Advances in Glass Strength and Its Impact on Society

American Ceramic Society – Ceramic Leadership Summit 2011
Baltimore, MD
August 3, 2011

Louis Mattos, Jr., PhD
The Coca-Cola Company
Co-Chair; Usable Glass Strength Coalition (UGSC)

Louis Mattos, Jr.

- NYSCC at Alfred University
  - BS Ceramic Engineering
  - MS Ceramic Science
  - PhD Ceramic Science
    - *"Ion Exchange of Mixed-Alkali Glasses"* (Dr. W.C. LaCourse)
- Ferro Corporation (1997 – 2001)
- Saint-Gobain Abrasives (2001 – 2005)
- The Coca-Cola Company (2005 – Present)
- Usable Glass Strength Coalition
  - Chairperson 2010
  - Co-Chair 2011
    - Douglas Trenkamp (OI) and Elam Leed (Johns Manville)

Glass – the Window to our World

Glass – the Window to our World

- Two perceived deficiencies of glass
  - Heavy
  - Breakable

Theoretical vs. Usable Strength of Glass

Condition of Glass	Strength (lb/in^2)
Theoretical/Lab Demonstrated	2,000,000
Pressed Articles	3,000-8,000
Blown Ware • Inner Surface	4,000-9,000 15,000-40,000
Drawn Tubing or Rod	6,000-15,000
Glass Fibers • Freshly Drawn • Annealed • **Telecommunication**	 30,000-40,000 10,000-40,000 **>100,000**
Window Glass • **LCD (0.65 mm)** • **Chemically Treated Cover Glass**	8,000-20,00 **45,000** **100,000-200,000**

