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Science/Tech

Article published Tuesday, February 10, 2004

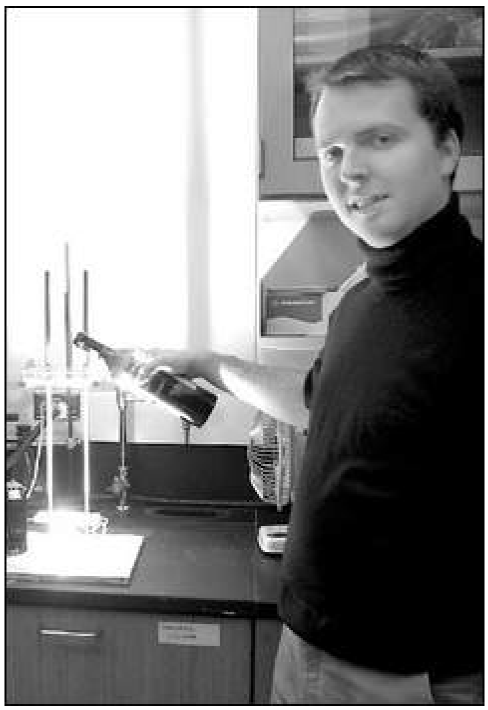
Red wine leads UT scientists to juice up potency of solar cells

By JENNI LAIDMAN
BLADE SCIENCE WRITER

Red wine, what can beat it? It reduces your risk of heart disease. It's full of cancer-fighting compounds. And now, researchers at the University of Toledo reveal yet another use for the juice of the grape.

It makes better solar cells.

UT researcher Yann Roussillon didn't expect wine to boost the efficiency of solar cells. Still, the doctoral candidate was game when UT physics professor Victor Karpov proposed the idea of wine-soaked solar cells in a brainstorming session.



UT doctoral candidate Yann Roussillon is part of a team that has found a way to increase solar cell efficiency.
(THE BLADE/JETTA FRASER)
Zoom

No, they weren't drinking at the time. Dr. Karpov had a hunch that the chemical properties of wine could help solve a major problem in solar cells made out of cadmium and telluride.

Unfortunately for Ohio's wine crop, this isn't really a practical way to make solar cells. So Mr. Roussillon found a substance that shared wine's properties. A paper in the current issue of Applied Physics Letters shows that the research team settled on a chemical called aniline.

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While a glass of aniline with dinner would have distressing effects, it works on solar cells because it too contains charged particles. In fact, aniline performed slightly better than wine, raising solar cell efficiency to the industry average of 12 percent.

While cadmium-telluride solar cells will convert sunlight into electrical energy, they do so stingily. Only 1 to 3 percent of the light that strikes the cell turns into electricity. Despite efforts to goose the efficiency rate to an average of 10 to 12 percent, methods generally are expensive and often inefficient.

Cadmium cells start with a layer of glass, then a slather of a transparent oxide, followed by a sheet of cadmium sulfide, then cadmium telluride, and finally a metal sheet that acts as the electrical contact.

While the solar cell looks ice-rink smooth, it’s really a roughlandscape. Electrons traveling across the surface lose their way in its many valleys.

Red wine contains microscopic spheres called colloidal particles. Each sphere carries an electrical charge. When wine spills across the cadmium-telluride layer, these particles fill in the valleys, smoothing the electrons’ path.

The result? Solar cells that can convert some 9 percent of the light that strikes them into energy - nearly as good as all-but the most experimental and expensive processes.

The university has applied for a patent on the aniline process.

"It’s interesting work," said Ken Zweibel, at the National Renewable Energy Laboratory. NREL is a part of the U.S. Department of Energy

However, the market value of the invention must be proven.

"It’s really too early to tell,’’ said Chip Hambro, general manager of First Solar, which makes cadmium-telluride solar cells.

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Red wine mends solar cells

By Eric Smalley, Technology Research News

Researchers from the University of Toledo have found a way to increase energy production using red wine.

One challenge in making solar cells more efficient is countering the effects of bad spots in the large areas of semiconductor material used to harvest energy from light. These spots drain current, making devices like solar cells less efficient.

The researchers have found a way to use properties of the bad spots to seal them off from the working area of the cell. The researchers used the method to boost the efficiency of a cadmium telluride/cadmium sulfide solar cell from 2 percent to 11 percent, said Yann Roussillon, a researcher at the University of Toledo.

Solar cell efficiencies range from about seven percent for low-cost thin film materials to about 24 percent for high-quality silicon crystal. Large solar cells are usually made from polycrystalline or amorphous semiconductor rather than the high-quality crystal used to make computer chips.

