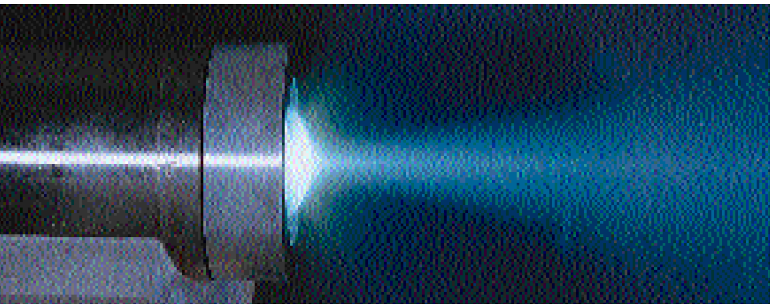
Cold Plasma Thin Films

André Anders, a research physicist at the Lawrence Berkeley National Laboratory, has developed a low-energy plasma source that has the potential for depositing amorphous or crystalline thin films on materials as diverse as silicon wafers and plastic sheets. Working with Michael Rubin and Michael Dickinson, Anders has demonstrated several versions of a constricted-plasma source that can ionize almost any gas at low or high pressures. Typical ionic energies are on the order of a few electron volts, which allows the formation of high-quality crystalline films that other plasma sources cannot produce directly.


Lawrence Berkeley Lab.

"The design is beautifully primitive," says Anders. The device consists of a pressure chamber with fittings for gas, electricity, and cooling water. The electric current and the gas are both forced through a narrow constriction, which can be a single hole or a series of holes in the plate between the cathode and anode. The anode can be located next to the constriction or farther away. If the target substrate is conductive, it can serve as the anode.

As pressure builds in the chamber, free electrons collide more frequently with the gas molecules to produce a low-temperature plasma. The electrons stream through the constriction toward the anode, causing additional ionization of the gas at the constriction; some of the plasma near the constriction is blown toward the target substrate.

"The plasma source can use virtually any gas," Anders says. For instance, it could be used to implant nitrogen ions in lithium for use in batteries, or assist molecular beam epitaxy in the formation of gallium nitride diodes that emit blue light. One version of the constricted plasma source is a thin long tube that fits into a standard molecular beam epitaxy vacuum chamber. Another possible application is depositing thin layers of indium tin oxide, a transparent conductor.

The low-energy plasma source can be used to form metallic oxides on other materials, including plastic film. A particularly promising application is the deposition of thin layers to produce variable-transparency, electrochromic glass at near room temperature. The process now requires heating the glass to 400° C. A glass manufacturer is testing a version with a number of discharge cells in a row. Several other companies are investigating the possibilities of the constricted plasma device.

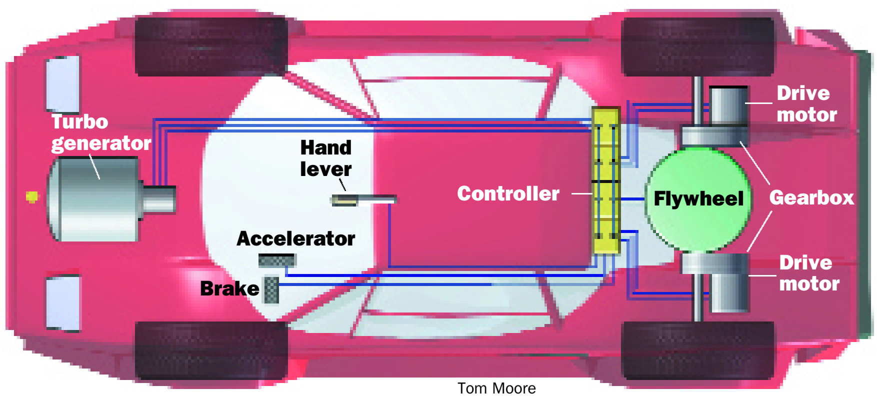
Another group at LBL, headed by Ka-Ngo Leung, has developed a radio-frequency ion source for the manufacture of flat-panel displays and semiconductors. The system selectively ionizes gases and creates a large-diameter beam from a small diverging beam.

Flywheel Technology

Angular momentum is a familiar concept to physicists, and in the next decade or so, it may also become a very profitable one for the promoters of flywheel energy storage—if they succeed in commercializing their new ventures. Flywheels are being considered for a surprisingly diverse range of applications. The most publicized is their use in hybrid electric vehicles and as auxiliary power sources for businesses and essential service providers such as hospitals and telephone systems. Flywheels are under study as well at the Argonne National Laboratory to power railroad locomotives, barges, and ships, and utilities are exploring flywheels to store energy to meet peak demand for electricity. The U.S. Army is testing a 5-kW flywheel system from Aura Systems, Inc. (El Segundo, CA), as an auxiliary ac and dc power source for its four-wheel-drive Hummer vehicles. Lawrence Livermore National Laboratory is seeking sponsors for its electromechanical battery technology, and Oak Ridge National Laboratory is applying its experience in developing high-speed gas centrifuges for uranium enrichment to the manufacture of flywheel components with very high tensile strengths.