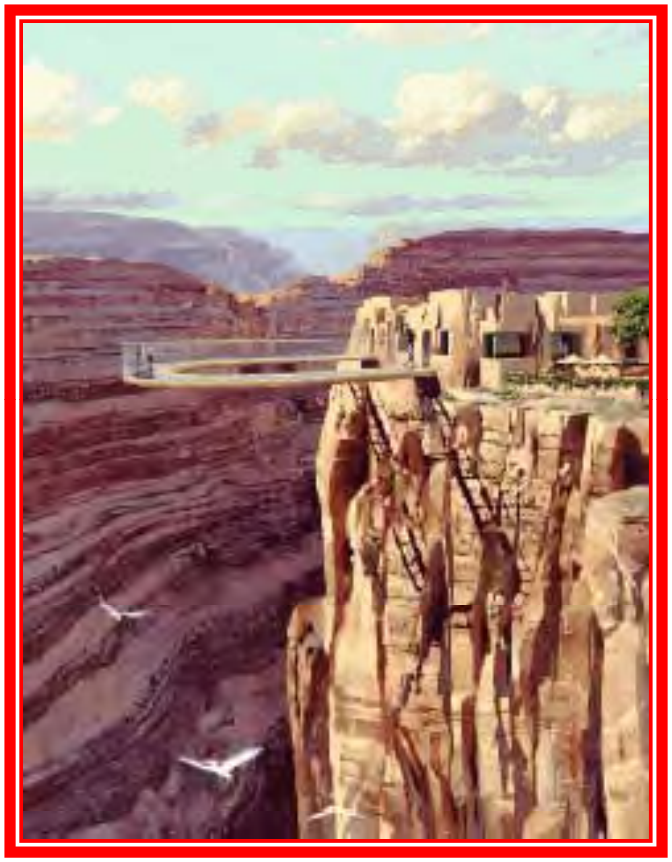
Laminated Glass

“Bulletproof” glass

“The Ledge”
at Skydeck;
Willis Tower, Chicago
4.3 ft wide -- 1,353 ft in the air

Thermal Tempered Glass

Safety Glass



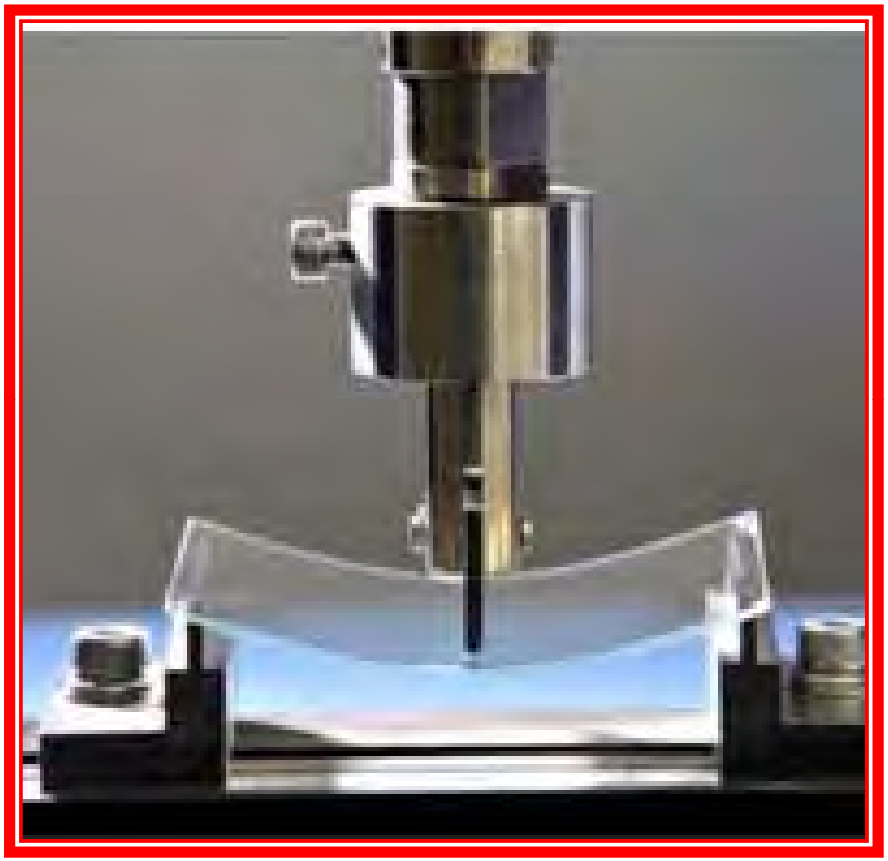
“Grand Canyon Skywalk ”

3 in thick glass bottom

70 ft from the rim

4,000 ft chasm

Chemical Tempered Glass



Asahi Dragontrail™

Mobile Phones

with scratch resistant cover glass

2007 Strength in Glass Contest

"if glass of any type were available at 50 times its current strength, what new products, engineering opportunities or cost savings could emerge into the marketplace."

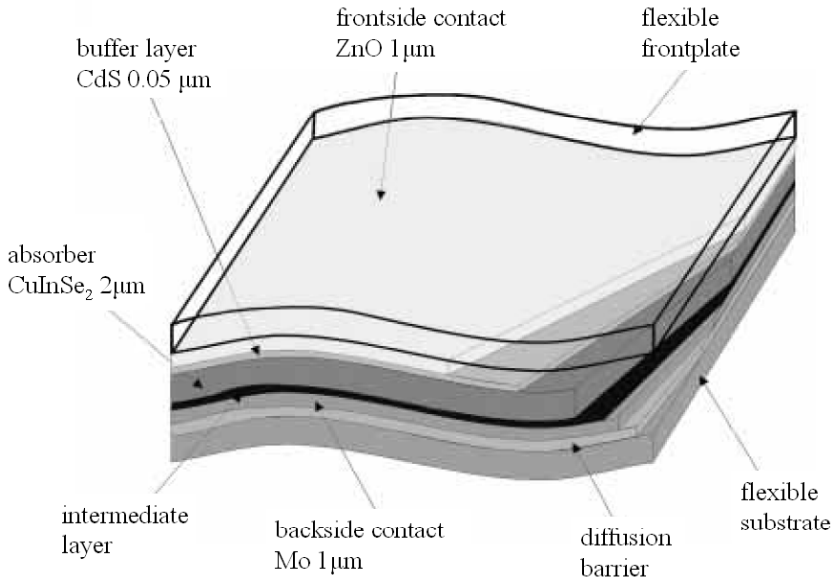
- 47 papers
- 28 universities
- 5 countries

