Building Technologies Program

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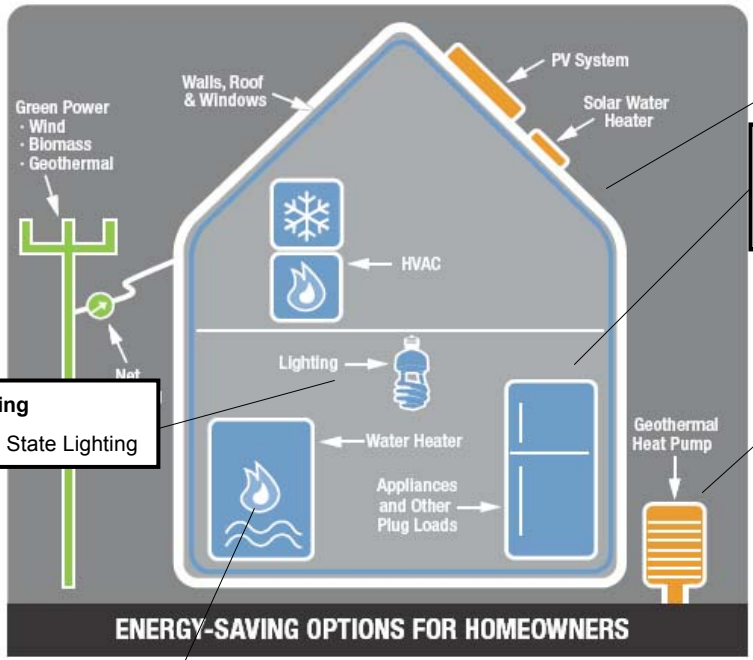
VENTURE CAPITAL TECHNOLOGY SHOWCASE
AUG 21 AND 22, 2007

Background And Outline

- Background
  - Building Technology Program (BTP) focused on a goal of zero-net energy homes (2020) and commercial buildings (2025)
    - Fund R&D
    - Conduct deployment programs
    - Promulgate appliance regulations and develop voluntary building codes
  - Research Funding Mechanisms
    - Directed research to DOE labs
    - Competitive procurements with labs, industry, and academia
    - Small Business Innovation Research (SBIR) managed by Office of Science
  - Use Stage-Gate process to ensure only those products with commercial potential advance and as such, many technologies have commercial partners or venture capital connections

- Outline
  - Zero Energy Home Overview
  - Solid State Lighting Overview
  - Potential Technologies of Interest

Building America Program is marching towards ZEH for all Americans



Thermal Envelope

•High R Walls and Roofs (60-70%)

Windows

•R-10 Dynamic Super Window (70-80%)

Appliances and Other Plug Loads

• Whole House Energy Control Standard

• Other Misc. Electric Savings (40-50%)

Space Conditioning and Refrigeration

•Integrated, low capacity heat pump. (60-70%)

