papers and been invited to give numerous lectures at national and international meetings and institutions around the world. In 2004, he organized the 9th International Conference on the Structure of Non-Crystalline Materials, NCM9, held in Corning & Alfred, NY and is the Conference Organizer for SSI-17, the 17th International Conference on Solid State Ionics, to be held in the summer of 2009, in Toronto, Canada. He has served on the organizing committees of a number of other scientific meetings. He is the Regional Editor, North America, for the journal Solid State Ionics.

3:20 – 3:40 p.m. **Break**

3:25 – 3:40 p.m. **Film: Commercial Applications Yielding Strong Glass Tableware**

Mike Doyle, World Kitchen, Inc.

About the Speaker

Mark Doyle Nuclear engineer and Master in Industrial Engineering, all from Rensselaer Polytechnic Institute. He had the pleasure of interviewing Admiral Rickover for his job on submarine duty in the navy and after 10 years in the Navy joined Corning Inc. for two years until the division was sold to World Kitchen where he is still working as the chief melting and process engineer after a total of 13 years in the Pressware Plant.

The Case for Improved Glass Strength – Frederic Quan

Glass is a unique material whose many useful properties such as transparency and chemical inertness have enabled many commercial applications. Mechanical strength of the material however, has always been a limiting factor in many of these applications. Indeed many glass components are overdesigned to compensate. The cost of this practice has affected the industry in general by limiting glass applications, and gross margins, by using more material to compensate for brittle failure.

As an example, the theoretical strength of silicate glass is dependent upon the silicon-oxygen bond and is measured in millions of pounds per square inch (psi) for modulus of rupture. However, industry practice has been to design glass articles with reduced stress around several thousands of pounds per square inch to compensate for component failure. This reduction between actual use strength and theoretical strength represents a great potential and opportunity for the glass industry.

The glass brittle material failure model has been well understood since the late 1930's. Unfortunately there has been little significant progress since that time which has affected industry practice. There is an opportunity to at least double or triple glass design strength with the application of modern 21st century technology. This will still allow a safety margin several orders of magnitude below the theoretical strength of glass. The impact of this strength improvement on the glass industry will be enormous, affecting gross margins and new applications for this material.

The reason these improvements have not already been made is due to the poor financial environment within the glass industry. As most glass products are commodity, the gross margins are extremely low and hence very little research and development (R & D) has been allocated to improve glass strength. University research has also been diverted to more flashier hi-tech fields and glass research has suffered from a lack of resources and funding. The opportunity for a break-through in this area would have immense economic impact on the industry.

The actual mechanism of glass failure is very different than the more common metal or polymer materials. Glass is classified as a brittle material and the mechanism for this class of materials was worked out in some detail by the 1950's from pioneering work in the 1930's. This understanding called the brittle material failure model describes the limitations of glass strength to this day.

Two phenomena dominate brittle material failure: fast fracture and fatigue degradation. The failure mechanism is identical, but the time to failure is different. Both conditions are dependent upon surface flaws, since the unflawed pristine glass exhibits very high tensile strength in the order of 1 to 2 million psi due to the aforementioned high bond strength of silicon dioxide. (The primary component of silicate glasses).

This failure model is very asymmetric in that brittle materials fail only under tensile loads. Compressive strengths of brittle materials are extremely high and failure is always initiated under tensile stress. An example of a ball tossed through a pane of glass will reveal that the failure is initiated through the rear surface of the glass. The impact front surface is under compression while the rear surface is under tensile load from bending. Hence, discussions on glass failure are always associated with tensile loading. Compression generally makes glass stronger!

Because surface flaws are the dominant factor in glass strength, their randomness imparts a probabilistic distribution to tensile failure. This was recognized very early in the glass industry through empirical tensile testing, where otherwise identical glass specimen's tensile strength varied by whole orders of magnitude. A Weibull plot was used to express this randomness where failing tensile stress is empirically plotted against failure probability. What this means is glass strength is not a single number but rather a probability function.

The surface flaws which cause these failures are extremely small, in the order of microns and sub-microns. Hence glass components may look dimensionally the same but have very different strength characteristics. The larger the flaw, the lower the tensile failure mode. Smaller microscopic flaws mean stronger glass. This strength variability is why most glass components are designed very conservatively.

In addition to initial flaw depth, another failure mechanism called fatigue degradation must be considered. This phenomenon has no exact analogy with metals or polymers except at cryogenic (near absolute zero) temperatures. Because glass does not deform plastically under tensile stress, any tensile loading becomes concentrated at the tips of the existing surface flaws. This will cause the flaws to grow if the stress is applied in the presence of moisture. Thus, three factors are required for fatigue degradation: flaws, tensile stress, and moisture. Because of the universal presence of flaws and water vapor, the only factor controllable for glass component designers is tensile loading. Tensile loads must be minimized, or otherwise negated, for greater reliability of all brittle materials such as glass.