In crystal semiconductors, atoms are arranged as a regular lattice. This gives a material like crystalline silicon good electrical properties, but makes it relatively expensive to produce. Amorphous materials contain disordered atoms, which makes them cheap to produce but less electrically efficient than crystal. Polycrystalline materials are made of aggregates of tiny crystals; they fall between crystals and amorphous materials in cost and efficiency. The University of Toledo method boosts the efficiency of the low-cost photovoltaic materials, which promises to make generating electricity from sunlight more cost-effective.

Solar cells consist of two layers of semiconductor material; one layer carries positive charges and the other negative. Sunlight is absorbed by the positive layer, and the photons excite the materials' electrons, which jump to the negative layer and are fed to an electrical circuit.

Amorphous silicon solar cells are made by spreading a thin film of silicon on a surface. Some polycrystalline semiconductor materials, including cadmium telluride, can also be made into thin films.

But thin-film polycrystalline solar cells usually have bad spots because it's nearly impossible to uniformly manufacture such large areas --

typically a square meter -- of the material, said Roussillon. Polycrystalline materials also have an intrinsically irregular molecular structure, including variations in chemical composition and crystal grain size.

These microscopic structures form microscale diodes, which allow electrical current to flow in only one direction. A photovoltaic cell is really a set of microdiodes connected in parallel, and the bad spots in the material are weak diodes, according to Roussillon. Surface voltage is lower at the weak diodes when photovoltaic material is exposed to light, he said.

The researchers' method takes advantage of the difference in electrical potential between weak and strong diodes to generate electrochemical reactions that block the weak diodes while leaving the strong ones intact. The researchers improved a photovoltaic panel by immersing it in an electrically conductive medium, or electrolyte, and exposing the panel to light. The variations in electrical potential at the surface result in currents in the electrolyte that work to even out those differences.

By choosing the right electrolyte, the researchers can focus electrochemical reactions where the currents are drawn to the weak diodes, according to Roussillon. The reactions "selectively block or etch the weak diodes and [leave] the good ones intact," he said.

One substance that can be used to cause these electrochemical reactions is red wine. One of the researchers, Victor Karpov, realized that microscopic particles in red wine should be attracted to the weak spots of the solar cell, said Roussillon. After they tested the process and found that red wine increased the solar cell's efficiency, the researchers switched to a mixture of an acid, water and aniline, a substance that turns solid in an acidic liquid and low electrical potential. "The problem is that red wine is a very complex chemical system," said Roussillon. "With the aniline system, it [was] easier to characterize what is going on on the surface of the device."

The researchers dubbed the process self-healing because the electrochemical reaction automatically acts on the weakest spots of the device.

The method could be used to improve other types of polycrystalline thin film photovoltaic devices, including light-emitting panels and liquid crystal displays, said Roussillon. The method could be used practically within two years, he said.

Roussillon and Karpov's research colleagues were Dean Giolando, Diana Shvydka and Alvin Compaan. The work appeared in the January 26, 2004 issue of *Applied Physics Letters*. The research was funded by the National Renewable Energy Laboratories (NREL).

Timeline: 3 years
Funding: Government
TRN Categories: Materials Science and Engineering; Energy
Story Type: News

Related Elements: Technical paper, "Blocking Thin-Film Nonuniformities: Photovoltaic Self-Healing," Applied Physics Letters, January 26, 2004

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Take Sunlight, Add Red Wine, Get More Power

Posted: Tuesday, April 06, 2004

By Jacob Gaffney

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Wine plays many roles in society -- it's used to make food taste better, to celebrate special occasions, even to benefit one's health. Now researchers at the University of Toledo in Ohio have discovered a truly novel use for the beverage.

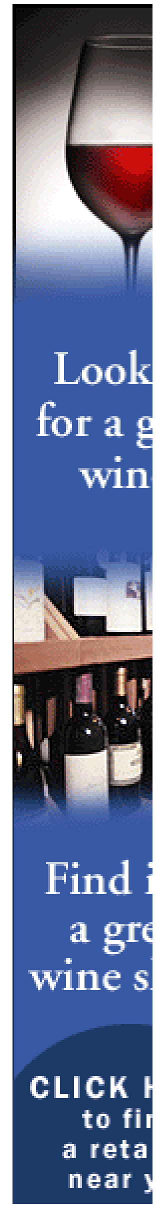
A team from the university's chemistry, physics and astronomy departments found that solar panels manufactured with red wine produce up to 12 percent more electricity than solar panels made without it, according to research published in a recent issue of *Applied Physics Letters.*

Red wine, which can conduct electricity, helps solar panels "self-heal" when the flow of electric current is interrupted or slowed down.