Lighting

•Solid State Lighting

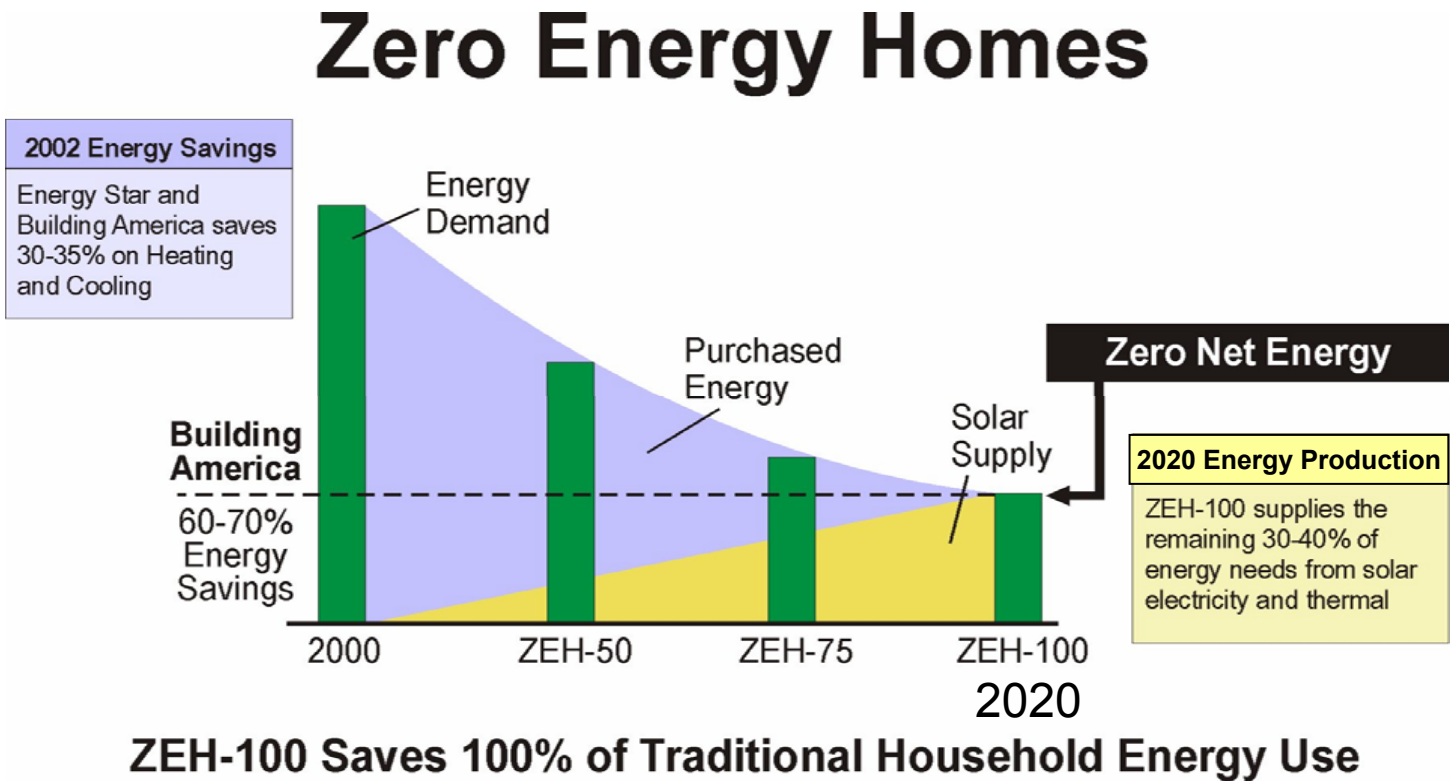
Domestic Hot Water

•Integration, low capacity heat pump (60-70%)

		Future Zero-Energy Home in Mixed Humid Climate	
		Percent Energy Offset (vs. Conventional Home)	Incremental Cost
Energy Use	Reduction (using State-of-the Art Design and Efficiency Technologies)	-52%	+ $16,883
	Reduction (from Accelerated Efficiency Research)	-15%	
	Avoided due to Solar PV	-33%	+ $16,500
	Total	-100%	+ $33,383
Associated Costs ($/yr)	Incremental Annual Mortgage Costs		+ $1,855
	Incremental Annual Utility Bills		- $2,022
	Total		- $167

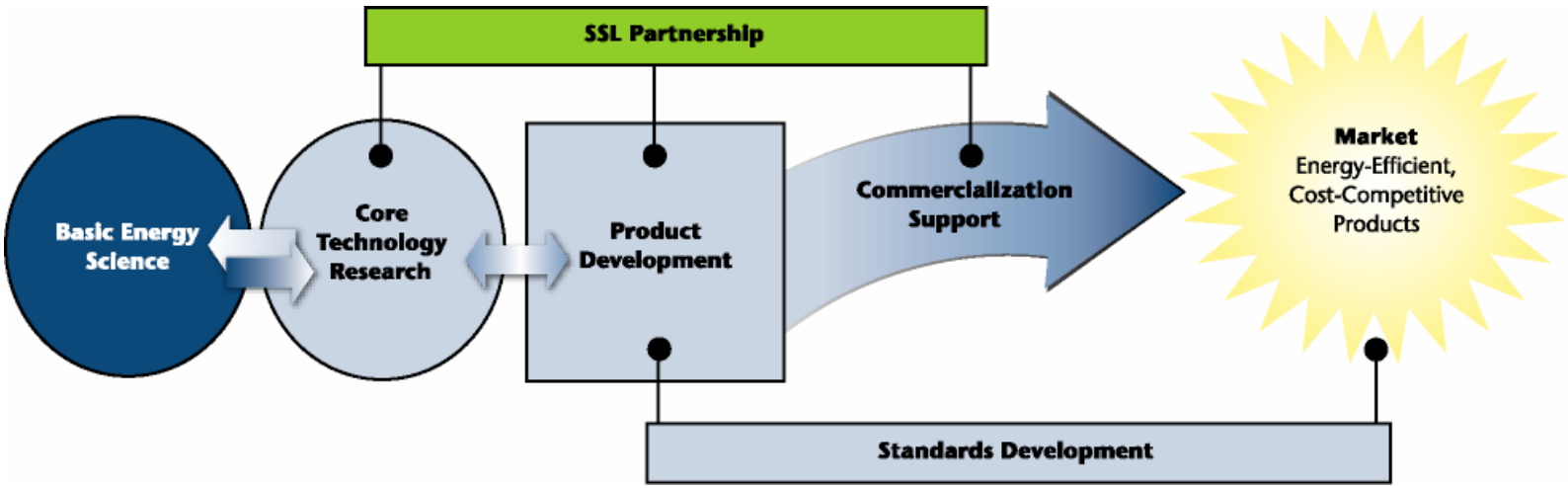
ZEH homes available now at high cost and only some climates. Goal is to make available to all Americans through technology breakthroughs and cost reduction.

Building America Program is marching towards ZEH for All Americans



Ultimate goal is a Zero Energy Home using cost effective tools, techniques and integrated technologies, systems and designs for buildings that generate and use energy so efficiently that buildings are capable of generating as much energy as they consume.

