Waste plastic yields high-quality fuel oil

Ironically, after all the trouble of reclaiming plastic waste from gooey trash, recycled products often cost more and look worse than virgin plastics — a situation that displeases consumers.

But fuel chemists M. Mehdi Taghiei and his colleagues at the University of Kentucky in Lexington report a new, efficient way of converting plastic waste into high-quality, saturated fuel oil.

"It's good oil, too — much like imported crude oil," Taghiei said this week in Chicago at a meeting of the American Chemical Society. "This oil is even lighter and easier to refine into high-octane fuel than imported oil. It has no sulfur and fewer impurities." Similarly, the chemists found they could liquefy plastic with coal, also producing high-quality fuel.

The researchers mixed various types of plastic with zeolite catalysts, including HZSM-5 and tetralin, in a sand bath, then placed the slurry in a "tubing-bomb" reactor. Pressurizing the mixture with hydrogen and heating it to 420°C for an hour caused high-molecular-weight plastics to break down into smaller compounds, similar to those in crude oil. Furthermore, oil yields proved high: Milk jugs generated 86 percent oil, soda bottles, 93 percent. Polyethylene, another common soft plastic, eked out 88 percent. When liquefied with coal in a roughly half-and-half mixture, the plastics turned into even better oil.

"In terms of the economics of this process, we have done some estimates," says Kentucky chemist Gerald P. Huffman, a coauthor of the report. "To convert coal and plastic simultaneously into oil right now costs about $27 or $28 per barrel, compared with $18 to $20 per barrel for imported oil. But we're quite confident that we can drive the cost of converted oil down to roughly the cost of imported oil. This process may be commercially viable within five to 10 years."

Plastics today account for roughly 40 percent of landfill trash, says Taghiei. However, of the total volume of plastic entering the waste stream, only 3.7 percent gets recycled, he adds. Why so little? The reason lies not only in high cost, he says, but also in contamination and impurities. Thus recycled polyethylene, for example, costs 10 percent more than virgin polyethylene.

Other methods exist for converting plastic to oil, Taghiei says, but usually they produce "unsaturated and unstable oils of low yield and low value." On the basis of the current rate of plastic disposal, he estimates that the United States could produce some 80 million barrels of oil a year.

This work stems from the Consortium for Fossil Fuel Liquefication Science, a five-university project sponsored by the Department of Energy. Overall, the project aims to make oil by liquefying many types of waste hydrocarbons with coal, using such garbage as paper, agricultural waste, sewage sludge, and rubber tires, as well as plastics.

Taghiei and Huffman argue that plastic-to-oil conversion plants could eventually supply the United States with substantial amounts of oil on an ongoing basis. Indeed, says Huffman, Germany has already started building a promising 200-ton-per-day plastic-to-oil reactor in the city of Bottrop. *— R. Lipkin*

Wetlands provide clue to greenhouse gas

Two researchers say they have answered a question that stumped scientists for years: What key factor determines how much methane — a greenhouse gas that warms Earth by trapping heat — the different types of wetlands emit? To find out, the researchers slogged through subarctic peat bogs in Canada and subtropical swamps in Florida, monitoring atmospheric gas levels. Their answer: Methane emissions depend on the total amount of carbon dioxide exchanged between the atmosphere and plants.

Identifying this factor provides a tool to measure methane emissions on a global scale and to pinpoint major sources of emissions, says Gary J. Whiting, a biologist at Christopher Newport University in Newport News, Va., who led the study. These measurements should prove valuable because, although the amount of atmospheric methane has more than doubled in the past 100 years, scientists do not know exactly where it all originates. They do know, however, that too much methane can contribute to global warming.

Whiting and Jeffrey P. Chanton, a chemical oceanographer at Florida State University in Tallahassee, report their findings in the Aug. 26 NATURE.

"They established a quantitative link between the total amount of plant growth and the amount of methane produced," says Robert Harriss, an earth systems scientist at the University of New Hampshire in Durham. Remote-sensing satellites can use this formula to indirectly map methane emissions, he explains. Satellites can directly measure the amount of biomass growing in an ecosystem. Correlating this figure to the amount of carbon dioxide exchanged and will reveal the volume of methane emissions from natural sources.

Methane comes from two major sources: natural, including wetlands, oceans, and termites; and human activities, including coal mining, landfills, rice farming. Natural wetlands, which make up just 5 percent of Earth's land surface, play a disproportionately large role in methane emissions. Bacteria that decompose organic material into methane thrive in such flooded, oxygen-starved soils.