http://www.gmic.org/Strength%20In%20Glass.html

First Prize: Armin Dillert

Friedrich Alexander University - Erlangen Germany

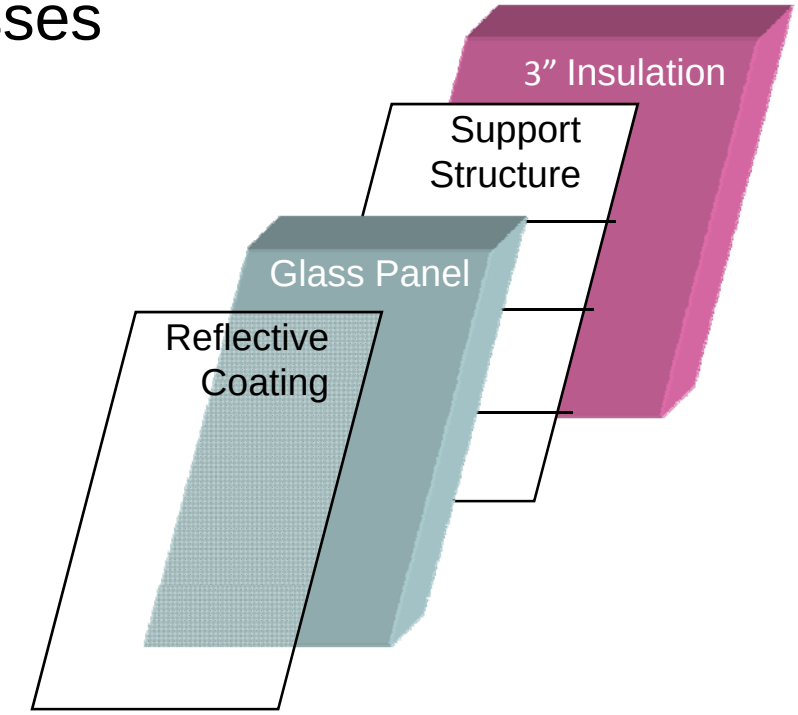
- "Flexible Thin Solar Panels"
- Envisioned "rollable" solar panels with a glass substrate
  - High chemical resistance for processing and in use performance
  - High temperature stability for processing will increase efficiency
  - UV resistant



Second Prize: Julieann Heffernan

New Mexico Institute of Technology – Socorro, New Mexico

- "Glass Roofs Save Energy and Money"
- Today: a 4' by 8' panel of silicate glass needs to be 6.25" thick to withstand heavy snow and impact from hailstones.
- Future: at 50x glass strength, glass panels need to be 1/8" thick to withstand typical roof stresses
- Results for a 2000 ft^2 roof:
  - Equivalent cost of goods and labor compared to asphalt shingles
  - Weight reduction of nearly 33%...over 4000 lbs
  - 50% increase in R-value…leading to a reduction in heat loss



Third Prize: Charles H. Rawlins

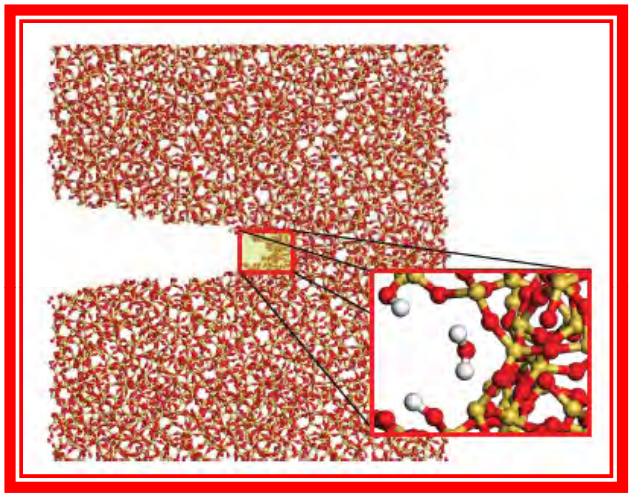
University of Missouri-Rolla – Rolla, Missouri