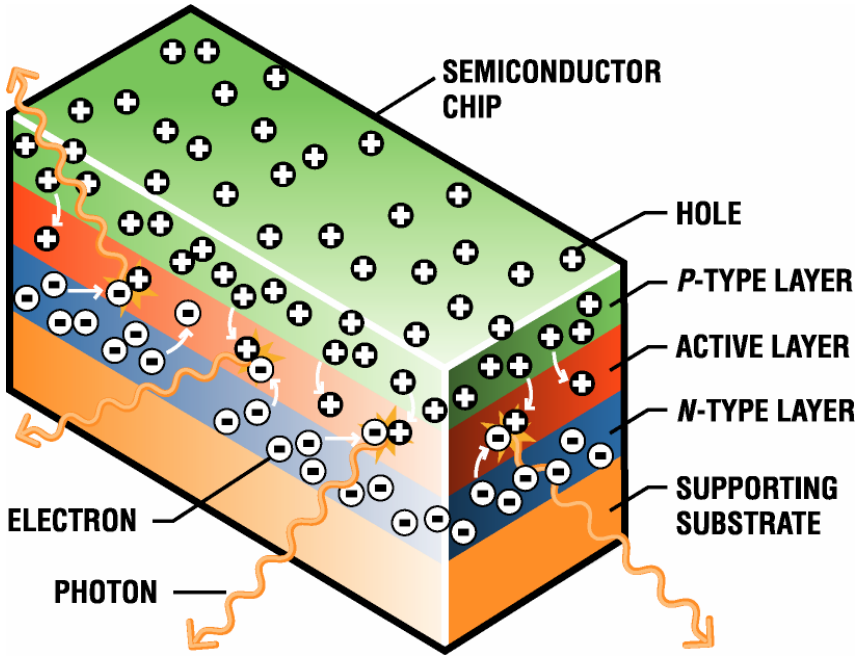
DOE Solid-State Lighting
5 Thrust – Total Program



Guiding technology advances from laboratory to marketplace

What is Solid-State Lighting?

- A semi-conducting device composed of layers
  - N-type layer (negative) releases electrons
  - Combine with “holes” from the P-type layer (positive)
  - Electron-hole pair recombinations produce photons, emitted from the active layer
  - Photon color depends on the chemical make-up of the active layers
- Two common types: Light Emitting Diodes (LEDs) and Organic Light Emitting Diodes (OLEDs)



Solid-State Lighting Today

- LEDs are commercially active in a limited market and limited range of applications (niche markets in general illumination)
- LEDs are cost-effective in colored-light applications
  - Exit signs, traffic signals, advertising signage, airport taxiway lights
  - Energy bill mandates LED exit signs and traffic signals
- LEDs are starting to compete in white-light applications
  - Airplane reading lights, directional / task lighting
- High-brightness LEDs represented ~$3.7 billion market in 2004
  - Top three applications are mobile appliances (40%), signs (23%) and automotive (18%)
- OLEDs focus on display applications and not general illumination

Source: Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications, Navigant Consulting, November 2003; KOPTI presentation 2004.

Examples of SSL Applications Today

©Dialight

©Lumileds

©Lumileds

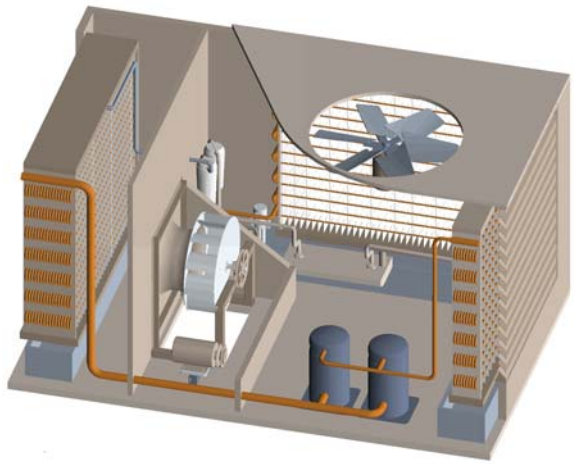
©Intercept Technology EVP

Potential Technologies of Interest

- Liquid Desiccant Air Conditioner
- Diagnostics for Heating and Cooling Systems
- Dimmable Ballasts for Fluorescent Lighting
- Solid State Lighting
- Advanced Windows

Integrated Liquid-Desiccant/Vapor-Compression AC

- **Problem:** Air conditioners (ACs) are very poor at controlling indoor humidity. High indoor humidity can create health problems and lead to growth of mold and mildew. Energy is wasted overcooling buildings to try to create comfortable conditions.
- **Description:** Incorporate advanced liquid-desiccant technology into an electric vapor-compression air conditioner that: (1) provides more than twice the dehumidification of a conventional system, (2) reduces compressor power by 24% or more, and (3) is easy to install on a residence or commercial building.
- **Impact:** High efficiency AC that also provides superior dehumidification would restore healthy indoor conditions while significantly reducing energy use. Independent control of temperature and humidity within homes would address problems of poor indoor air quality, mold and mildew growth, and the waste of energy from over-cooling. The technology also should be applicable to the very large market for commercial rooftop ACs.
- **IP position:** Owned by AIL Research, Inc.
- **Status:** SBIR Project
  - Phase I: Proof-of-Concept model of liquid-desiccant AC successfully tested
  - Phase II: Two-ton breadboard model designed and fabricated. Goals of doubling the dehumidification and decreasing compressor power by 25% (compared to conventional AC) successfully demonstrated.



