# SYMPOSIUM C

## Material Innovations for High-Performance Building Systems

November 29, 2005

### Chairs

**John E. Fernandez**
Dept. of Architecture
Massachusetts Institute of Technology
Room 5-418
Cambridge, MA 02139
617-253-5266

**Oral Buyukozturk**
Dept. of Civil & Environmental Engineering
Massachusetts Institute of Technology
Rm. 1-280
Cambridge, MA 02139
617-253-7186

**Stephen Selkowitz**
Environmental Energy Technologies Div
Lawrence Berkeley National Laboratory
Bldg. 90-3111
Berkeley, CA 94720
510-486-5064

**Tom Schwartz**
Consulting Engineers
Simpson Gumpertz & Heger Inc.
Bldg. 1, Ste. 500
41 Seyon St.
Waltham, MA 02453
781-907-9000

* Invited paper

SESSION C1:
Chair: David S. Ginley
Tuesday Morning, November 29, 2005
Beacon A (Sheraton)

**8:30 AM C1.1**
**A Water-Free, High-Performance Cement Based on Polymer Intercalation and Exfoliation Technologies.** Jigar K. Deliwala, Xinguo Kong and Yu Qiao; Department of Civil Engineering, University of Akron, Akron, Ohio.

For many decades, developing advanced cements of high tensile strength has been an active research area. One of the promising ways is to use polymeric materials to improve the interparticle bonding. The recent rapid progress in polymer intercalation-exfoliation (PIE) techniques has provided a simple yet promising method to mix silicate nanolayers and polymer chains at the nanometer level. The major component of cements is calcium silicate and alumina silicate of highly ordered layered structure. It is, therefore, feasible to apply similar PIE techniques on cementitious materials. Recently, a novel cement, polymer intercalated/exfoliated cement (PIEC) was developed by the author's research team. According to the experimental data, the PIEC of high tensile strengths larger than 100 MPa, and the thermal/moisture resistances are superior. Other attractions include the low permeability and high fireproofness. This material is ideal for precast and rapid repair applications, as well as permanent bases or outposts on the Moon or the Mars.

**9:00 AM C1.2**
**Geometry and Performance of Phononic Noise Abatement Materials.** Meredith Alexandra Aronson[1], Dale Clifford[2] and Pierre Deymier[1]; [1]Materials Science and Engineering, University of Arizona, Tucson, Arizona; [2]Architecture, University of Arizona, Tucson, Arizona.

New findings in materials science suggest promise for acoustic band gap or "phononic" materials, which are materials that forbid the propagation of certain acoustic frequencies, creating gaps. We are interested in the application of phononic materials in acoustic noise abatement structures, providing noise protection in the audible range of 200-20,000 Hertz. Phononic materials are a novel and exciting alternative to traditional noise abatement materials. They have the potential to significantly improve acoustic performance while increasing aesthetic design possibilities, allowing for new architectural forms that use less space and offer more interesting visual reading. Using rapid prototyping, we assess the relationship between geometry and performance in these materials. Relationships between theory and experiment will be presented.

**9:30 AM C1.3**
**The UP!house: A new Concept for the Prefabrication of The Single Family Home.** Craig Konyk, [1]GSAPP, Columbia University, New York, New York; [2]Parsons School of Design, New York, New York.

The design for the UP!house was commissioned for dwell magazine dwell home invitational of April 2003, a case study of the potential for prefabrication in home design. The UP!house is an investigation into a prefabricated architecture that borrows from the world of industrial design, specifically automotive design and production techniques. With options ranging from power windows to home theater entertainment packages, the UP!house is an attempt to make the purchase of the single family house more akin to that of the latest model Volkswagen. The UP!house employs an innovative structural concept known as a double cantilever. Acting as a balance beam from a center support, the weight of one side is counter-balanced by the weight of the other, not unlike a see-saw. When assembled, the lightweight steel structure box beam acts like an occupiable vierendeel truss. The advantage of this lightweight steel system is that it minimizes onsite foundation work, allowing the entire house to be supported by only two reinforced concrete walls on spread footings, the only elements constructed on the site. The interstitial space of the UP!house helps moderate interior temperatures through natural ventilation and serves as storage space for books, clothes and other domestic items. The interstitial space also conceals the plumbing and other services of the house behind an illuminated twin-wall polycarbonate surface. The ends of the UP!house, made of Kalwall, are open sections, revealing the chassis structure of the UP!house. The chassis of the UP!house is a factory welded lightweight uni-body steel construction. Upon this chassis, an exterior body is attached. This body is made from alternating exterior high glass panels and tinted glass. Options for additional volumes of space or additional rooms are made by selecting UP or UNDER extensions to the main body of the house. The exterior cladding is a three-inch high-density polyisonate bonded sandwich panel. The outer layers of this panel are coated with polyvinylidene fluoride (PVDF) with a clear coat UV resistant finish. An additional feature of the UP!house is its ability to be disassembled into its constituent components allowing residents to add on or remove sections from the house as their needs change. The UP!house can also be demounted and reassembled on a new site if the owner decides to move. If you move, UP!house moves with you. The UP!house is presented as a higher value fabrication product for the making of a home. Utilizing the latest techniques and materials commercially available, the UP!house seeks to be a clear alternative to the delivery methods and quality of the current procurement process for the home.

