Improving PECs: The platinum plan

Photochemists are searching for their "perfect 10" — a solar energy converter that operates at the 10 percent efficiency widely believed to be the minimum useful efficiency for such devices. Thus far in that search, researchers have been able to develop photoelectrochemical cells (PEC's) — one type of solar energy converter — with efficiencies of only around 1 percent. Now, Mark S. Wrighton and colleagues of the Massachusetts Institute of Technology in Cambridge — in research reported in the November PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES and at the recent American Chemical Society regional meeting in New Orleans — have demonstrated PEC solar efficiencies of around 3 percent.

A PEC is a device that uses light energy to drive a chemical reaction or produce electrical power. The type of PEC cell that Wrighton and co-workers have modified uses the light energy absorbed by a semiconductor electrode immersed in an electrolyte solution to split water (H_2O) to produce hydrogen (H_2). PEC's eventually may be able to use sunlight to produce hydrogen fuel from water.

Previous work in Wrighton's laboratory demonstrated that hydrogen evolution is the step that limits the efficiencies of these cells. Improving efficiencies, therefore, meant finding a way to catalyze, or accelerate the rate of, that hydrogen-generating step. So Wrighton and colleagues designed and synthesized a suitable catalytic system that attaches to the semiconductor electrode of the PEC.

Wrighton's system consists of platinum — "the best catalyst known for the evolution of hydrogen from water" — embedded in a complex polymer (a chemical chain of repeated units, or monomers) that binds to the semiconductor electrode. When light is absorbed by the semiconductor, its electrons become excited. These excited electrons are passed on to the surface-confined polymer that readily accepts them. With the help of the embedded Pt catalyst, the electron-charged polymer reacts with water to generate hydrogen and OH^- ions. The OH^- ions flow through the electrolyte solution to a counterelectrode that grabs electrons from the ions. These electrons travel in a circuit to the first, or semiconductor, electrode, replacing those that left in an excited state.

"The general concept of the surface-confined catalyst system should be applicable to all photoelectrodes," Wrighton says. "Application in other energy technologies such as fuel cells and batteries should also be possible." □

Deep impurities yield new semiconductors

A new family of semiconductor devices that could lead to smaller, simpler, less expensive and more versatile electronic equipment has been developed at the University of Cincinnati. Called "deep impurity" devices, they are selectively impregnated — or doped — with different impurities than are used in conventional semiconductors. The result is devices with volt/ampere characteristics "akin to the terminal characteristics that you obtain on conventional semiconductor devices," explains H. Thurmon Henderson. What's different is the physics at play.

There's a certain electricity in his tone as Henderson describes his preoccupation for the past 15 years with deep-impurity semiconductors. But don't feel embarrassed if you have never heard of them or have difficulty understanding how they work. Henderson, associate dean of engineering at UC, says that even many colleagues in electrical engineering find his laboratory's research arcane.

But NASA, which has funded UC's work for many years, is anxious to lift the fog obscuring deep impurities. The agency convened a conference at UC a month ago to unveil the field's prospects — which NASA feels are close to being ready for industrial application, Henderson says.

Dopants used — such as gold and thallium — are deep only in the sense that their energy lies deep within the energy gap separating a semiconductor's conduction and valence bands. Characteristics of a given device are determined by holes or electrons injected at the appropriate topology in the semiconductor material to alter the charge state of impurities in the energy gap.

"All semiconductor devices that you're used to dealing with are, in one way or another, based on P-N junctions [the junction of n-type — electron donor doped — and p-type — electron acceptor doped — materials]," Henderson explains. His devices are not. "We are injecting charge through a very simple electrode" — not a P-N junction, just an ohmic electrode.

Simpler than conventional semiconductor devices and using the same materials and manufacturing techniques, deep-impurity devices should cost far less to produce. Also offering functions unheard of in any other single device — such as voltage-control delays in the millisecond range — the devices promise to reduce the size and complexity of electronics. And because the new devices are compatible with conventional ones, Henderson expects to see a marriage of both devices on a single hybrid silicon chip.

"We're talking about a new kind of semiconductor physics," Henderson says. "We're talking about a significant array of devices that do things no conventional devices will do." □

Big payoffs from early education

Project Head Start seemed like a good idea until the first evaluation of children who took part in it suggested that they were only marginally better off than children who had not had preschool education. This finding almost completely discredited the idea of early intervention as a means of preventing academic retardation among disadvantaged children. Now the pendulum is swinging back. A longitudinal study that started with three- and four-year-old children in 1962 is finding that preschool education pays off in a number of important ways — including financially.

The study, called the Ypsilanti Perry Preschool Project, involves 123 children from poor black families in Ypsilanti, Mich. Half of them served as a control group and received no preschool education. The other half received 12½ hours of schooling a week that emphasized active learning and problem-solving and a high degree of adult-child and child-child interaction. In addition, teachers visited each mother and child at home for 90 minutes a week — not to teach but to arouse the parent's interest in and attention to her child's curiosity for learning. The project is being conducted by the High/Scope Educational Research Foundation with partial funding from the Carnegie Corp. of New York.

On 48 measures of school and life success, the study finds that by age 15 children who had attended a quality preschool on average significantly outperformed children who had not. Major findings are that:

- Children who had attended preschool scored higher on reading, arithmetic and language achievement tests at all grade levels than children who had not.
- By the end of high school, only 19 percent of the children who had attended preschool had been placed in special education classes, compared with 39 percent of those who had not.
- Children who attended preschool showed less tendency to display antisocial or delinquent behavior in or outside of school.
- Children who attended preschool were more likely to hold jobs after school, suggesting that the effects of preschool will extend to employment and other kinds of success beyond the classroom.
- The long-term benefits of preschool outweigh the costs. The $3,000 per child per year of preschool is recouped almost immediately in savings on special education and other special services.
- Although the data are incomplete, early indications are that children who had attended preschool will show a higher high school completion rate, a greater likelihood of attending college, less tendency to use welfare, higher employment and lower arrest rates than those who had not. □