Ahmed Shuja (above) and Praveen Medis (center) have developed the world's brightest LED source (left). Rated at 15,000 lumens, it not only outshines metal halide lamps, but uses 60 percent less energy.

From Concepts to Companies

Siemens' Technology-to-Business Centers are providing support to a range of young companies. On tap are energy-stingy LEDs capable of outshining metal halide lamps, PV panels that use one tenth the silicon of conventional models, battery-powered vehicle detection systems that last ten years, and an ultra-efficient transmission.

Light emitting diodes (LEDs) have a reputation for running cool. Touch one and all you'll feel is a serene glow. But just try and pack dozens of them together in a tight space and they'll get so hot that they can burn out within seconds. Now, however, Progressive Cooling, a startup company funded by Siemens' Berkeley, California-based Technology-to-Business Center (TTB), has developed a solution that makes it possible to pack over 80 of the brightest white LEDs onto a one-square-inch circuit board. The result: A light source significantly brighter yet far more energy efficient than the metal halide or sodium lamps now used to light factories, warehouses, streets and airport runways. "In the U.S. alone there are about 100 million so-called 'high-bay' fixtures in commercial buildings and about 60 million bulb changes per year," explains Progressive Cooling CTO and founder Dr. Ahmed Shuja.

The technology that allows tightly-packed LEDs to keep their cool is a patented micro thermal management engine that contains some 60 million vertically-etched uniform pores per square centimeter on a flat silicon substrate. The technology allows capillary force to efficiently channel heat away from diodes and into a halo of fins that surround Progressive Cooling's light source.

Originally developed at the University of Cincinnati to reduce the cooling requirements for microchips on miniature satellites and subsequently adapted to server farms (see *Pictures of the Future* Spring 2008, page 22), Progressive Cooling's concept has been "re-vectored to the LED market to take advantage of the fact that a totally integrated LED fixture will have significant competitive advantage in the commercial illumination market over traditional metal halide bulbs," says Shuja.

Based on Osram's newest Oslon LED, which can be driven to produce up to 200 lumens, Progressive Cooling's new device delivers some 15,000 lumens over an 80-degree angle from a height of 18 to 30 feet, resulting in an ideal 30 foot candles on the work surface. "To put that in perspective," says Progressive Cooling Senior Scientist Dr. Praveen Medis, "a 100-Watt incandescent bulb typically produces 1,200 lumens. So what we are saying is that we have packed the equivalent of twelve100-watt bulbs into a flat one-square-inch device, making it the brightest LED source in the world."

In addition, the device cuts energy demand by 60 percent compared to conventional metal halide lamps, and, thanks to the fact that it can be addressed wirelessly and dimmed from zero to 100 percent, its power demand can be reduced by an additional 20 to 25 percent in response to changing lighting requirements.

Reduced maintenance costs are another major advantage. While metal halide lights typically last 12 to 18 months, Progressive Cooling's device is rated to last five years and has been designed to screw into an existing mount. "That's a key feature," says Shuja, "because changing high-bay lights at a height of 18 feet requires a scissor jack and two experienced workers." Plans call for Progressive Cooling to begin seeding the market with its mercury-free LED product this year.

Banyan: Focus on the Sun. Probably the biggest barrier facing widespread implementation of photovoltaic energy is the high cost of silicon panels. With this in mind, five former graduate students of the University of California at Berkeley and Stanford University have formed Banyan Energy, a company whose patented technology and proprietary intellectual property promise to reduce the area of silicon photovoltaic material in a standard module by 90 percent while producing the same amount of power as a conventional module. What's more, the inventors calculate that the cost of production facilities for such modules will be 75 percent lower than for today's facilities.