Solutions to enable stronger glass will first have to minimize the formation of surface flaws initially in the fabrication process. This will generally mean going meticulously through the manufacturing process and eliminating all sources of abrasion and other flaw inducing operations. Techniques to eliminate flaws after fabrication such as fire polishing and/or other more modern techniques have been used to mitigate the fast fracture phenomena. It is generally acknowledged that initial high strength glass can be produced without sacrificing economic viability. The more challenging problem is the fatigue degradation over time, when glass components are used in the real world.

There are very many clever approaches to solve this dilemma, many of them as yet untried, due to the economic constraints within the industry. They all involve minimizing the three required factors for fatigue degradation: surface flaws, tensile stress, and moisture/water vapor.

Flaws, minimized from the manufacturing process, often are prevented by strength preservation coatings which will keep the pristine glass surfaces from abrasion. New silanes, (chemicals which link the inorganic glass with organic polymers), and other modern polymers promise many different strategies to protect the surfaces and maintain the initial glass strength.

Tensile stress minimized through good mechanical engineering practices, can further be reduced using compensating compressive forces from lamination and tempering. Heat, chemical, and other innovative techniques offer many potential approaches which need to be more fully explored.

Moisture and water vapor can be excluded using hermetic coatings and other hydrophobic techniques. There are many new modern coatings such as graphene which utilize research techniques which are as yet not fully understood. Hence, there is the need for further research.

Historically many of the great discoveries made by our industry were made more than 40 years ago, and technology has made great leaps in the intervening years. Knowledge, not only in process and materials, but fundamental molecular structure and the ability to measure and characterize, will enable breakthroughs. New applications and uses for glass will create new unbeknownst products.

In summary, the probability of a breakthrough improving the strength of glass by a conservative factor of 2-3 is definitely within the realm of possibility. For a modest investment in research and development the economic return can be enormous for the industry. The challenge is before us….

Frederic Quan

11 March 2009

News to know

Architects want energy savings, strength in glass

Energy efficient and impact resistance seemed to become the mantra for many of the near 30 presenters during the Engineered Transparence: Glass in Architecture and Structural Engineering conference Sept. 26-28 at Columbia University in New York.

Many of the conference speakers addressed the limits of glass, **primarily in terms of strength**. Architects want more light and transparency in their buildings, but increasing demands for safer building envelopes has forced glass manufacturers to come up with stronger products.

“Glass is being forced to improve from a technical standpoint,” said Roberto Bicchiarelli, executive vice president for Permasteelisa Cladding Technologies LP, with U.S. headquarters in Windsor, Conn. Permasteelisa has addressed architect demands by testing and developing blast-mitigating curtain wall systems, many that use the company’s cable-net designs.

So far, the design community’s demand for light and the glass industry’s efforts to develop stronger products have allowed glass to stay as an essential building envelope product, said Laurie Hawkinson, professor for Colubia’s Graduate School of Architecture, Planning and Preservation. “Light and visibility pushes continued use of glass. Look at Homeland Security structures—light and visibility are a main aspect of design, despite [blast-mitigation] challenges,” she said.

However, Hawkinson, Bicchiarelli and other conference speakers agreed **industry and building engineers need to be vigilant about continuing the creation of better and stronger glass and systems**.

In addition to strength, the design community is demanding better energy performance and sustainability in their glass.

Graham Dodd, engineer for Arup in London, says the **photovoltaic industry needs to create better solar glass options for architects. One huge improvement in cost and performance would be maximizing the capture of the sun’s energy in the PV modules**. “Right now we’re only using the visible portion of the electro magnetic spectrum. Why aren’t we using all parts?”

Dodd also **recommended the glass industry change its coatings so coated glass can be recycled after it’s removed from buildings**. “We need recyclable coatings instead of the disposable coatings we have right now,” he said. Removable coatings would be one option of a recyclable coating.

Thomas Richardson, material scientist for the Lawrence Berkeley National Laboratory, part of the University of California at Berkeley, said **dynamic glazings are another viable option to improve performance**. “What’s missing is our ability to control the amount of light and radiation that comes through glass,” he said.

The conference was hosted by the Graduate School of Architecture, Planning and Preservation, the Fu Foundation School of Engineering and Applied Science, Department of Civil Engineering and Engineering Mechanics, and the Institute of Building Construction, Techniche Universitat Dresden. Oldcastle Glass of Santa Monica, Calif., sponsored the event.

