Milling electronic waste into nanoscale particles allows polymers, oxides and metals to be separated for recycling into new products. The process takes advantage of changes to the materials' properties in very cold conditions.

Pulverizing e-waste is green and clean

Indian Institute of science and Rice University researchers use cryo-mill to turn circuit boards into separated powders

Indian Institute of Science researchers along with researchers of Rice University 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 are relatively simple compared to processes used to recycle electronic junk now.

Chandra Sekhar Tiwary, a graduate student of Indian Institute of Science and a postdoctoral researcher at Rice used a cryo-mill designed at Indian Institute of Science to pulverize electronic waste – primarily the chips, other electronic components and polymers that make up printed circuit boards (PCBs) at low temperatures 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The researchers intend it to replace current processes that involve dumping outdated electronics into landfills, or burning or treating them with chemicals to recover valuable metals and alloys.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."

The researchers estimate that so-called e-waste is expected to 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 according to the Environmental Protection Agency is the fastest-growing waste stream in the United States.

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 kelvin (minus 182 degrees Fahrenheit).

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."

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