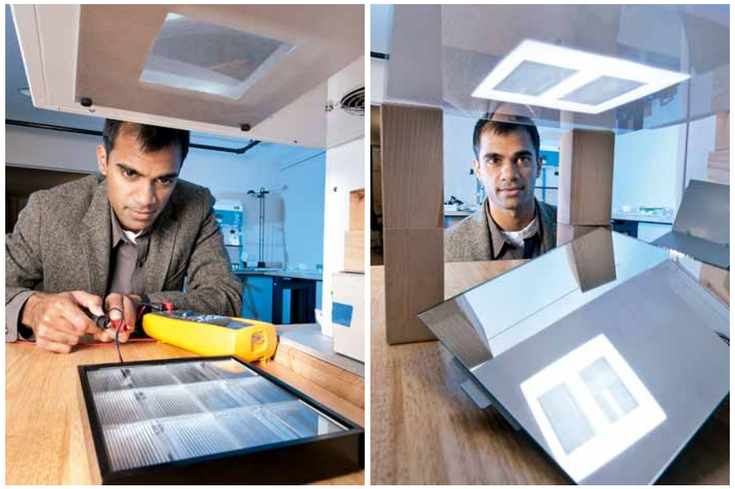
Funded by an investor group led by Siemens, the company has been selected by the U.S. Department of Energy for a technology development subcontract and is already working with the U.S. National Renewable Energy Laboratory. "Siemens TTB not only invested in us from the start," says Banyan CEO Shondip Ghosh, "they really drove the process and did the due diligence." Adds Ayman Fawaz, PhD, Director of Venture Technology at TTB Berkeley, "We are helping Banyan demonstrate that their technology is viable. The next step will be to see if Siemens' solar organization will adopt the technology." Simply put, Banyan's concept is to replace expensive silicon cell material with economical optics. Ghosh explains that while many other companies have attempted to adapt clumsy magnification systems to PV panels, Banyan's "aggregated total internal reflection" concept uses a sheet of optical elements that is only 1 cm thick.

"The energy falling on the optics is aggregated and delivered to a focal area, which is where the photovoltaic material is located. The key is that the collection process is performed by the optical layer rather than by the silicon cells," says Ghosh.

> The brightest LED source worldwide, the device packs the equivalent of twelve 100-watt bulbs on one square inch.

Since the technology can be integrated into the standard dimensions of current PV panels, it offers numerous downstream advantages, including identical shipping, handling, installation, and cleaning requirements. But perhaps its greatest advantage is that it reduces the capital expenditure of manufacturing the panels themselves. Today, such panels are covered with silicon wafers. The wafers are sliced from ingots and then processed and mounted. "To build a conventional fabrication facility with a

Banyan CEO Shondip Gosh measures the efficiency (left) and response to different angles (right) of an optically-based photovoltaic module in a device that duplicates sunlight.



gigawatt worth of annual production capacity, you would have to spend about $1.2 billion," says Ghosh. "But with our system you can shrink your plant size for the ingot, wafer and cell steps by a factor of ten. As a result, a gigawatt facility would now cost only about $300 million. So we can significantly reduce the capex for manufacturing, which means that for every dollar such a company invests, they can build four times the production capacity as they otherwise would."

Banyan is particularly interested in entering the market for large field installations that are designed for tracking the sun – an application that maximizes the yield from its unique optics. "Installations that track the sun produce about 25 percent more energy than static installations," says Ghosh. "This more than offsets the added cost of tracking systems. What's more," he adds, "the growth rate in large field installations is twice the rate of the rest of industry." The world market for solar panels is now at five gigawatts per year and rising rapidly.

Sensys: A Startup Hits the Road Running. Two of the hard facts of modern life are that traffic congestion is rising but road capacity is not. In order to make the best of this situation, Sensys, a mature startup with close ties to Siemens, which is headquartered in Berkeley, California, has developed a unique magnetic sensor technology that helps road authorities continuously and reliably detect traffic levels in real time.

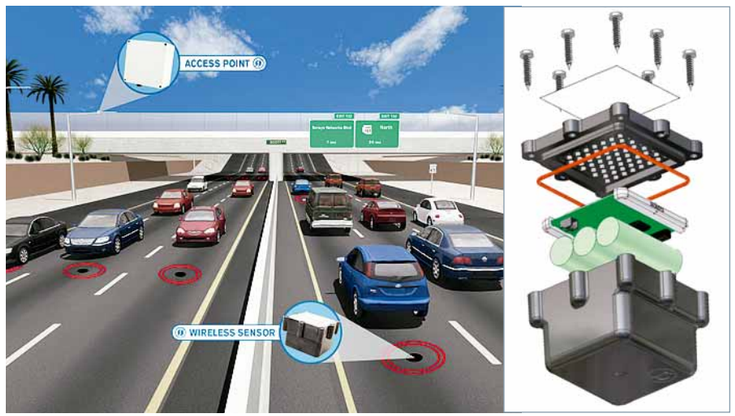
At the heart of the company's sensor is the ability to extend the lifespan of three AA batteries to ten years. "That is essential, because once the device is in the pavement, it is difficult to access," explains CEO Amine Haoui, PhD. Adds Sensys Vice President for Marketing Floyd Williams, "In terms of low power sensing and battery life, I don't think there is another application anywhere that comes close to what we have achieved."