**10:30 AM C1.4**
**Transparent Ormosil Aerogels for Highly Energy Efficient Windows.** Duan Li Ou, Wendell E. Rhine, Reduoue Begag and Jong Ho Song; R&D, Aspen Aerogel Inc, Northborough, Massachusetts.

A large portion of energy is lost in buildings and homes through windows whose R-value (oF ft2 h/Btu) is only a small fraction of those of walls and roofs. Affordable, more energy efficient windows are not being manufactured due to the absence of an insulating material that is highly transparent and a good insulator. Aerogels are the best insulating materials known and have the potential for being used to make superinsulating windows. Transparent monolithic silica aerogels are highly porous materials with higher than 90% porosity and nanometer size pores. The nanostructure of aerogels makes them highly insulating materials with thermal conductivities lower than that of air. In addition to its low thermal conductivity, the high infrared and visible light transmittance of this material also makes it ideal for the use in highly insulating windows with high solar heat gains. Yet the commercialization of silica aerogels has been limited because of their low strength, brittleness, and high cost. Although there have been numerous attempts to overcome the weakness and brittleness of silica aerogels, no significant improvements in their mechanical properties have been reported so far. In the present study, linear polymers were successfully incorporated into the silica network leading to the formation of a class of novel transparent ormosil aerogels with improved mechanical properties and low thermal conductivities. Monolithic 12 x 12 x 0.5 inch transparent aerogel panels have been made of these ormosil aerogels and an aerogel panel was inserted between panes of glass to study the properties and potential of aerogel insulated windows. The nanostructure of these novel aerogels has been investigated by the nitrogen adsorption method, their transparency has been evaluated by UV-Vis-NIR spectroscopy, and their thermal conductivity determined. The results of systematic studies to establish the formulation-structure-property relationships of these novel hybrid aerogels will be presented.

**11:00 AM C1.5**
**Formation of $TiO_2$/TiN/$ZrO_2$ stacked-films with application to a photocatalytic heat-mirror.** Masahisa Okada, Masato Tazawa, Yasusei Yamada, Ping Jin and Kazuki Yoshimura; National Institute of Advanced Industrial Science and Technology, Nagoya, Japan.

