Scientists advance in quest for alternative energy source

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• Heat from toxic waste sites in developing countries linked to rising cases of disease, disability, early death

A research team from the University of Michigan (U-M), United States (U.S.), has found a way to nearly double the efficiency of a particular class of thermoelectric material that is made with organic semiconductors.

It has been demonstrated that thermoelectric materials can be used to turn waste heat into electricity or to provide refrigeration without any liquid coolants.

According to the study published recently in Nature Materials, the U-M researchers improved upon the state-of-the-art in organic semiconductors by nearly 70 per cent, achieving a figure-of-merit of 0.42 in a compound known as PEDOT:PSS.

Also, a solar-powered airplane that developers hope eventually to pilot around the world landed safely in Phoenix on the first leg of an attempt to fly across the U.S. using only the sun's energy, project organisers said.

The plane, dubbed the Solar Impulse, took 18 hours and 18 minutes to reach Phoenix on the slow-speed flight, completing the first of five legs with planned stops in Dallas, St. Louis and Washington on the way to a final stop in New York.

According to a report by Reuters, the spindly-looking plane barely hummed as it took off Friday morning from Moffett Field, a joint civil-military airport near San Francisco.

The report reads: "It landed in predawn darkness at Sky Harbor International Airport in Phoenix, according to a statement on the Solar Impulse's website. The flight crew plans pauses at each stop to wait for favorable weather. It hopes to reach John F. Kennedy International Airport in New York in about two months.

"Swiss pilots and co-founders of the project, Bertrand Piccard and Andre Borschberg, will take turns flying the plane, built with a single-seat cockpit. Piccard was at the controls for the first flight to Arizona.

"The lightweight carbon fiber Solar Impulse has a wingspan of a jumbo jet and the weight of a small car and from a distance resembles a giant floating insect.

"The plane was designed for flights of up to 24 hours at a time and is a test model for a more advanced aircraft the team plans to build to circumnavigate the globe in 2015. It made its first intercontinental flight, from Spain

to Morocco, last June.

“The aircraft is propelled by energy collected from 12,000 solar cells built into the wings that simultaneously recharge four large batteries with a storage capacity equivalent to a Tesla electric car that allow it to fly after dark.

“The lightweight design and wingspan allow the plane to conserve energy, but make it vulnerable. It cannot fly in strong wind, fog, rain or clouds. The plane can climb to 28,000 feet and flies at an average of 43 miles per hour (69 km per hour).

“The project began in 2003 with a 10-year budget of €90 million ($112 million) and has involved engineers from Swiss escalator maker Schindler and research aid from Belgian chemicals group Solvay.”

Meanwhile, a study in three developing countries has found that living near a toxic waste site may represent as much of a health threat as some infectious diseases.

According to the study published in Environmental Health Perspectives, researchers analysed 373 toxic waste sites in India, Indonesia and the Philippines, where an estimated 8.6 million people are at risk of exposure to lead, asbestos, hexavalent chromium and other hazardous materials. Among those people at risk, the exposures could cause a loss of around 829,000 years of good health as a result of disease, disability or early death, the team reports May 4 in

In comparison, malaria in these countries, whose combined population is nearly 1.6 billion, causes the loss of 725,000 healthy years while outdoor air pollution claims almost 1.5 million healthy years, according to the World Health Organisation (WHO).

Organic semiconductors are carbon-rich compounds that are relatively cheap, abundant, lightweight and tough. But they have not traditionally been considered candidate thermoelectric materials because they have been inefficient in carrying out the essential heat-to-electricity conversion process.

Today’s most efficient thermoelectric materials are made of relatively rare inorganic semiconductors such as bismuth, tellurium and selenium that are expensive, brittle and often toxic. Still, they manage to convert heat into electricity more than four times as efficiently as the organic semiconductors created to date.

This greater efficiency is reflected in a metric known by researchers as the thermoelectric “figure of merit.” This metric is approximately one near room temperature for state-of-the-art inorganic thermoelectric materials, but only 0.25 for organic semiconductors.