The key to such extended battery life is, in principle, disarmingly straightforward. Most of the sensor circuitry is technically asleep 99 percent of the time. But each time a vehicle passes, thus disturbing the earth's magnetic field, the sensor wakes up, wirelessly transmits a packet of information to an access device, and goes back to sleep. Two sensors are embedded in each lane, and over eight sensor-equipped lanes can communicate with the same access point. Typically mounted on a lighting mast, the access device, which includes a mini Linux computer outfitted with a radio receiver and transmitter, relays speed, traffic volume and density information via the Internet or Ethernet to a centralized location. The data can be used by highway authorities to optimize roadway planning and performance through signal optimization, ramp metering or road pricing. In the near future it may also be used to provide real-time information for maps and automotive navigation systems.

Unlike inductive loops that are stretched across roads, either on the surface or in the pavement and which are prone to break at the weakest point in a line, Sensys wireless sensors are point devices that are buried beneath the road surface, are weatherproof, sterile, and maintenance free.

In view of the fact that Sensys vehicle detection systems are very cost effective when compared with inductive loops, governments around the world are installing the systems. Caltrans, the California Department of Transportation, has deployed 800 Sensys traffic monitoring stations on California freeways. And in Melbourne, Australia, a 75-km stretch of freeway has been equipped with groups of the sensors at 500-meter intervals. The sensors are used to control ramp meters and lane speed gantries. "The local transportation authority has shown that the system reduces the number of accidents, increases safety and improves freeway throughput by about 30 percent. So it is a dramatic improvement, especially when you consider the total cost of a multi-lane freeway," says Haoui.

Siemens, which provided Sensys' first source of finance through the TTB, is now integrating the company's wireless sensor with its family of traffic light controllers. The first such combined controller-sensor system is now being installed in Minneapolis, Minnesota. "This will be a very advanced adaptive signal system that will use an algorithm called SCOOT to optimize traffic performance around the city's new stadium," says Haoui. "With SCOOT, our sensors collect data at each intersection and feed it to a Siemens centralized system that creates a web of optimized traffic lights. If a city were to replace all its traditional time-of-day signal timing with such a system, it could expect a 20 to 30 percent improvement in traffic flow efficiency and a corresponding reduction in vehicle-caused emissions."



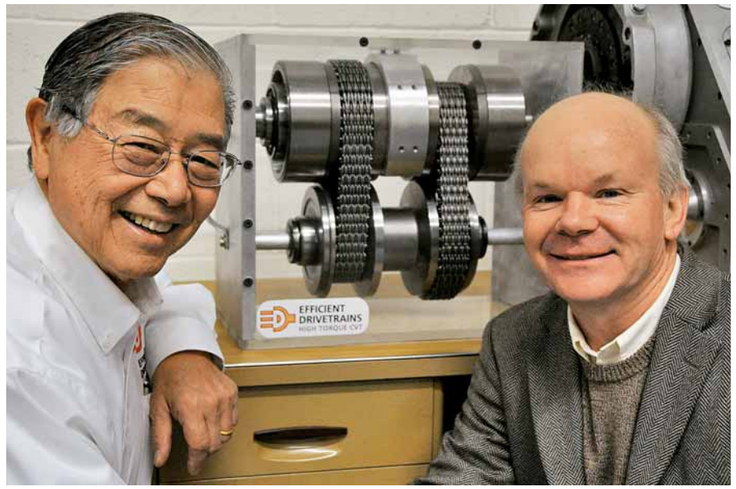
Thanks to an advanced sleep mode, Sensys traffic detection devices work for ten years on three AA batteries.