Heat-mirror window coatings based on $TiO_2$/TiN/$TiO_2$ stacked-films can play a major role in architectural energy conservation. This type of heat-mirror has high transmittance in the visible region and reflects as much as possible of the invisible solar radiation in the infrared. Furthermore, $TiO_2$ films have excellent photocatalytic and photoinduced-hydrophilic properties and have been widely used in environmental applications such as air-purification, sterilization, antifogging, and self-cleaning. From these points, it is expected a $TiO_2$ outer layer of $TiO_2$/TiN/$TiO_2$ stacked-films could work as a photocatalyst as well as the anti-reflection coating. In order to apply for antifogging or air-purification inside the building, the film-coated surface of the window-glass should face the indoor. In the case of UV irradiation at the back of the $TiO_2$/TiN/$TiO_2$-coated glass, however, their photocatalytic performance becomes poor because of UV absorption in the $TiO_2$ inner layer. In this study, we propose the novel structure of $TiO_2$/TiN/$ZrO_2$ stacked-films, which can be applied on the photocatalytic heat-mirror for indoor use. Since the band-gap of $ZrO_2$ is larger than that of $TiO_2$, the $TiO_2$ outer layer of $TiO_2$/TiN/$ZrO_2$ stacked-films are expected to absorb UV photons efficiently, even in the case of the rear UV irradiation. $TiO_2$/TiN/$ZrO_2$ stacked-films were deposited on quartz glass substrates by using reactive magnetron sputtering under precisely controlled process parameters. Optical evaluation was performed by measuring the transmittance/reflectance with a spectrophotometer in wavelength of 250-2500 nm and the good heat-insulating performance of the samples was represented. The photocatalytic properties were also evaluated by measuring the photo-decomposition of gaseous acetaldehyde under UV light irradiation condition. It was confirmed that the UV irradiation at the back of $TiO_2$/TiN/$ZrO_2$ stacked-films produces an efficient photcatalytic performance. Moreover, it was found that $TiO_2$/TiN/$ZrO_2$ stacked-films show superior photocatalytic activity, compared to $TiO_2$/TiN/$TiO_2$ stacked-films, in the case of UV irradiation at the front of those. In the case of the heat-mirror with stacked-films such as $TiO_2$/TiN/$ZrO_2$ and $TiO_2$/TiN/$TiO_2$, the thickness of the outer $TiO_2$ layer (about 35 nm thick) may be too thin to absorb all of irradiated UV photons. We deduce that the photocatalytic activities of the $TiO_2$ layer are improved effectively, by the appreciable UV reflectance from the TiN layer, which have a higher energy than the energy of the $TiO_2$ bang-gap. Furthermore, the optical property of TiN layers depends strongly on their crystalline-quality and may be affected by the crystal structure of underlying oxide layers such as $TiO_2$ and $ZrO_2$, which leads to the difference of the photocatalytic activities between $TiO_2$/TiN/$ZrO_2$ and $TiO_2$/TiN/$TiO_2$ stacked-films.

SESSION C2:
Chair: David S. Ginley
Tuesday Afternoon, November 29, 2005
Beacon A (Sheraton)

**1:30 PM C2.1**
**Comparison of Traditional and Innovative Condensation Control Strategies in North American Commercial Steel Stud Wall Assemblies.** Stanley Dmitri Gatland, Building Science, CertainTeed Corporation, Valley Forge, Pennsylvania.

Several types of innovative polymer-based vapor retarding films, available throughout the world, have the ability to change their water vapor permeance with the change in relative humidity or the condensation of water vapor. Commonly referred to as smart vapor retarders, the films function as effective interior vapor retarders during the heating season and allow substantial drying towards the interior during periods of warm, humid weather. Moisture transport mechanisms will be described for each film. Water vapor transmission properties of four commercially available products will be compared with traditional interior vapor control building materials. In addition, the paper will compare and contrast the hygrothermal performance of common commercial steel stud wall assemblies using different vapor control strategies in the various climates present in North America. Results of one-dimensional transient heat and moisture transfer models, using the proposed ASHRAE Standard 160P "Design Criteria for Moisture Control in Buildings" methodology, will compare quantitative thresholds for mold growth and building component moisture content. The impact of changing building materials within an assembly will be examined.

**2:00 PM C2.2**
**Dynamic Architectures: Beginning With Shape Memory Polymers.** Billie Faircloth[1] and Ben Dietsch[2]; [1]School of Architecture, University of Texas at Austin, Austin, Texas; [2]Cornerstone Research Group, Dayton, Ohio.

This paper documents the on going process, products and discourse of SMARTstudio, an advanced design studio at The University of Texas at Austin which seeks to re-systematize architecture based on the potential of smart material attributes. SMARTstudios design research is founded at the common intersection of material science and architecture: material character and material scale. It originates with one smart material attribute; form changing response to environmental stimuli. Materials exhibiting this attribute are known as shape memory materials, or polymers, alloys, composites and foams with a remembered shape and programmable transformation. The studio is working directly with shape memory polymers, initially asking: How does a dynamic, shape changing material become a catalyst for reinventing spatial compositional and temporal conditions within architecture? The studios research is structured as a macro-micro dialogue of thinking and making between students of architecture, professional chemists, and professional material engineers. It receives weekly consultation at the molecular scale. The studio intentionally asks: In what ways can architects recast the relationship between architecture and material science? Can architecture reposition itself to involve all scales of inquiry, including the molecular and the elemental? Can a dialogue between architecture and material science result in material, spatial and structural attributes not yet imagined by either discipline? The work of SMARTstudio exposes shape memory materials to a range of conditions that tests multiple properties, find limits, and demand more material performance. Ultimately, the studios proposals invent new materials and new material properties, ones that go beyond shape-memory, contributing to a radical rethinking of the structural, spatial, and environmental systems of architecture.