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Pulverizing electronic waste is green, clean—and cold

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Circuit boards from electronics, like computer mice, can be crushed into nanodust by a cryo-mill, according to researchers at Rice University and the Indian Institute of Science. The dust can then be easily separated into its component elements for recycling. Credit: Chandra Sekhar Tiwary/Rice University

Researchers at Rice University and the Indian Institute of Science have an idea to simplify electronic waste recycling: Crush it into nanodust.

Specifically, they want to make the particles so small that separating different components is relatively simple compared with processes used to recycle electronic junk now.

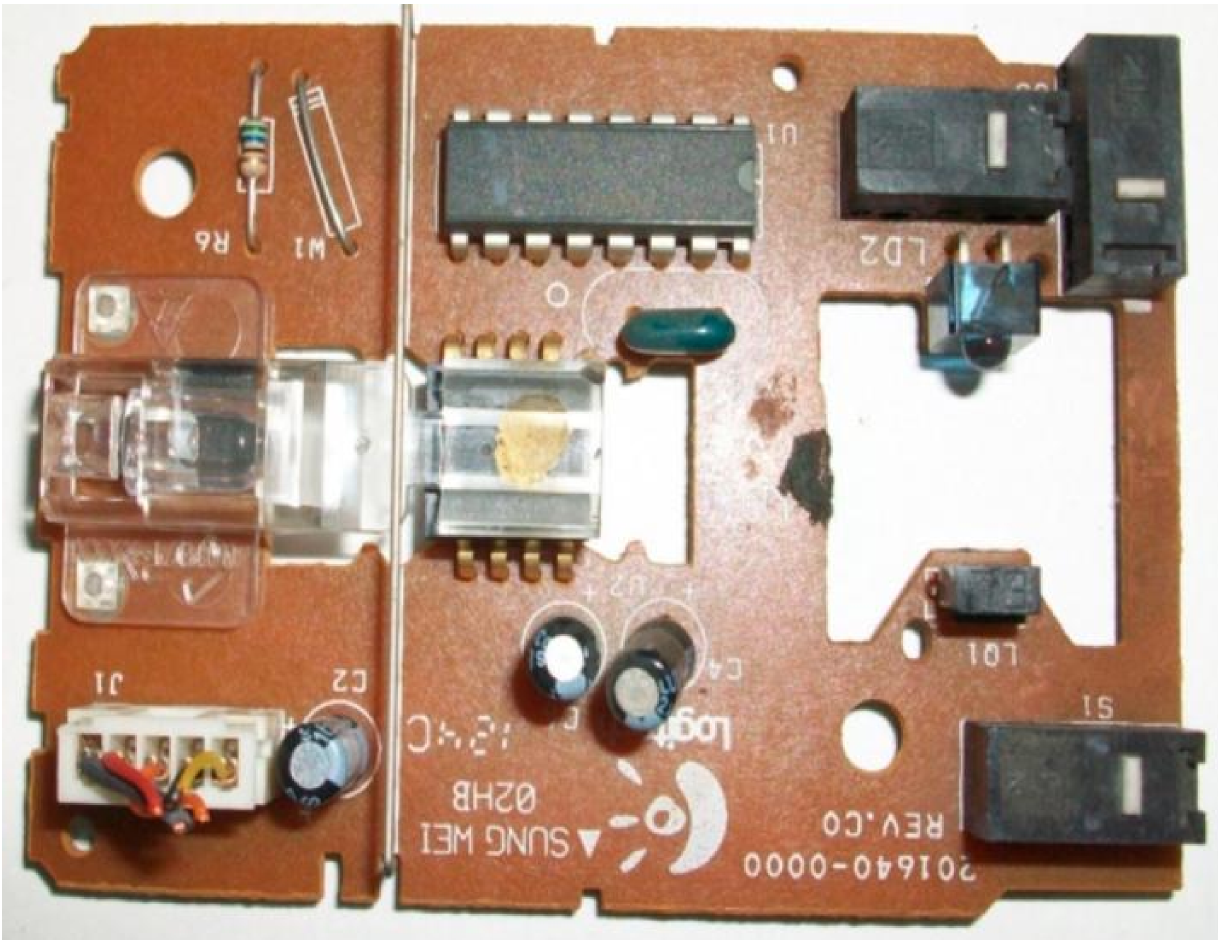
Chandra Sekhar Tiwary, a postdoctoral researcher at Rice and a researcher at the Indian Institute of Science in Bangalore, uses a low-temperature cryo-mill to pulverize electronic waste - primarily the chips, other electronic components and polymers that make up printed circuit boards (PCBs)—into particles so small that they do not contaminate each other.

Then they can be sorted and reused, he said.

The process is the subject of a *Materials Today* paper by Tiwary, Rice materials scientist Pulickel Ajayan and Indian Institute professors Kamanio Chattopadhyay and D.P. Mahapatra.

The researchers intend it to replace current processes that involve dumping outdated electronics into landfills, or burning or treating them with chemicals to recover valuable metals and alloys. None are particularly friendly to the environment, Tiwary said.

"In every case, the cycle is one way, and burning or using chemicals takes a lot of energy while still leaving waste," he said. "We propose a system that breaks all of the components - metals, oxides and polymers - into homogenous powders and makes them easy to reuse."