EDI: More Power for Hybrid Vehicles. Prof. Andy Frank's laboratory in Dixon, California looks a lot like the kind of place you'd take your car for a tune up. But the people who are driving in for service are not looking for spark plugs or an oil change, but rather to get an entire industry on the road. Otherwise known as "the father of the plug-in hybrid electric vehicle" (see *Pictures of the Future*, Spring 2008, page 22) Frank, who is Director of Hybrid Vehicle Research at the University of California-Davis and founder of Efficient Drivetrains, Inc. (EDI), has put together a test vehicle whose fuel economy is 80 percent better than that of a comparable conventional vehicle. It is also capable of operating all-electrically for about 70 km without using any liquid fuel. "As a result," says Frank, "with gasoline priced at roughly $3.00 per gallon and electricity at about 10 cents per kilowatt-hour, a typical user would pay about 75 cents per gallon-equivalent when operating our vehicle electrically."

Behind EDI's results is a continuously variable transmission (CVT) protected by multiple patents that is smaller, lighter, and considerably more efficient – 96 percent – than any other CVT or automatic transmission. Part of the reason for this is that EDI's CVT uses only 60 parts, compared to up to 2000 parts in a conventional 7 to 8 speed transmission; the other is that it is based on a patented chain from a European partner that transfers power with extreme efficiency from the motor (be it electric or conventional) to the rest of the drive train.

"An average automatic or manual transmission will have five to seven speeds," says Frank. "But ours has an infinite number of gearing ratios." He explains that this is particularly important for hybrid vehicles "because electric motors are designed to operate at high torques and speeds. But by adding a transmission, you expand the torque-speed range, meaning that the motor can operate at maximum efficiency across a much wider spectrum of load conditions."

Prof. Andrew Frank (left) and Jörg Ferchau have developed a continuous variable transmission based on a patented chain. Using only 60 parts, the transmission is ideal for electric motors.



Working closely with Siemens' Technology-to-Business Center in Berkeley and with Siemens' Drive Technologies Division, EDI has steadily harmonized its transmission to become an integral part of a drivetrain for hybrid and electric vehicles that can be easily scaled up or down in size depending on a manufacturer's requirements.

"We expect that our collective research will result in a Siemens electric motor and EDI continuous variable transmission that can be sold as one, integrated package," says EDI CEO Joerg Ferchau. "We estimate that our package will cost one third less than a motor and a conventional transmission in hybrids and electric vehicles."

Although applicable to the automotive market, EDI's technology is initially being focused on the needs of the light- medium- and heavy-duty hybrid commercial vehicle market, which includes everything from delivery trucks and airport shuttle vans to hybrid buses and excavators. "Our CVT is rated at 220 kW, which makes it one of the biggest around. But it can easily be scaled up to 1,000 kW," says Frank.

■ *Arthur F. Pease*

TTB China: Affordable LEDs

Most consumers are comfortable with the look and feel of incandescent bulbs, but would like them to consume much less power. Light emitting diodes (LEDs) placed inside a conventionally-shaped bulb could offer a solution. With a view to eventually providing an affordable product along these lines for the vast Chinese market, Siemens' Technology-to-Business Center (TTB) in Shanghai has extended its "outside-in-innovation" strategy to include potential suppliers. Traditionally, outside technologies are spun in to Siemens business units. The new idea is to spin-in external technologies to suppliers. "By doing this, we believe we can overcome any technology gaps while leveraging the cost-innovation strength of local suppliers to accelerate the launch of a Siemens product with the right performance at the right price," explains Shih-Ping Liou, who heads TTB China. Concretely, TTB China is working with Siemens' Osram lighting subsidiary's procurement and R&D organizations to create a consumer LED product in China that can be made for about 25 percent less than Osram's current offering. "To help Osram accomplish this, TTB scrutinized the technology of five short-listed suppliers. Specifically, we looked at the connections between what Siemens wants to achieve and what the short-listed suppliers can offer," says Liou. "We then looked for external technologies and worked with Osram's R&D people in the Asia-Pacific region to come up with new design options to balance performance with cost." The next step, he says, "will be to optimize the new designs and spin the final blueprints to the selected supplier."