Read about the importance of communication between glass manufacturers and architects here. (see below)

—By Katy Devlin, e-Newsletter Editor, e-glass weekly (October 2007)

News to know

Glass professionals talk technology and trends with architects and engineers

The Engineered Transparency conference, Sept. 26-28 at Columbia University in New York, provided a rare opportunity for members of the glass industry to discuss innovations and trends in glass with architects, engineers and consultants.

The event, sponsored by Oldcastle Glass of Santa Monica, Calif., had a registered attendance of about 300. Columbia University's Graduate School of Architecture, Planning and Preservation and the Department of Civil Engineering and Engineering Mechanics partnered to host the conference.

Susan Trimble, director of corporate communications for Oldcastle Glass, says the event served as an opportunity for the company to become a more involved partner in the design and building processes. "We are committed to architecture and design innovation, and want to have a place at the table to participate. Designers can see new technology, and we can see what architects need," Trimble says.

Moty Emek, consultant to Oldcastle Glass says the **design dreams of architects push glass manufacturers to constantly develop better and smarter products**. "As an industry, we have to keep up with technology. New innovative architecture will be happening as long as our industry is pushing ahead," he says.

Mark Wigley, dean of the School of Architecture for Columbia, says communication between manufacturers, engineers and architects, like that during the conference, is much needed for the design-build community.

"There is not enough communication taking place. ... [Architects and engineers] never get to compare notes with manufacturers," Wigley says. "Here, we are sharing the best practices not within an industry, but best practices across the spectrum."

Having students involved in the dialogue is just as important, if not more, he says. "Industry and the university can use each other. … Students will take something from the conference, and it spreads out into the world. With the new ideas from the conference, we're creating an intellectual laboratory," Wigley says.

Topics covered during the conference included energy issues in all-glass buildings, the limits of glass, the latest trends and security glazing. Read about specific presentations in the next issue of e-glass weekly.

What makes glass break?

Physics : **November 03, 2005**

After 2,000 years of making and breaking glass, one might think there would be a definitive answer. But at the Third International Workshop on the Flow and Fracture of Advanced Glasses, held Oct. 2 to 5 at The Penn Stater Conference Center Hotel, 50 or so of the world's top glass scientists scratched their heads as researchers presented sharply conflicting views on the topic.

This image shows a simulation of glass shattering. Image courtesy of Matt Sprinsky, MRI

Glass is a versatile material that is ideally suited for any number of medical and optical uses in addition to its wide application in the building and automotive trades, said Carlo Pantano, director of Penn State's Materials Research Institute and one of the conference's organizers. Glass products, from microscope slides to optical fibers to space telescopes, are a $22 billion contributor to the U.S. economy. Glass is beautiful, but fragile.

"**An understanding of the basic structure of glass, including how and why it breaks and how it can be strengthened to lessen its fragility, will extend the functionality of glass into new areas,**" Pantano said.

In the workshop's opening session, American Sheldon Wiederhorn of the National Institute of Standards and Technology disputed the findings of French glass scientists who, in 2003, published research proposing that **glass fractures through submicroscopic cavities that form ahead of the crack tip**. Wiederhorn and colleague Jean-Pierre Guin had compared fracture surfaces using an atomic force microscope, an exceedingly sensitive instrument that measures peaks and valleys at the atomic level with a tiny probe, and found no indication of the cavities that should appear if the French researchers were correct.

As Pantano recounted, "Wiederhorn argued in favor of the classical model, which says that **glass fractures through the stretching and breaking of individual inter-atomic bonds one after another, and that this process is accelerated by the condensation of water at the tip of the crack**."

Not so, replied the program's next speaker, Elizabeth Bouchaud of CEA, a French government-funded research organization in Saclay, France. A subscriber to the cavity model, Bouchard presented experimental evidence that both common silicate glasses and newly developed metallic glasses, as well as some ceramics, fracture via cavities that form and flow together ahead of the crack tip. The size of the cavities she observed ranged from a few nanometers in fast-moving cracks, to hundreds of nanometers in ultra-slow stress fractures, she said.

Wiederhorn interrupted: "If there are cavities, then they should be found in high concentration along the fracture surface." He had found none.

"Our difference is in how we measure the fractures," Bouchaud rejoindered, suggesting that a little more precision might set Wiederhorn straight.

"If experimentalists cannot solve their differences, then computer modelers and their simulations will have to come in," exclaimed Rajiv Kalia of the University of Southern California. Using video animations of molecular dynamics simulations conducted on ultra-fast computers, Kalia described how atoms under pressure slide across one another, causing friction and giving rise to cracks. In Kalia's model, these cracks extend through "nanovoids," cavities so small that they can be closed up or "healed" by the same pressure that caused the glass to fracture in the first place. Maybe this healing masks the true fracture process, he suggested.