In space, flywheels will likely replace batteries one day because they are lighter and can store more energy, and the momentum of the flywheel can be used to control a satellite's attitude. SatCon Technology Corp. (Cambridge, MA) is building a three-flywheel prototype system for testing by the U.S. Air Force Phillips Laboratory at Kirtland Air Force Base, New Mexico. NASA's Lewis Research Center is putting together a flywheel experiment for testing aboard the Space Shuttle, and the agency even predicts that flywheels in the future will supply peak electrical power in airplanes.

The space agency and the U.S. Department of Energy (DOE) are co-sponsoring a research program called Solar-Spin to demonstrate how flywheels can store electrical ener-



Tom Moore

gy from solar panels. Other organizations are designing hybrid wind-solar-diesel-flywheel systems for generating electricity at remote sites, such as in developing countries.

DOE says it wants to put hybrid electric vehicles (HEVs) on the road in the United States by 2003. It is funding the production of HEV prototypes by Chrysler, Ford, and General Motors, each of which is supposed to deliver its first model next year. The HEV Propulsion Program is managed by the Midwest Research Institute (Kansas City, MO) through its National Renewable Energy Laboratory (Golden, CO).

A company that has not sought government funding, however, may be the leader in developing a market-ready HEV. Rosen Motors (Woodland Hills, CA) is developing a flywheel-turbine power train that will accelerate an automobile from 0 to 60 mph in under 7 seconds, offer double the gas mileage of today's cars, and emit virtually no pollutants. The company has formed a subsidiary, Capstone Turbine Corp., to manufacture its highly efficient MicroTurbines and market turbine-flywheel power generation systems directly to other companies. It has sold some units to Ford for its HEV project.

Rosen Motors is a privately held company founded by Benjamin M. Rosen and his brother Harold. Ben Rosen is a founding investor and chairman of Compaq Computer. His venture capital firm, Sevin Rosen Funds, has financed more than 80 start-up companies, including Silicon Graphics, Lotus, Borland, and Cypress Semiconductor. As a vice president at Hughes Aircraft, Harold Rosen led development of the geostationary satellite. The stated goal of Rosen Motors is to manufacture the RosenTurboFlywheel (RTF) power train and form a strategic relationship with one or more major automakers and have them integrate the power train into their vehicles.

Other companies such as SatCon Technology are preparing to compete with Rosen Motors and Capstone. SatCon, through its Beacon Power Corp. subsidiary, is also commercializing flywheel energy storage for terrestrial, uninterruptible power. In September, Active Power, Inc. (Austin, TX), made available a flywheel energy storage system called CleanSource, which provides on-site back-up electrical power in place of batteries or standby generators.

High-IQ Highways

This summer, several convoys of "smart cars" drove themselves down a 7-mile stretch of I-15 just north of San Diego. The demonstration was not an engineering test but rather a staged show for the media. One "platoon" of eight cars traveled as a unit, accelerating, braking, and even swerving together in unison. On the automated highway, passenger-drivers in these cars were free to work, read a newspaper, watch TV, or play with their computers.

The smart cars in the platoon tailgated, staying about one car length apart by using radar and digital radio communication. They centered themselves on the lane by following magnets placed 1 meter apart. These simple tasks required two separate computers in each car.

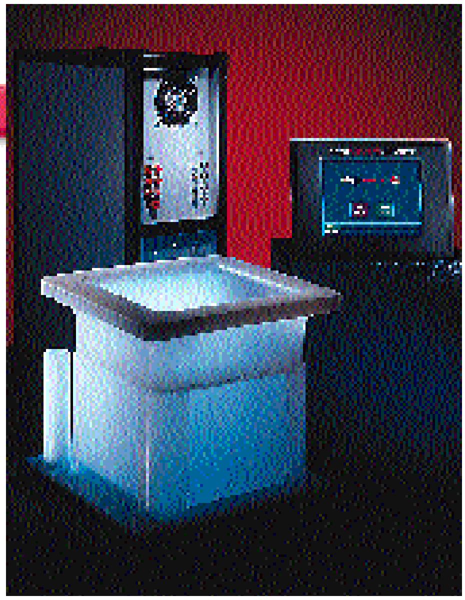
Two cars that coupled human drivers with intelligent-driver support systems also were demonstrated. These vehicles warned drivers when they drifted from the center of their lanes, and laser distance sensors kept the cars a suitable distance from each other with automatic braking or acceleration.