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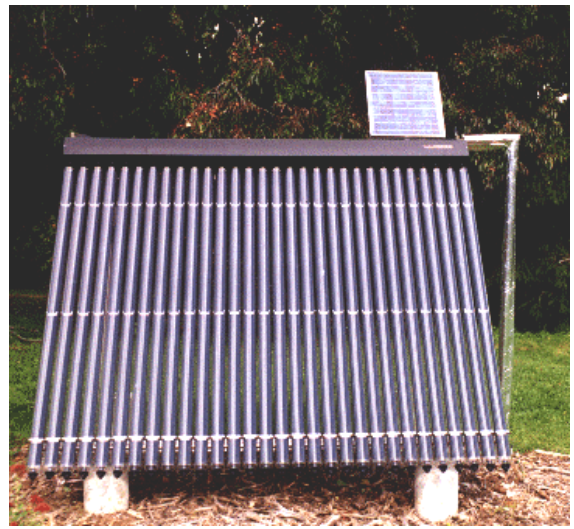
Integrated Liquid-Desiccant/Vapor-Compression AC

- Additional technical work is needed to map performance over all possible operating conditions. Also, manufacturable prototypes must be designed, fabricated and field tested.
- Earliest start of commercial sales for a liquid-desiccant/vapor-compression (LDVC) product would be 2009 or 2010.
- The LDVC air conditioner is expected to have a slightly lower cost (e.g., 15%) to manufacturer than other air conditioners that are designed specifically for humidity control. It will be able to be sold for a premium since it will have a moderately higher efficiency.
- Compared to other air conditioners specifically designed for humidity control, the LDVC air conditioner will have lower operating costs and a smaller size.
- Important early market is high growth HVAC market for Dedicated Outdoor Air Systems (ACs dehumidify and cool ventilation air in humid climates). Specific applications include natatoriums, health care facilities, theaters, supermarkets and where either large amounts of fresh air required or the humidity must be controlled to low levels.
- U.S. sales of air conditioners that specialize in humidity control is now estimated at $300M/year with significant growth. Most sales are in humid eastern half of U.S.
- AILR now looking for a manufacturing partner for the LDVC air conditioner. Discussions in very early stage with one potential partner.
- The IP play will most likely be a joint venture with a manufacturing partner in which AILR stays closely involved with the initial set up of manufacturing facilities and the marketing/sales organization.

Solar Powered Liquid-Desiccant Heating/Cooling System

- **Problem:** Conventional air conditioning consumes a large amount of energy contributing to overloaded electrical grids, air pollution and global warming.
- **Description:** A solar-powered air conditioner, which runs on heat, that is exceptionally well suited to controlling indoor humidity
- **Impact:** A competitive liquid-desiccant air conditioner should significantly reduce energy use for cooling and reducing emissions of greenhouse gases and other pollutants. Technology should also allow our schools, homes, offices and other buildings to be better ventilated without the deleterious effects of high indoor humidity.
- **IP position:** Owned by AIL Research, Inc.
- **Status:** SBIR Project
  - Phase I: The solar liquid-desiccant air conditioner was designed and a strategy for its commercialization identified. Computer modeling showed that, with tax credits now available, the solar air conditioner could have a payback of less than ten years.
  - Phase II and III: Two on-going field tests in which liquid-desiccant air conditioners are running on heat provided by gas-fired water heaters will be completed in 2007. Demonstrations of solar cooling will begin in 2008.



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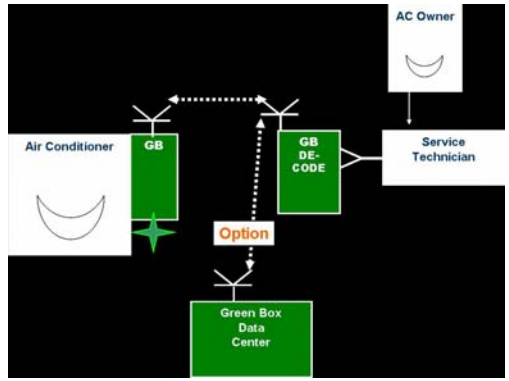
Solar Powered Liquid-Desiccant Heating/Cooling (LDAC) System

- No significant technical work needed to get to a marketable product.
- Limited commercial sales will begin in 2008.
- Conventional ACs that specialize on humidity control are ~$2,400/ton. Solar LDAC cost ~$5,500/ton w/o 30% federal investment tax credit, and $3,850/ton w/ credit. Higher first cost recouped in 6-12 years at today's energy prices.
- The value proposition to builders or owners is that it provides buyer with hedge against higher future energy costs and improves health and comfort through better humidity control and increased ventilation.
- Important early market is high growth HVAC market for Dedicated Outdoor Air Systems (ACs dehumidify and cool ventilation air in humid climates). Also regions w/ drier climates and high solar availability where LDAC can operate as desiccant assisted indirect evaporative cooler. If utilities allowed to meet RPS through reduced load, then solar LDAC could be part of utility programs.
- U.S. sales of ACs specialized in humidity control ~$300/yr w/ significant growth.
- Looking for manufacturing partner for LDAC (applied as either gas-fired unit or solar-powered unit). Discussions in very early stage with two potential partners.
- IP play will most likely be a joint venture with partner where AILR stays closely involved with initial set up of manufacturing facilities and the marketing/sales organization.