Or is there another mechanism entirely, as J.J. Mecholsky Jr. of the University of Florida contended? "**Mecholsky showed the fracture process as a series of changes in the atomic bonds at the crack tip," said Pantano. "His simulations showed the glass's atomic structure pulling apart like stretched rubber bands through the rearrangement of atoms -- not the rupture of bonds -- to propagate the growing crack**."

A potential international fracas was averted during a coffee break, when Wiederhorn approached Bouchaud and complimented her on her eloquent presentation. Bouchaud, in turn, suggested collaboration between the two groups to settle their dispute experimentally.

Pending the results of this joint effort, they can always fall back on the empirical data. Some of the things that make glass break, after all, are beyond dispute. Just for starters, how about baseballs, broom handles and bricks?

Source: Research/Penn State (By Walt Mills)

3:40 – 5:40 p.m. **Panel Discussion**

The Panelist's

About the Panelist

Julide Bayram is currently Research and Engineering Manager of Sisecam a company in the manufacture of glass and chemicals.,encompassing all the key areas of glassmaking ;flat glass,glassware,glass packaging and glass fiber. Sisecam's global rank varies from third to eigth in its field amongst the world's most distinguished glass manufacturers. Sisecam reached its current position with a concentration on corporate standarts and a focus on R&D.

Jülide began her career as a Project Engineer in the Technical Group at Sisecam's Headquartes. As part of the RD& E team she worked on various furnace design projects, regenerative, recuperative and oxyfuel furnaces. She was part of the team doing various development work , Improving the energy efficiencies of furnaces and environmental management . She has taken part in the project management of many greenfield investment projects like float, tableware, container glass plants both in Turkey and abroad.

Additionally, Julide has received bachelor's degree in chemical engineering from the University of Bosphorous in Istanbul. She had MSc degree in chemical engineering from the University College of Swansea in U.K.After she joined Sisecam she has taken courses in glass technology held for ten weeks for students from the ındustry in University of Sheffield,

About the Panelist

Steve Freiman, PhD graduated from the Georgia Institute of Technology with a B. ChE. and a M.S. in Metallurgy. After receiving a Ph.D. in Materials Science and Engineering from the University of Florida in 1968, Dr. Freiman worked at the IIT Research Institute and the Naval Research Laboratory. He joined NIST (then NBS) in 1978. From 1992 to 2002 Dr. Freiman served as Chief of the Ceramics Division at NIST. Prior to his leaving NIST in 2006 to start a consulting business (Freiman Consulting Inc.), Dr. Stephen Freiman served for four years as Deputy Director of the Materials Science and Engineering.

Dr. Freiman has published over 150 papers focusing on the mechanical properties of brittle materials. He was the first Chairman of the ASTM Subcommittee addressing brittle fracture and a past Chair of the VAMAS steering committee. In the American Ceramic Society, he served as Chair of the Glass and Optical Materials Division, Chair of the Program and Meetings Committee, Treasurer, and President of the Society. He is a Fellow and Distinguished Life Member of the American Ceramic Society.

About the Panelist

Jill Glass manages the Materials Reliability Department at Sandia National Laboratories in Albuquerque, New Mexico. Her department encompasses expertise in corrosion, electrochemistry, cleaning and contamination, gas analyses, multivariate data analysis methods, and the mechanical behavior and reliability of glasses and ceramics. Jill joined Sandia in 1990, and as a Principal Member of the Technical Staff, led and contributed to research, development, production, and failure analysis activities primarily focused around the mechanical behavior or glasses and ceramics. Her areas of research included joining, ceramic powder compaction, stressed glasses, fragmentation of brittle materials, cermets, and glass ceramics. Jill obtained her B.S. in Ceramic Engineering (1984) from McMaster University in Hamilton, Ontario, and her M.S degree (1987) and Ph.D (1990) in Ceramic Science from Penn State University. Her graduate work under Dr. David Green covered the processing and mechanical properties of novel infiltrated alumina-zirconia composites.

About the Panelist

Suresh Gulati, PhD is a Senior Scientist, with over 30 years of experience in catalytic converter technology with Corning, Inc. Dr. Gulati is an expert consultant for the Company. He is an authority in the catalytic converter business with his extensive experience in the development of emissions control catalysts and ceramic substrates for catalytic converter application. He is a regular speaker at Society of Automotive Engineers (SAE) conferences and technical courses. Dr. Gulati has authored or co-authored over 25 papers related to emissions control and received numerous company and industry awards, including Corning Research Fellow (1983). Dr. Gulati holds a Ph.D. in Applied Mechanics from the University of Colorado, an M.S. in Mechanical Engineering from the Illinois Institute of Technology and a B.S. from the University of Bombay, India.