Pulverizing old circuit boards into nanodust with a cryo-mill makes its elements easier to recycle than current methods, according to researchers at Rice University and the Indian Institute of Science. Credit: Chandra Sekhar Tiwary/Rice University

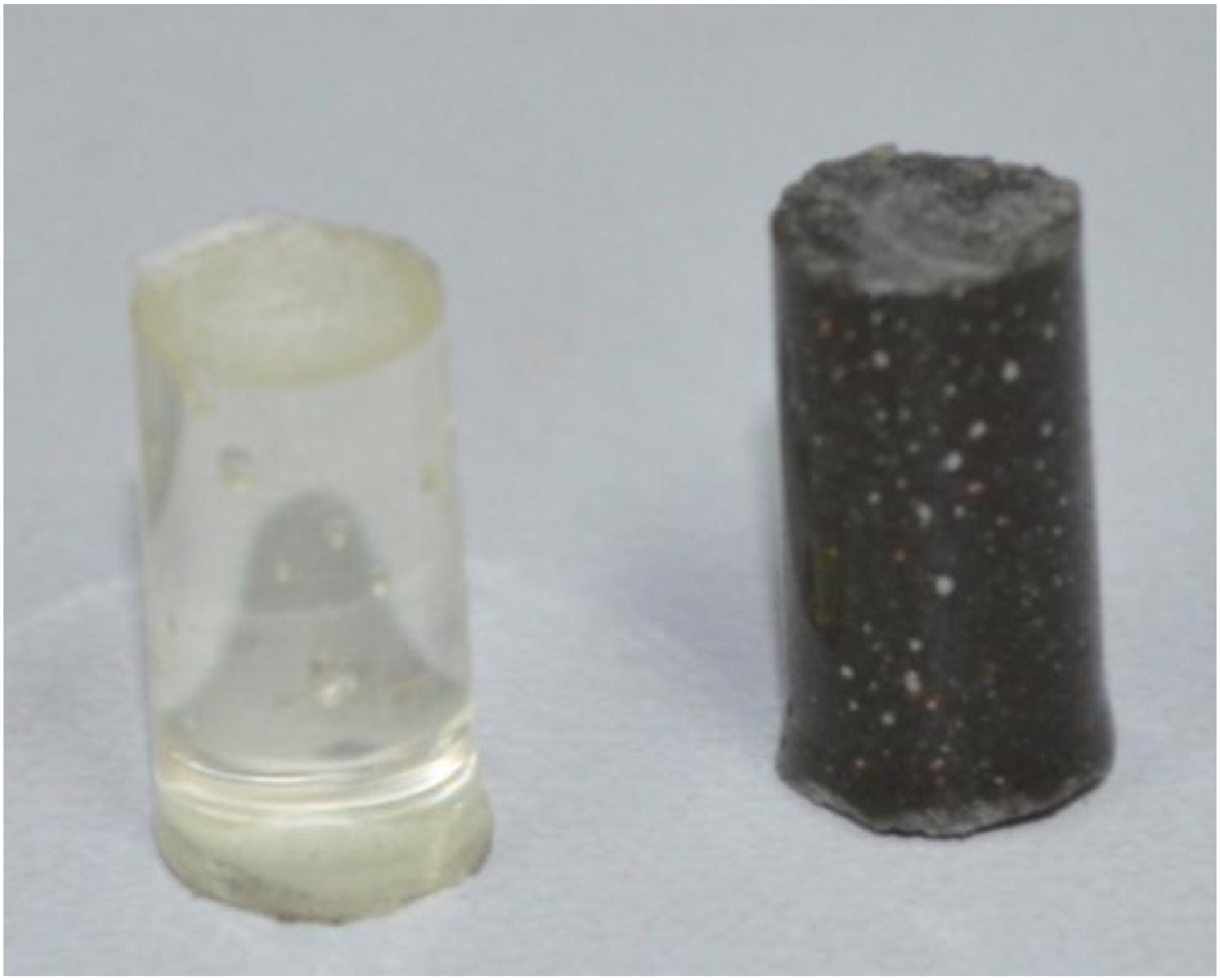
The researchers estimate that so-called e-waste will grow by 33 percent over the next four years, and by 2030 will weigh more than a billion tons. Nearly 80 to 85 percent of often-toxic e-waste ends up in an incinerator or a landfill, Tiwary said, and is the fastest-growing waste stream in the United States, according to the Environmental Protection Agency.

The answer may be scaled-up versions of a cryo-mill designed by the Indian team that, rather than heating them, keeps materials at ultra-low temperatures during crushing.

Cold materials are more brittle and easier to pulverize, Tiwary said. "We take advantage of the physics. When you heat things, they are more likely to combine: You can put metals into polymer, oxides into polymers. That's what high-temperature processing is for, and it makes mixing really easy.

"But in low temperatures, they don't like to mix. The materials' basic properties - their elastic modulus, thermal conductivity and coefficient of thermal expansion - all change. They allow everything to separate really well," he said.

The test subjects in this case were computer mice - or at least their PCB innards. The cryo-mill contained argon gas and a single tool-grade steel ball. A steady stream of liquid nitrogen kept the container at 154 kelvins (minus 182 degrees Fahrenheit).



This is a transparent piece of epoxy, left, compared to epoxy with e-waste reinforcement at right. A cryo-milling process developed at Rice University and the Indian Institute of Science simplifies the process of separating and recycling electronic waste. Credit: Chandra Sekhar Tiwary/Rice University

When shaken, the ball smashes the polymer first, then the metals and then the oxides just long enough to separate the materials into a powder, with particles between 20 and 100 nanometers wide. That can take up to three hours, after which the particles are bathed in water to separate them.

"Then they can be reused," he said. "Nothing is wasted."

More information: C.S. Tiwary et al, Electronic waste recycling via cryo-milling and nanoparticle beneficiation, *Materials Today* (2017).
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