The sponsor of the I-15 smart car demonstration, the joint industry-government National Automated Highway System Consortium (Troy, MI), sees it as a major milestone in its program to develop a working

Lockheed Martin IMS

model of an automated highway by the year 2002. A much broader program, Intelligent Transportation Systems (ITS), has received money for a number of years from the U.S. Department of Transportation and the Federal Highway Administration. The ITS program is a hodgepodge of technology projects such as centralized traffic control systems, advisory in-vehicle navigation systems, intelligent cruise control, automatic nonstop toll collection, and electronic identification systems for trucks. A report on intelligent transportation systems by the consulting firm of Frost & Sullivan lists more than 100 companies active in this market. Technology companies outnumber transportation companies on the list.

The most rapid adoption of "smart" technology is taking place in the trucking industry rather than in passenger vehicles. Today, trucks with a PrePass transponder can be weighed and have their state credentials checked electronically as they drive by checkpoints at highway speeds. Lockheed Martin IMS (Teaneck, NJ) developed and operates PrePass for HELP, Inc. (Phoenix, AZ), a nonprofit corporation that is working to implement electronic license plates for trucks nationwide. PrePass currently operates in parts of California, Arizona, New Mexico, and along stretches of I-75, which runs from Michigan to Florida. Similar plans exist for trucks crossing U.S. borders.



ProSys, Inc.

Radiation Detector

A handheld high-energy radiation detector that works almost as well at room temperature as nitrogen-cooled germanium or silicon detectors has reached the market from eV Products, a division of II-VI, Inc. (Saxonburg, PA). The portable detector opens up a variety of applications that are impractical with cryogenically cooled detectors, such as industrial and environmental monitoring in the field, medical diagnostics, and astrophysical gamma-ray detection from balloons and satellites. The International Atomic Energy Agency is evaluating the handheld detector for use during nuclear-safeguards inspections.

The coplanar grid detector (CGD) marketed by eV Products is based on a patented design, which eV licensed from the Lawrence Berkeley National Laboratory (LBL). Developed by Paul Luke, an LBL staff scientist, the detector utilizes two parallel interconnected electrodes on one face of a cadmium-zinc-telluride crystal and a planar contact on the other face. A technique called charge subtraction yields a signal that is insensitive to charge trapping. As a result, the CdZnTe detector can measure gamma rays and X-rays with energy resolution close to that of germanium and silicon detectors. Luke recently developed a smaller detector module using surface-mounted amplifiers.

Another feature of the technique is that induced charge signals can be used to determine the depth of the radiation interaction in the detector and the direction of the incoming radiation. This, in turn, gives the detector an imaging capability. According to Bruce Glick of eV Products, some researchers have begun testing CGDs in imaging applications such as a gamma-ray camera for nuclear medicine.

Other radiation detection devices from eV Products use CdZnTe crystals with more conventional planar and multipixel electrodes. For instance, the company has developed a handheld probe for use in cancer surgery in conjunction with tumor-seeking radioisotopes. The probe can be used both externally and internally during surgery to detect tumors in a patient. Ω

Megasonic Cleaning

Piezoelectric technology, developed by the U.S. Navy as an elegant part of its antisubmarine warfare effort, is being used by ProSys, Inc. (Campbell, CA), for the removal of contaminating submicron particles from semiconductor substrates. The company calls its method megasonics, a term chosen to distinguish its technology from conventional ultrasonic cleaning. The new ProSys Megasonics Cleaner is currently in use to clean such important high-technology elements as raw silicon, integrated circuits and masks, flat-panel displays, and hard disks and their read-write heads. The cleaning tank can hold a 300-mm silicon wafer or a substrate up to 14 × 14 in., and the company says the system can be scaled for larger substrates. Future applications envisioned by ProSys include the cleansing of optical elements and medical instruments.

Conventional ultrasonic cleaning typically operates at 20 to 350 kHz with continuous power input, which produces random, and occasionally violent, cavitation. The Megasonic Cleaner uses ceramic piezoelectric crystals composed of lead, zirconate, and titanate (custom-made by Channel Industries, Santa Barbara, CA), which generate frequencies of 700 kHz to 1 MHz. Switching the crystals on and off produces controlled cavitation and uniform waves that virtually eliminate the likelihood of detrimental surface damage caused by cavitation erosion. The pulsed input power also achieves greater acoustic power levels in the cleaning bath than continuous input at the same power. An automatic crystal-tuning feature of the ProSys Megasonics Cleaner returns each crystal to its natural frequency at the start of every cycle. Ω