- "Eversphere Glass Balloons"
- High-strength glass for the manufacture of vacuum-based, thin-wall glass spheres to serve as permanent balloons.
- High-altitude polymer balloons
  - limited to altitudes of 40 km (25 miles)
  - Require a land based tether for permanent positioning; impractical above a few hundred feet.
- Potential use as cell phone relays in remote areas

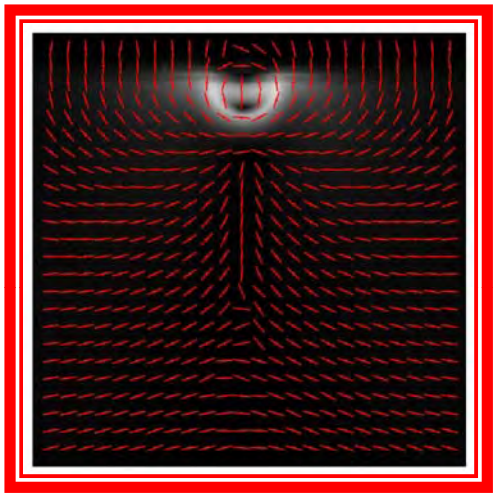
Why Glass Strength? Why Now?

- Advanced research techniques allow us to understand the true nature of flaw generation, flaw growth and glass failure

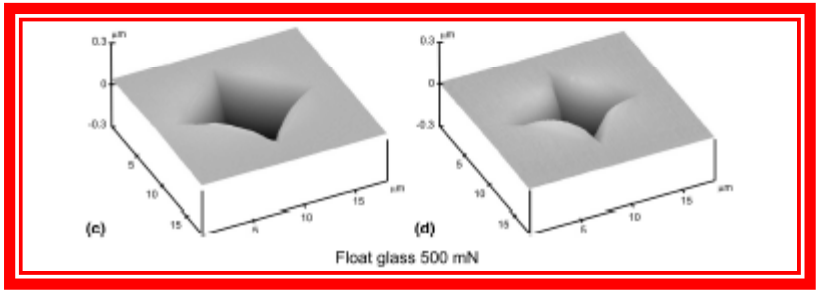
Two-point Bend
Courtesy D. Brow



Molecular Modeling
Courtesy E. Leed



Abrio Stress Birefringence
Courtesy C. Kurkjian



Atomic Force Microscope
Courtesy C. Kurkjian

Usable Glass Strength Coalition (UGSC)
Two Year Journey

- PacRim 2009 ; Vancouver – June 2009
- Alfred University – August 2009
- Penn State – September 2009
- ASTM; Washington DC – January 2010
- GOMD; Corning, NY – May 2010
- The Coca-Cola Company; Atlanta, GA – September 2010
- Savannah, GA – April 2011

Coalition Mission

"Glass companies cannot independently support a fundamental research agenda to understand and significantly improve the usable strength of glass. However by working together with pooled funding and shared risk, the opportunity to significantly improve the usable strength of glass is achievable."

- **Objective:** To develop a pre-competitive research program to identify critical parameters for improving the usable strength of glass.
  - Fundamental understanding of methods for improving usable glass strength.
  - Develop and standardize new tools and testing methods
  - Develop next generation of glass technical experts and researchers

Strength Research Coalition Begins

Core Research Team (CRT)	Affiliation
Brow, Richard	MST
Brown, John	GMIC
Click, Carol	O-I
Cormack, Alastair	Alfred University
Green, David	Penn State
Gulati, Suresh	Corning Incorporated
Gupta, Prabhat	OSU
Hamilton, Jim	Johns Manville
Huff, Norman (Tom)	Owens Corning
Kurkjian, Chuck	Rutgers U & U of S.ME
LaCourse, William	Alfred University
Pantano, Carlo	Penn State
Sakoske, George	Ferro
Tomozawa, Minoru	RPI
Varner, James	Alfred University
Varshneya, Arun	Alfred University
Wiederhorn, Sheldon	NIST
Yoldas, Bulent	consultant