Project leader of the thermoelectric study and an associate professor of mechanical engineering as well as electrical engineering and computer science, Kevin Pipe, said: “That is about half as efficient as current inorganic semiconductors.”

Pipe is a co-author of a paper on the research published in Nature Materials on May 5, 2013.

PEDOT:PSS is a mixture of two polymers: the conjugated polymer PEDOT and the polyelectrolyte PSS. It has previously been used as a transparent electrode for devices such as organic LEDs and solar cells, as well as an antistatic agent for materials such as photographic films.

One of the ways scientists and engineers increase a material’s capacity for conducting electricity is to add impurities to it in a process known as doping. When these added ingredients, called dopants, bond to the host material, they give it an electrical carrier. Each of these additional carriers enhances the material’s electrical

conductivity.

In PEDOT doped by PSS, however, only small fraction of the PSS molecules actually bond to the host PEDOT; the rest of the PSS molecules do not become ionised and are inactive. The researchers found that these excess PSS molecules dramatically inhibit both the electrical conductivity and thermoelectric performance of the material.

Pipe said: “The trouble is that the inactive PSS molecules push the PEDOT molecules further apart, making it harder for electrons to jump between PEDOT molecules. While ionized PSS molecules improve electrical conductivity, non-ionized PSS molecules reduce it.”

To improve its thermoelectric efficiency, the researchers restructured the material at the nanoscale. Pipe and his team figured out how to use certain solvents to remove some of these non-ionised PSS dopant molecules from the mixture, leading to large increases in both the electrical conductivity and the thermoelectric energy conversion efficiency.

This particular organic thermoelectric material would be effective at temperatures up to about 250 degrees Fahrenheit.

“Eventually this technology could allow us to create a flexible sheet - think of Saran Wrap - that can be rolled out or wrapped around a hot object to generate electricity or provide cooling,” Pipe said.

The coauthor of the toxic waste study and a pediatrician at the Icahn School of Medicine at Mount Sinai in New York City, U.S., Kevin Chatham-Stephens, said: “Although scientists have known for years about the risks of pollutants at toxic waste dumps, no one had quantified the health effects in this way.”

In 2010, researchers with the Blacksmith Institute, a nonprofit environmental health organisation, identified the toxic waste sites, such as lead battery recycling centers and former tanneries. For each site, the investigators determined the main pollutant; whether the pollutant is in the water, soil or air; and how many people might regularly come into contact with the polluted area.

Chatham-Stephens and colleagues plugged those data into a computer program that estimates how much of a material should be in the human body given a particular exposure. The team then used another program to estimate how many people should be afflicted with particular diseases or disabilities linked to a toxic material. Lead, for example, can cause mild mental retardation in children, anemia and cardiovascular disease. The researchers determined the number of lost healthy years by weighting each disease based on its relative severity.

Lead and hexavalent chromium, a carcinogen, accounted for more than 99 per cent of the lost healthy years. The team estimates that the three countries could house an additional 5,000 toxic waste sites that weren’t studied, affecting another 35 million people. In total, they suggest, the studied and unstudied toxic sites could result in more than 4.3 million lost healthy years.

Almost 65 per cent of the affected people are children and women of child-bearing age, Chatham-Stephens says, providing cause for concern: “In utero and early childhood are the stages of life that are most vulnerable to toxic insults.”

In a related study, the team looked at 200 toxic waste sites in 31 developing countries. Nearly 780,000 kids younger than age five who live near these sites may be exposed to lead. The team determined that exposures could be high enough to cause mild mental retardation in six out of every 1,000 kids, Chatham-Stephens

reported May 6 at the Pediatric Academic Societies annual meeting in Washington, D.C.

The results are “sobering,” says Howard Hu, a physician and epidemiologist at the University of Toronto. The next step, he says, is to directly measure the level of toxicants in people living near these sites and the diseases that affect them. He also points out that the study only considered one pollutant per site and only eight materials total, so future work should try to look at more toxicants and how they interact to influence health.

The actual health impacts could be even higher, Suk notes, because many people living near these sites may also suffer from nutritional deficiencies and infectious diseases. Having a weakened immune system may make these individuals more vulnerable to environmental threats, he says.

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