Nanotube ink: Desktop printing of carbon nanotube patterns

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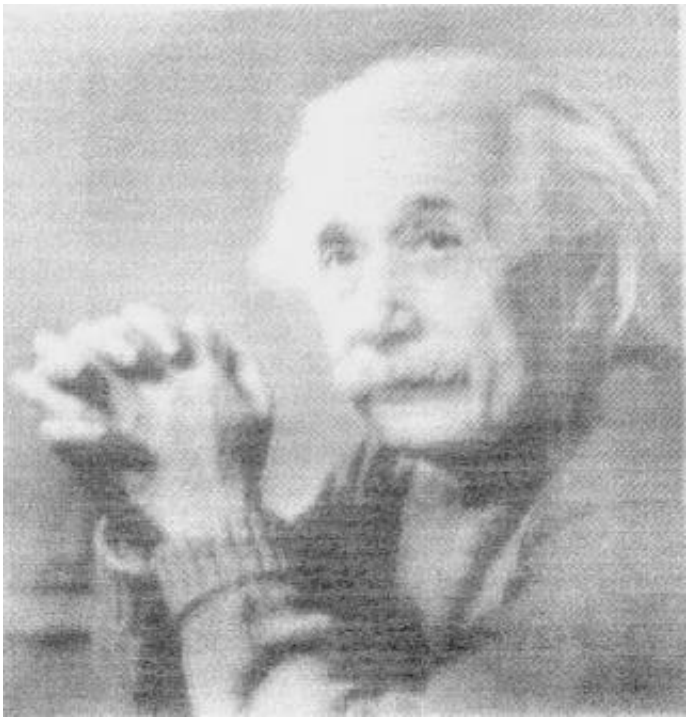

Electrically conductive image of Albert Einstein printed on copier paper with carbon nanotube ink. Credit: University of Oulu/K. Kordas and G. Toth

Using an off-the-shelf inkjet printer, a team of scientists has developed a simple technique for printing patterns of carbon nanotubes on paper and plastic surfaces. The method, which is described in the August 2006 issue of the journal *Small*, could lead to a new process for manufacturing a wide range of nanotube-based devices, from flexible electronics and

conducting fabrics to sensors for detecting chemical agents.

Carbon nanotubes have enticed researchers since their discovery in 1991, offering an impressive combination of high strength, low weight, and excellent conductivity. But most current techniques to make nanotube-based devices require complex and expensive equipment. "Our results suggest new alternatives for fabricating nanotube patterns by simply printing the dissolved particles on paper or plastic surfaces," said Robert Vajtai, a researcher with the Rensselaer Nanotechnology Center at Rensselaer Polytechnic Institute and corresponding author of the paper.

Vajtai and his colleagues at Rensselaer - along with a group of researchers led by Krisztiőn Kordős and Gőza Tyth at the University of Oulu in Finland - have developed an approach that uses a commercial inkjet printer to deposit nanotubes onto various surfaces. They simply fill a conventional ink cartridge with a solution of carbon nanotubes dissolved in water, and then the printer produces a pattern just as if it was printing with normal ink. Because nanotubes are good conductors, the resulting images also are able to conduct electricity.

"Printed carbon nanotube structures could be useful in many ways," Vajtai said. "Some potential applications based on their electrical conductivity include flexible electronics for displays, antennas, and batteries that can be integrated into paper or cloth." Printing electronics on cloth could allow people to actually "wear" the battery for their laptop computer or the entire electronic system for their cell phone, according to Vajtai.

The technique could be used to print optical tags on money and other paper items that need to be tracked, and it could even lead to an electronic newspaper where the text can be switched without changing the paper, he said. The researchers printed different samples, some of

which show sensitivity to the vapors of several chemicals, which also could make them useful as gas sensors.

The approach is simple, versatile, and inexpensive, which makes it superior to other methods for producing conductive surfaces, according to Vajtai. "A great advantage of our process is that the printed patterns do not require curing, which is known to be a limiting factor for conventional conductive ink applications," he said. "And since our ink is a simple water-based dispersion of nanotubes, it is environmentally friendly and easy to handle and store."

Because the process uses off-the-shelf printers, cartridges, and paper or plastic surfaces, the only real expense is the cost of the nanotubes. For this experiment, the researchers made their own multi-walled carbon nanotubes, which were then chemically modified to allow them to dissolve in water. But similar nanotubes can be purchased for as little as a tenth of the price of the more expensive single-walled variety of carbon nanotubes, Vajtai said. And the cost of nanotubes should continue to drop as commercial demand for higher volumes grows.

The researchers plan to continue optimizing the process to improve the quality of the nanotube ink and the conductivity of the printed images. At present, the paper or plastic must be run through the printer multiple times to get an electrically conductive pattern, with the conductivity increasing after each repetition. They also hope to experiment with different chemical modifications to produce a diversity of ink "colors," each producing surface patterns with different properties, Vajtai said.

Source: Rensselaer Polytechnic Institute