Strength Steering Team (SST)	Company
Bratton, Kenneth	Emhart
Brossia, Charlie	Retired A-B (SST Vice Chair)
Brown, John	GMIC Technical Director
Cornelissen, Madonna	Corning
Greenman, Michael	GMIC Executive Director
Gulati, Suresh	Corning (retired)
Hamilton, Jim	Johns Manville
Hand, Russell	U. of Sheffield (UK)
Hartman, David	Owens Corning
Huff, Norman (Tom)	Owens Corning
Iturbe Acha, Enrique	Vidrala (Spain)
Kurkjian, Chuck	CRT (Chair)
Lubitz, Günter	Vetroconsult
Mattos Jr., Louis	Coca-Cola (SST Chair)
McCarthy, Patrick	Owens Corning
Pantano, Carlo	Professor, Penn State
Quan, Frederic	Corning (retired)
Roos, Christian	IPGR
Sakoske, George	Ferro
Strahs, Glenn	DOE
Trenkamp, Douglas	OI
Uriarte, Alex	Vidrala (Spain)
Zach, Chris	Energetics

UGSC Members

- **Seed Funding of UGSC has two targets:**
  1) To fund the development of a formal membership agreement
  2) To fund the development of a formal research roadmap

Organization	Classification	Glass Sector
Corning Inc.	Manufacturer	Specialty
Johns Manville	Manufacturer	Fiber
Owens-Illinois	Manufacturer	Container
Owens-Corning	Manufacturer	Fiber
Saint-Gobain Containers Verallia	Manufacturer	Container
AB/InBev	Manufacturer & User	Container
International Partners in Glass Research (IPGR)	R&D Association	Container
The Coca-Cola Company	User	Container
Diageo	User	Container
Emhart	Supplier	Container
Rio Tinto Minerals	Supplier	All

Key Considerations

- Membership Structure
  - Foreign Membership
  - Antitrust Issues
  - Multiple Membership Levels
- Intellectual Property
  - IP Ownership
  - Publication of Research
  - Member Funded Research
- Funding Model
  - NSF/IUC
  - Matching Funds
    - Submerged Combustion Melter
  - Self-funded