Advanced Onboard Diagnostics for HVAC Systems

- **Problem:** The majority of air conditioning systems are not installed or maintained correctly. Recent studies have shown that 60% of the systems are significantly deficient in evaporator airflow, refrigerant charge, or both. When duct efficiency problems are included, over 95% of the systems are running well below their design efficiency.
- **Description:** The device determines an air conditioner's performance and pinpoints corrective actions, directs a responding technician to the cause of the problem in plain English, and confirms that it has been fixed.
- **Impact:** The device is applicable to all residential and small commercial air conditioners. It can be applied in the factory, or retrofitted to existing equipment. The device also provides a ready platform for monitoring and reacting to pollutants important to building occupants.
- **IP Position:** Owned by Proctor Engineering Group.
- **Status:** SBIR Project
  - Phase I, determined the identification of that critical parameters of proper HVAC operation is possible with appropriate sensor elements. Updated algorithms for detecting air conditioner faults were generated from analyzing air conditioner data, and potential designs and costs were analyzed.
  - Phase II, developed and tested the device in residential and small commercial air conditioners. Final cost, ease of installation, ease of use, and reliability were determined to be satisfactory.



Diagnose,Correct, Confirm, and Monitor

The Green Box

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Advanced Onboard Diagnostics for HVAC Systems

- Saves time, detects faults before they are failures, reduces maintenance costs
- Adaptation to each manufacturer's capabilities is needed to get to a marketable product. Manufacturing partners sought.
- A product will be available in 6 Months to 1 Year.
- There is no conventional technology to compare against, except having a technician come out multiple times a year which cost about $100+ per visit. The retail for this device is estimated to be less than $400 as a retrofit
- California new construction is a potential early market
- Market size estimated at 133 million units in the US
- The IP play will be through licensing

Dimming Electronic Ballast (DEB) and Control Systems Coupled with Unique Power Line Communications System

- **Problem:** Daily and seasonal electricity demand (load) changes, planned and unplanned outages, and other factors impact electricity reliability and generation costs.
- **Description:** Distributed intelligent solution with ballast level sophistication, robust control system and PPLT power line communications for ease and efficiency.
- **Impact:**
  - Daylighting: Adjusting electric lighting levels in response to increased daylight levels
  - Task Tuning: Reduce electric lighting levels according to occupant preference
  - Scheduling: Automatically turnoff lights when space is vacant; building level control or occupancy sensors
  - Load Shedding, Demand Response: Reduce electric lighting levels in response to electric market signals
- **IP position:** Owned by Lumenergi.
- **Status:** Commercial Products
  - Dimming Electronic Ballasts (DEBs)
  - Lighting Management Control System (LMCS)
  - Passive Power Line Communications path (PPLC)

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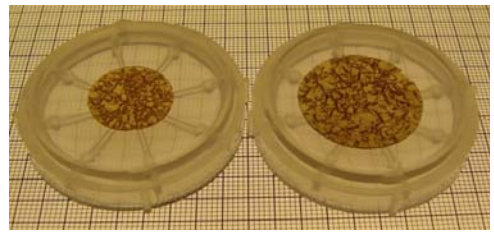
Dimming Electronic Ballast (DEB) and Control Systems Coupled with Unique Power Line Communications System

- Production engineering for mass production including tooling, cost reduction engineering is needed to get to a marketable product.
- Initial product in discrete version is available now – just received UL approval.
- Lumenergi product could cost as low as $20 to the user – competition $100 or more
- The value proposition to builders or owners is Very high ROI, low first costs (i.e. initial payback well under two years without utility or tax incentives) no maintenance, no liability
- The architectural dimming sub-market is ~$150M/year. Existing market is >$1B/year.
- The market size is 60-62 million new units, and 1.2 billion unit retrofit in the US. Worldwide market – 2.5 times US.
- Looking for trade allies and additional manufacturers. Currently have small manufacturing facility in China and plans for mass production with multi-billion dollar highly capable plants and vendor financing. Would like to speak with additional manufacturers in South America and EU if appropriate.
- The IP play will be to both license and manufacturer products. Software code is contained in a One Write Chip for additional IP protection, which is very difficult - if not impossible - to copy and allows us an extraordinary measure of control over the products.