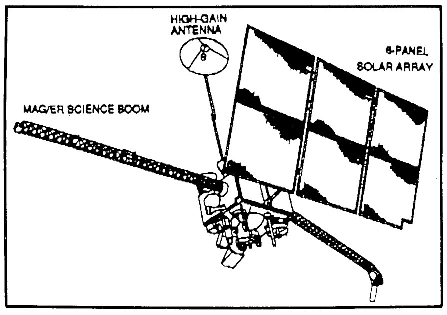
Scientists estimate that wetlands contribute up to one-half the methane emitted into the atmosphere — a total of between 100 and 200 million metric tons a year. "Satellite-generated methane maps can be used to narrow our uncertainty," Harriss says.

The same technique could help analyze rice paddy emissions, Whiting says. As rice became more important in feeding the world, farmers converted more land to these shallow fields of grain, which now emit up to 150 million metric tons of methane each year.

Whiting and Chanton tallied their gas measurements on a daily basis; seasonal and yearly tabulations would provide an even more accurate formula, they say. Harriss adds that measurements of vast, remote wetlands — the Siberian lowlands and the deep-peat swamps of Borneo and Sumatra — would complete the picture. *— B. Wuethrich*

NASA loses contact with Mars Observer

Aug. 21 proved a remarkably bad day for the nation's space program. NASA engineers lost all communication with the Mars Observer shortly before the $980 million spacecraft was to begin orbiting the Red Planet. And NOAA-13, a new weather satellite, fell silent as well.



NASA

Mars Observer: A silent spacecraft.

The reason for the sudden silence from the Mars Observer remains a mystery. Glenn Cunningham, project director for Mars Observer at NASA's Jet Propulsion Laboratory in Pasadena, Calif., says he remains "cautiously optimistic" that the craft has retained a set of critical commands — designed to send it into an elliptical orbit around Mars on Aug. 24 — beamed to the craft the day before communications ceased.

But he and other scientists worry that the commands may have become distorted or erased from the craft's on-board computer. If so, Mars Observer could not have fired its engines as planned and thus will not go into a low orbit around the planet. The craft simply may have sailed past Mars, ending a two-year mission before it ever began.

If communications should resume by the end of August, engineers could still instruct a wayward Mars Observer to orbit the planet. But calculations show the craft would take 40 days in a highly elliptical path to orbit Mars instead of the 118-minute circular path desired for a detailed study of the planet.

Trouble began about 9 p.m. Eastern Daylight Time on Aug. 21. Technicians had commanded the craft to pressurize its fuel tanks, a procedure that requires the craft to detonate a valve so that helium gas can flow into the tanks. Because the explosion might shock the craft's transmitters, technicians had deliberately switched them off minutes before, silencing the craft's only link with Earth. Five minutes later, with pressurization completed, engineers commanded the transmitters to turn on again. The craft remained mute.

Cunningham says there's "less than a 0.1 percent chance" that the valve detonation – a routine procedure with no more power than a firecracker – might have destroyed the craft. But a NASA contractor who wished to remain anonymous was less confident: "They [JPL officials] are calling it a 'loss of downlink.' But you might just as well call it a 'loss of spacecraft.'" He added that if a leak occurred in the tanks as pressure increased, it could have spun the craft wildly, hurling its solar arrays and other vital parts into space.

Scientists familiar with the Venus-orbiting Magellan spacecraft said that its transmitters – built by a different company than those on the Mars Observer – were not turned off before valve detonations. "That's just the time [during detonation] when you'd like to have as much communication with the craft as possible," notes Frank McKinney, project manager for spacecraft mission operations at Martin Marietta Astronautics in Denver.

Cunningham says that if the transmitters had remained on during pressurization, engineers might have gathered more hints about the cause of the communications failure. But he adds that the manufacturer had recommended that NASA turn off the transmitters during such procedures, advice followed previously without problems.

NASA expressed even greater pessimism about the fate of NOAA-13, a new weather satellite intended to replace an aging, but identical model that monitors Earth from a polar orbit. Researchers attribute the loss to a bad battery and don't expect to recover a signal.

– R. Cowen

Superheating and repairing a metal surface

A crystalline solid typically melts at a characteristic temperature. But short, intense pulses of laser light can cause certain surfaces of metal crystals to melt at temperatures below the solid's normal melting point. In contrast, other types of crystalline surfaces – made up of more closely packed atoms – resist melting.