Consensus Coalition Research Program

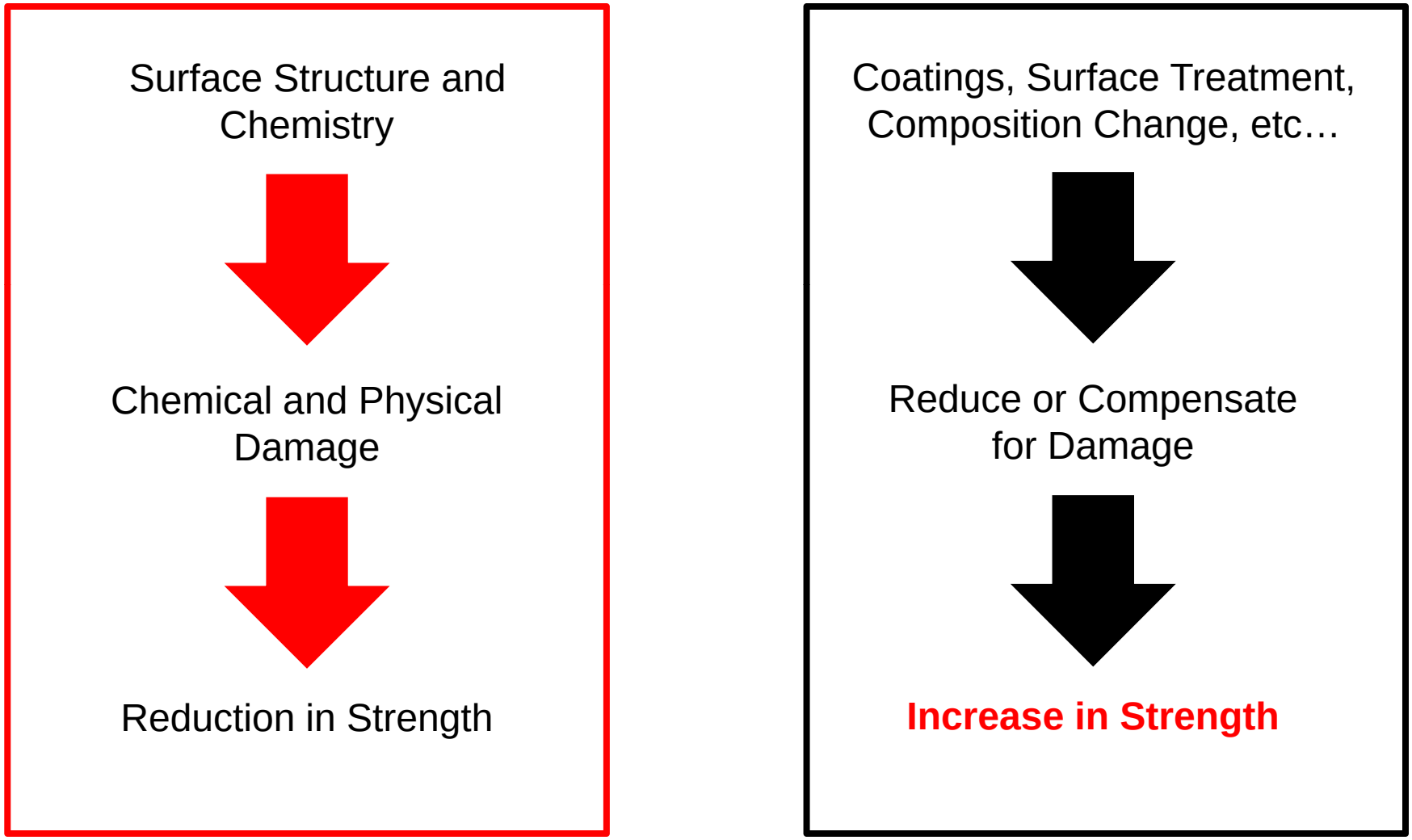
- Minimum 5 yr fundamental research
- Start applying research findings internally after ~3 years
- 10 student researchers
  - $1 mil/year for students
- equipment expenses (~$1 million total)
- 3-5 broad topics of research

$6 million total estimated funding

Research Roadmap

- **Crack initiation inevitably occurs at the surface of glass.**
- **How do cracks nucleate?**
  - What structural features which facilitate crack nucleation, particularly on pristine surfaces?
  - What are the weakening mechanisms?
  - What is the role of surface roughness?
  - Are there melt history effects?
- **What is the relationship between crack initiation and contact damage?**
  - What is the correlation between abrasion and indentation?
  - The creation of a library of known manufacturing defects would be beneficial.
- **What are the differences between mechanical and chemical damage?**
  - What role does the chemistry of the glass play in this?
  - What is the role of surface structure – defect and reactive sites – on flaw generation and crack initiation?
- **KEY THREAD: Modeling**
  - Atomistic
  - FEA