Novel Growth Technique for Large Diameter AlN Single Crystal

- **Problem:** Nitride-based, high-brightness, ultraviolet, visible, and white LEDs are candidates for replacing incandescent and fluorescent lights in general illumination. Poor crystalline quality prevents higher efficiency from being achieved. Aluminum-nitride (AlN) single crystal has been shown to have the same crystal structure and a close lattice match to group III-nitride epilayers, and can be grown in bulk single crystal form.
- **Description:** This project will develop a novel, physical vapor transport (PVT) technique to grow large diameter, high quality AlN bulk single crystals, which can be used as substrates for the growth of high quality nitride LED epitaxial layers.
- **Impact:** Significant improvements in light output efficiencies have made GaN-based LEDs the most promising contender for future general illumination application. High brightness LEDs have tremendous energy saving potential, long life time, compactness, and potential cost savings.
- **IP position:** Owned by Fairfield Crystal Technology.
- **Status:** SBIR Project
  - Phase I, PVT technique for AlN single crystal growth studied extensively to understand effect of crucible/insulation set-up, used for PVT growth. Protective TaC coatings on graphite crucibles fabricated and tested, and crystal growth process developed, defects and impuritiescharacterized, and AlN crystal boules fabricated into wafers.
  - Phase II, Develop aluminum nitride substrates suitable for growth of high quality nitride epitaxial layers, leading to fabrication of high brightness LEDs for general lighting applications. AlN wafers and epi-ready AlN substrates will be fabricated from the aluminum nitride crystal boules. III-nitride epi-layers will be grown on aluminum nitride substrates, using a metal-organic chemical vapor deposition technique.



Polished Aluminum Nitride Wafers of 19mm And 27mm In Diameter

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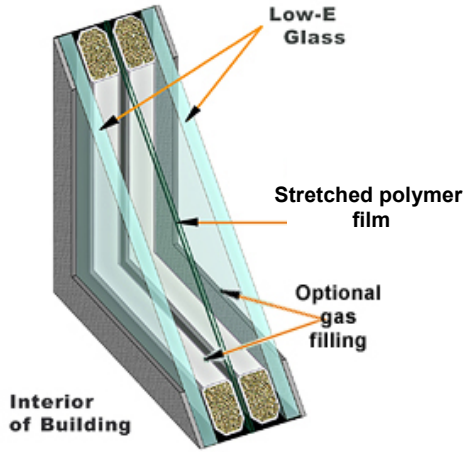
Novel Growth Technique for Large Diameter AlN Single Crystal

- Still need to increase the diameter of a single crystal area to a minimum of one-inch and reduce defect levels to get to a marketable product.
- Target is to introduce product by end of 2008.
- Cost at early stages is not the main driver because current technology has not achieved higher efficacy (150-200 lumens/watt) for general illumination. Aluminum nitride (AlN) as native substrate to gallium nitride (GaN) should be able to reduce defects as better “matched” substrate compared to current technology. Expect initial price premium in range of $4-$6K for 2” wafer.
- The value proposition to builders or owners is that AlN can provide greater price-performance characteristics for certain applications, in variety of technology fields. Increasingly greater performance demanded by end users and nearing limitations of other materials providing opportunities for AlN. Application of interest is high-performance LED markets; improved efficacy for general illumination. Additional applications include microcontamination detection, water purification, high frequency communication, scientific analysis and other areas.
- AlN as substrate for GaN epitaxial layers has direct application within high-powered RF devices, which traditionally build on silicon substrates. AlN has been demonstrated to be superior for deep UV light-emitting applications and may ultimately surpass silicon carbide in both cost and performance for high power RF - (AlN) is highly insulating which is attractive for high frequency devices.
- End users demand semiconductor devices that can achieve shorter wavelengths so as to move into cutting edge applications (UV and Deep UV LED). The more Al added to semiconductor, the shorter the output wavelength, but material becomes harder to grow and harder to flow electricity. Key step in achieving high power is getting high-quality growth at high Al percentages.
- Based on forecast demand for high-brightness LEDs, blue-violet laser diodes, and high-power, high-frequency electronic devices, demand for substrates for GaN devices expected to grow from $340m in 2006 to $880m in 2010. Advanced substrates such as GaN and AlN forecast to be >50% of market in 2010.
- Might consider an epi partner, but there is no need for a substrate manufacturer.
- The IP play will be to continue manufacturing substrates using patented technology.

Highly Insulating Windows: Multiple Glazings and Coatings

- **Problem:** Windows influence 20-50% of building energy use, Low-E coatings revolutionized markets in 1980s but now "stuck" at that performance level.
  - Current product sales ~ $40B/yr US; (x5 globally)
  - Current U.S. annual heating energy cost ~$30B/yr
  - New generation of technologies needed for heat loss reduction; potential to create "zero net energy windows"
- **Description:** Goal is to create a highly insulating product that can become a mainstream product in most U.S climates.
  - Near term solution for cost-effectiveness
  - Multiple glazing layers, including rigid plastic or thin glass center layer
  - Low-E coatings with optimized optical properties
  - Low conductance gas fills, e.g. krypton to reduce gap size
- **Impact:** This technology package could effectively reduce the $30B cost to "0" while providing purchasers with significant economic and related benefits
  - Energy and peak demand savings
  - Smaller heating and cooling systems
  - Electric load peak benefits
  - Occupant comfort and amenity with large windows; occupants want views



Existing Highly Insulating Windows perform well but have captured only minimal market share; challenge to provide higher performance at lower cost.