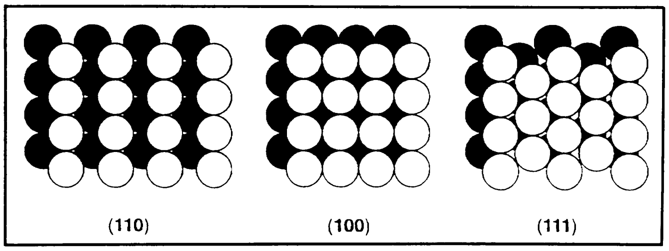
Last year, researchers demonstrated that a lead crystal's surface can be heated as much as 120 kelvins above the metal's melting point of 327.5°C (600.7 kelvins). Now, computer simulations of the behavior of copper (which has the same crystal structure as lead) confirm that laser pulses can "superheat" a surface made up of tightly packed atoms – even when the surface has defects.

"This was surprising," says Uzi Landman of the Georgia Institute of Technology in Atlanta. "Defects are normally suspected to be the cause of melting." However, under the influence of a superheating laser pulse, an initially flawed copper surface resists melting and actually mends itself.

Landman and Hannu Häkkinen report their findings in the Aug. 16 Physical Review Letters.

Slicing through a crystal of lead or copper in different directions exposes surfaces having different atomic arrangements (see diagrams below). The metal atoms are most closely packed on the type of surface labeled (111) and least closely packed on the (110) surface.

Researchers had previously observed that the lead (110) surface can start melting well before the crystal reaches a temperature of 600.7 kelvins. Last year, Hani E. Elsayed-Ali, now at Old Dominion University in Norfolk, Va., and John W. Herman of the University of Rochester (N.Y.) showed that the lead (111) surface can be substantially superheated (SN: 9/12/92, p.164).

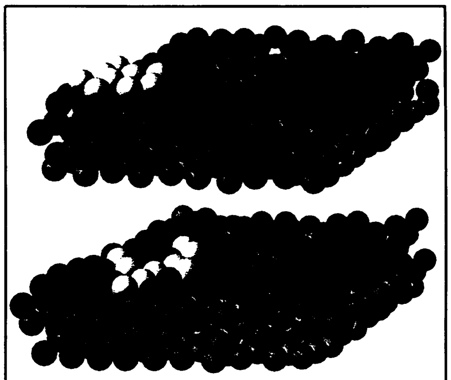


Elsayed-Ali

Arrangement of atoms on different types of crystal surfaces.

This result inspired Landman and Häkkinen to simulate the response of a metal (111) surface to intense laser pulses. To get a better sense of what happens on an atomic scale, they chose to model a copper crystal, made up of orderly rows and layers of copper ions immersed in a sea of free electrons.

To obtain a more realistic picture of this interaction, they modeled how the laser light excites the electrons, which in turn influence the motion of the ions in the lattice. "We tried to capture the whole sequence of events that occur in a laboratory experiment," Landman says. "This had not been done before."



Landman

Before irradiation by a short laser pulse, an island of copper atoms (light gray spheres) sits atop a copper (111) surface (dark gray spheres) near a hole in this upper layer of atoms (top). Computer simulations show that superheating causes the island to sink into the surface layer, while other atoms shift their positions to fill in the hole (bottom).

The researchers first simulated the response of a perfect crystal surface to a laser pulse and obtained clear evidence of superheating. Then they introduced a number of vacancies into the surface and found that superheating still occurred. Even when they placed an island of atoms atop the copper (111) surface and gouged out a large hole nearby, the surface didn't melt.

"We gave it every opportunity to melt, but to our surprise, it still wouldn't melt," Landman says. In fact, the surface repaired itself, filling in the hole (see diagrams above).

"This was of great interest to us," Herman says. "Because you would naturally think that defects would act as nucleation sites for disorder and melting, we had been wondering why you could superheat a surface that has defects." Real metal surfaces always have some defects.

Superheating can also occur in solids whose crystal structures differ from those of lead and copper. In the Aug. 15 Physical Review B, Herman, Elsayed-Ali, and Elizabeth A. Murphy at Rochester report that a bismuth surface remains orderly at temperatures as high as 90 kelvins above bismuth's melting point.

"This shows how general this phenomenon is," Elsayed-Ali says.

– I. Peterson