Research Roadmap

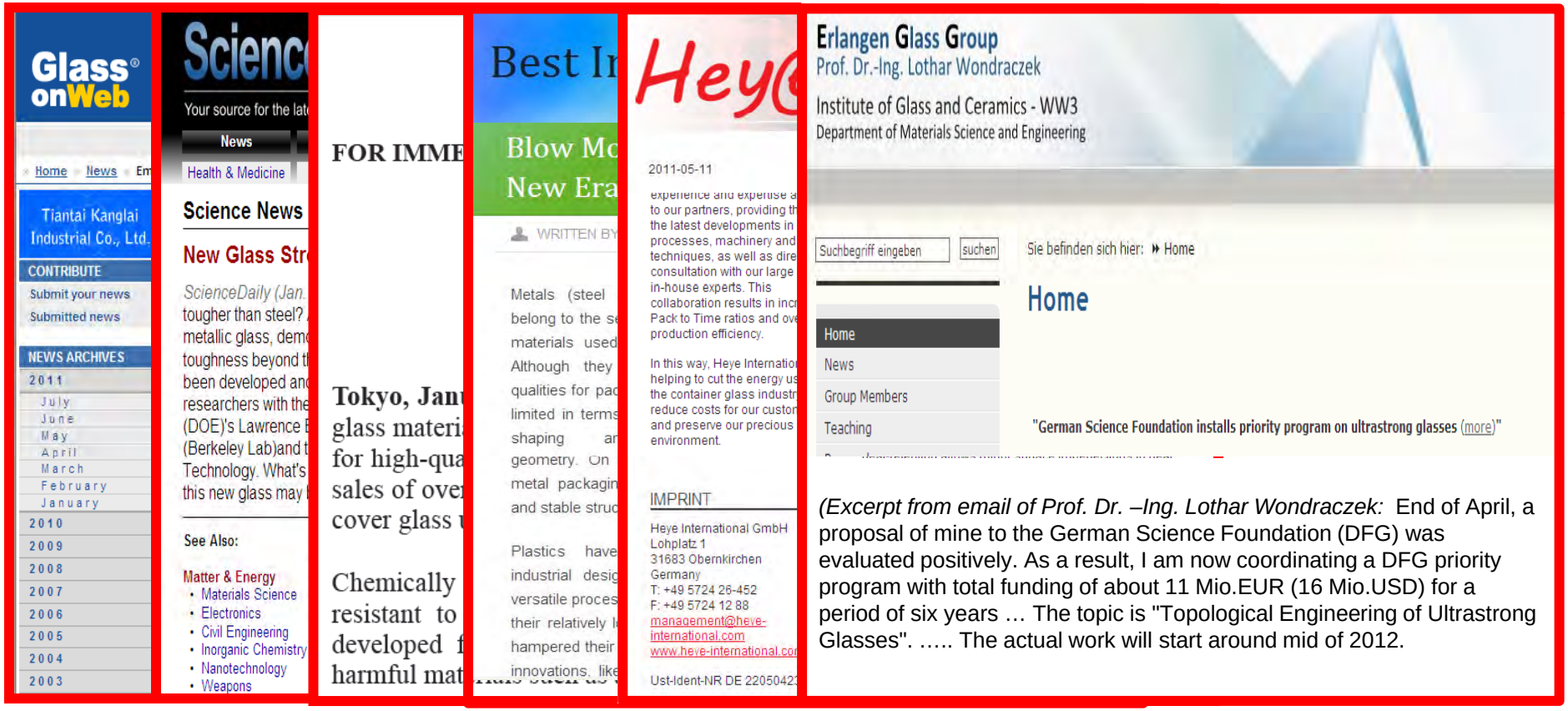


Draft Membership Agreement

- Forming the UGSC entity under the current GMIC umbrella
  - Manage the research program
  - Manage the ownership, protection and commercialization of IP
- Funding Model
  - Self-funded for initial 3-year period
    - Fee: TBD; targeted at $50K per year
    - Target: six (6) to ten (10) members
  - After year three (3); leverage a matching fund pool
- Research Proposals
  - Issue Requests for Proposals (RFPs) for strategic research platforms
    - Surface structure and chemistry
    - Chemical and physical strength
    - Coatings, Surface Treatment, Composition Change, etc…

Lesson Learned

- Forming a coalition is hard work!!!
  - Companies join coalitions, they do not start coalitions
- We are on the right track!!!



(Excerpt from email of Prof. Dr. –Ing. Lothar Wondraczek: End of April, a proposal of mine to the German Science Foundation (DFG) was evaluated positively. As a result, I am now coordinating a DFG priority program with total funding of about 11 Mio.EUR (16 Mio.USD) for a period of six years … The topic is "Topological Engineering of Ultrastrong Glasses". ….. The actual work will start around mid of 2012.

Acknowledgements

- GMIC
  - Michael Greenman
  - John Brown
  - Robert Lipitz
- Glenn Strahs; DOE
- Lynnette Madsen; NSF
- Chris Zach; Energetics
- Charlie Brossia; AB, retired
- CRT
  - Chuck Kurkjain; retired
  - Carlo Pantano; Penn State
  - Dick Brow; MST
  - Alastair Cormack; Alfred Univ.
- SST/UGSC Coalition
  - Doug Trenkamp; OI
  - Elam Leed; Johns Manville
- Mark Krohn; legal counsel

Thank you

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