Researcher Victor Karpov, a physics professor at the university, explained how the process works. Solar cells are made with two layers of semiconductor material; the top layer carries a positive charge and the bottom carries a negative charge. When energy from sunlight hits the top layer, the electrons get "excited" and jump to the negatively charged layer, where it is harnessed into an electrical circuit.

The larger a solar cell is, particularly if it is bigger than one square meter, the more likely it is to have irregularities in the material. These bad spots may cause energy to flow in the wrong direction -- laterally, rather than downward -- and be lost, Karpov said. This decreases the panel's efficiency.

Red wine fits into a category of liquids called electrolyte colloids, which have electrical charges. This charge may be used to counteract



the bad spots on panels where energy is not produced efficiently. "This property of electrolyte systems is well known in physics," Karpov said. "Wine is the most curious, funny, and easily available electrolyte. That is why we have started with that."

The ions in red wine naturally flow to the spots where the lateral currents are located, Karpov explained. Red wine's electric charge redistributes these currents, thus balancing the electric field. "We call such a process self-healing," the researchers wrote, "to reflect the fact that [red wine] selectively acts on the device's weakest spots."

The scientists -- who also included Alvin Compaan, Dean Geolando, Diana Shvydka and Yann Roussillon -- built their own solar panels, immersing them in red wine right before adding the metal electrode that absorbs the produced electricity. The researchers added the wine to two different panels, one that was manufactured in sunlight and the other in artificial light. They repeated the process immersing panels in aniline, another electrolyte, instead of wine, and also produced a solar panel without either substance.

When the researchers turned on the solar panels, they found that the two panels immersed in red wine produced electricity 3 percent to 12 percent more efficiently than the solar panel not immersed in red wine.

The panels that were manufactured in sunlight also performed better than those built in artificial light. At its peak, the red wine panel built in sunlight produced 0.8 volts, the one in artificial light, 0.6 volts. The regular solar panel produced 0.2 volts. The solar panels made with aniline performed similarly to the red wine panels.

Despite red wine's positive performance, Karpov and his team aren't sure if the beverage has much of a future in manufacturing solar panels.

"We are not sure if the red wine should be used more in solar panels," he said. "First, there may be more efficient and cheaper electrolytes. Second, it's too good to waste for chemical treatments."

# # #

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US007098058B1

(12) **United States Patent**
Karpov et al.

(10) **Patent No.: US 7,098,058 B1**
(45) **Date of Patent: Aug. 29, 2006**

(54) **PHOTOVOLTAIC HEALING OF NON-UNIFORMITIES IN SEMICONDUCTOR DEVICES**

(75) Inventors: **Victor G. Karpov**, Toledo, OH (US); **Yann Roussillon**, Mountain View, CA (US); **Diana Shvydka**, Toledo, OH (US); **Alvin D. Compaan**, Holland, OH (US); **Dean M. Giolando**, Toledo, OH (US)

(73) Assignee: **University of Toledo**, Toledo, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 78 days.

(21) Appl. No.: **11/035,170**

(22) Filed: **Jan. 13, 2005**

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(51) **Int. Cl.**
H01L 21/00 (2006.01)

(52) **U.S. Cl.** **438/22**; 257/79

(58) **Field of Classification Search** 438/4, 438/22, 88, 95, 96; 257/79, 80, 113
See application file for complete search history.

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(Continued)

Primary Examiner—Phuc T. Dang
(74) *Attorney, Agent, or Firm*—MacMillan, Sobanski & Todd, LLC

(57) **ABSTRACT**

A method of making a photovoltaic device using light energy and a solution to normalize electric potential variations in the device. A semiconductor layer having nonuniformities comprising areas of aberrant electric potential deviating from the electric potential of the top surface of the semiconductor is deposited onto a substrate layer. A solution containing an electrolyte, at least one bonding material, and positive and negative ions is applied over the top surface of the semiconductor. Light energy is applied to generate photovoltage in the semiconductor, causing a redistribution of the ions and the bonding material to the areas of aberrant electric potential. The bonding material selectively bonds to the nonuniformities in a manner such that the electric potential of the nonuniformities is normalized relative to the electric potential of the top surface of the semiconductor layer. A conductive electrode layer is then deposited over the top surface of the semiconductor layer.

28 Claims, 10 Drawing Sheets