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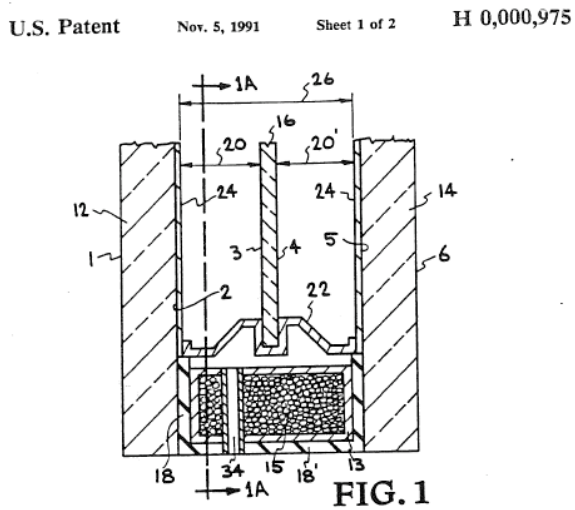
Highly Insulating Windows: Multiple Glazings and Coatings

- **IP position:** LBNL published basic approaches in 1990s so cannot be controlled by others; opportunities for new IP for manufacturing process
- **Status:** Basic concepts proven with extensive simulation and lab testing of prototypes.
  - Builds on existing underlying low-E technology and gas fills so minimizes risk and start up costs
  - Needs materials and design optimization with manufacturing cost in mind
  - Lab prototypes of new solutions exist; new investment could accelerate progress to market; market advantage to first mover
  - Interest from window manufacturers if cost and performance target met



Novel concept increases performance at lower cost

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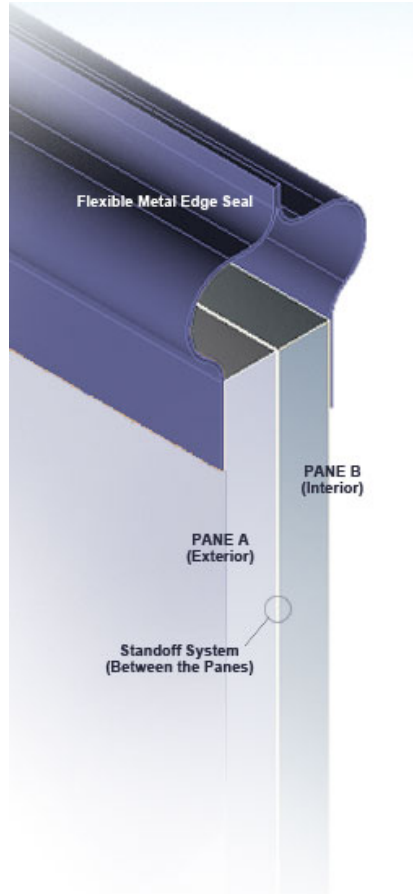
Highly Insulating Windows: Multiple Glazings and Coatings

- Engineering development to minimize manufacturing costs is needed to get to a marketable product. Additional materials for use as rigid center. Some window manufacturers may redesign frames to go with the improved glazing.
- A product could be brought to market in 12-18 months
- The projected cost would be an additional $3-$5/sf for insulating glass unit; this new glazing could add 10- 25% to cost of complete window.
- The value proposition to builders or owners is: saves energy, reduces peak demand, reduces heating and cooling system size and simplifies system - e.g. not necessary to run ducts to the perimeter of the building. Ability to place windows on "bad" side of a house, e.g. north; possibly better acoustics.
- Initial Markets: High end housing which values quality of space and indoor environment, owners wanting a "green home", off-grid or zero energy home, ~50% of windows sold are for replacements and could provide good market opportunities since owner is often directly involved in the decision making. If EnergyStar tightens its requirements and becomes effective in 2009 this could also move the early market.
- Potential market is very large if cost is low enough, e.g. in the US: 50 million units per year for residential; more for commercial. Initial markets probably in cold northern and north central, (Plus all of Canada) but hot sunbelt, e.g. Arizona, Las Vegas may be good markets also.
- Need a manufacturing partner: investor could develop new manufacturing company or partner with existing insulating glass manufacturer or with key supplier of components. Also need to sell to or partner with a window manufacturer to incorporate the insulating unit in the frame; window manufacturer could play a role in manufacture of insulating glass unit as well.
- Basic thermal engineering design was initially published and made public so that it could not be captured by any single firm. Stronger play may be development and patenting of novel manufacturing processes
- A related opaque insulating material, gas filled panels, based on this glazing work, was patented and licensed to several firms making building insulation and insulation for shipping containers.

Highly Insulating Windows: Vacuum Insulated Glass

- **Problem:** Windows influence 20-50% of building energy use. Low-E coatings revolutionized markets in 1980s but are now "stuck" at that performance level.
  - Current product sales ~ $30B/yr US; (x5 globally).
  - Current U.S. annual heating/cooling energy cost lost through windows~ $60B/yr.
  - New generation of technologies needed for heat loss reduction; potential to create "zero net energy windows"; or even "positive net energy windows".
- **Description:** Goal is to create a highly insulating product that can become mainstream in most U.S (and world) climates.
- **Impact:** This technology package could effectively reduce the $60B cost to "0" while providing purchasers with significant economic and related benefits.
  - Windows with ESW's VIGs become extended-life appliances, lasting for 40 years.
  - Significant energy savings are produced, full-proof and the over the long haul.
  - Smaller heating and cooling systems are possible, lowering building construction costs.
  - Peak energy demand loads are reduced across US.
  - Occupant comfort and large window amenities are enhanced – occupants want views.



A Vacuum Insulating Glass Unit (VIG) comprises two panes of glass separated with spacers and sealed at the edges.

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Highly Insulating Windows: Vacuum Insulated Glass

- **Status:**
  - **Completed Technology Development:** Flexible Gas-Tight Metal Edge Seal that moves like an accordion, allowing the individual panes of a VIGU (or non-vacuum IGU) to expand and contract independently, in response to different – and changing – inside and outside temperatures.
    - This revolutionary design improves the reliability and durability of window seals significantly while providing high thermal resistance.
  - Metal-to-Glass Diffusion Bonding Process that creates truly hermetic, permanent seals.
  - **Work in Progress:**
  - Nearly invisible Standoff System maintains consistent separation of panes in VIGU.
  - Design and specifications for a full-scale turnkey production line (equipment and processes) required by licensees manufacturing ESW's VIGUs.

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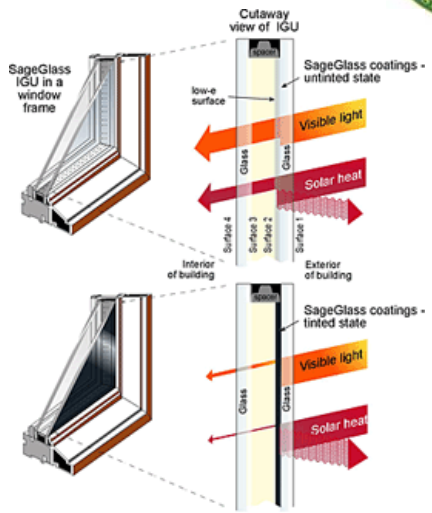
Highly Insulating Windows: Vacuum Insulated Glass

- At least one year of concentrated technical work is needed to get to a marketable product. Have demonstrated hermetic glass-to-metal bonding for the “bellows” but need to develop the glass stand-off system, demonstrate durability and reliability, assemble residential-sized VIGs and perform rigorous accelerated testing of performance and reliability.
- A product will be available no sooner than mid-2009, but most realistically, late 2009 to early 2010.
- Residential gas-filled IGs cost about $3.50 per square foot to manufacture; VIG will cost about double.
- The value proposition to builders or owners is reduced energy costs, fewer drafts and ‘cold spots’, enhanced occupant comfort, increased useable floor space, long-term clarity, noise reduction, larger window areas, more natural lighting, improved productivity, extended lifetime.
- U.S. market is anywhere insulating windows or insulating glass doors are used (~$30B/yr) with IG accounting for ~10% of manufacturing cost of window. Extrapolating, IG’s ~$3B/yr.
- Market for VIG is anywhere where there are differences between desired indoor temperatures and actual outdoor temperatures. For U.S., this is most of the continental U.S. and Alaska. Payback period would be excessive for Southern California, but less than 3 years for most of the U.S. The greater the outdoor temperature extremes and the higher the energy costs, the faster the payback.
- Have initiated discussions with IG manufacturing line integrators offering an exclusive for the production equipment which would allow Everseal a way to control the process/product quality for several years and a built-in system to meter the production output of every licensee.
- We intend to license our IP to the maximum number of IG producers, both domestic and foreign.

Electrochromic Windows

- **Problem:** Windows influence 20-50% of building energy use, Low-E coatings revolutionized markets in 1980s but now "stuck" at that performance level.
  - Current product sales ~ $40B/yr US; (x5 globally)
  - Current U.S. annual heating energy cost ~ $30B/yr
  - New generation of technologies needed for heat loss reduction; potential to create "zero net energy windows"
- **Description:** Electrochromic (EC) glass is electronically tintable glass that can be switched from clear to darkly tinted (and from darkly tinted to clear) at the push of a button. EC glass can be operated manually or integrated into an automated building management system.
- **Impact:** In contrast to traditional fixed "static" windows, EC smart glass can be either automatically or manually adjusted as desired: darkened to minimize solar heat gain in summer (while still preserving the external view) and lightened to a near-clear state to augment residential heating in winter and provide natural lighting year round. By regulating solar heat in this manner, EC smart windows can reduce the demand for building heating and cooling energy and lower peak electricity demand in most parts of the country
- **Status:**
  - SAGE, founded in 1989, opened its first commercial production facility in 2005 and currently manufactures EC smart glass under the SageGlass® brand, for sale to select window and skylight OEMs.
  - SageGlass products are currently available in dimensions up to 42.5" wide (or tall) and 60" tall (or wide)



Layers of metal oxides are applied to cnventional glass and then fabricated into an insulating glass unit (IGU).

Windows darken when voltage is applied

Neil	Sbar	SAGE Electrochromics, Inc.
(507) 331-4904	nsbar@sage-ec.com	

Electrochromic Windows

- SageGlass has been in the market since 2004, today we are growing production capacity and market awareness and presence.
- The product is on the market now, and highly competitive at volume production
- The value proposition to builders or owners is energy saving and glare control without loss of view.
- Markets are in both commercial and residential construction windows, as well as certain transportation window applications.
- The glass and window industry is a large global business
- SAGE is in discussions for expanding both production and distribution.
- SAGE has large and strong IP position as well as growing portfolio of manufacturing trade secrets.