



Stamps and glue make circuits

By Eric Smalley, Technology Research News

Rubber stamps, ink and glue -- tools of choice for grade school art projects -- are the inspirations for a printing technique that could rapidly and cheaply produce integrated circuits at least as small as those in today's computer chips.

Researchers at Lucent Technologies' Bell Laboratories have developed a way of stamping microscopic circuits onto surfaces such as plastic and silicon. The method calls for etching circuit patterns into a stamp and using glue to transfer gold from the stamp to a surface. The circuit patterns can contain features 10 times smaller than a bacterium.

The nanotransfer printing process could eventually be used to make circuits and connectors for plastic electronics, an emerging technology used to make electronic paper and flexible displays.

The researchers are not the first to apply stamps to the task of making microscopic circuits, but the technique is the first that can stamp out a circuit in a single step, said John A. Rogers, director of nanotechnology research at Bell Labs. This gives it the potential to become a relatively inexpensive manufacturing process, he said. The key to the single-step stamping process is a type of glue.

As the stamp makes contact, a pair of dry chemicals glue the gold ink to the printing surface. "The printing... does not use solvents, developers [or] liquid etchants... and it can be performed in open air and at room temperature," said Rogers.

In contrast, standard chipmaking processes use light and chemicals to etch layers of metal and semiconductor materials. The processes are expensive and some chipmaking facilities cost more than \$1 billion.

To make the stamps, the researchers etched patterns into a small blocks of rubber, glass or gallium arsenide, and put a thin layer of gold on the raised parts of the stamps. It is important that the gold does not stick to the material of the stamps, said Rogers.

The researchers then coated the printing surface with one chemical, and the gold ink with a second chemical that reacted to form a bond when it came into contact with the first. "When we contact the stamps to the substrate, these tailored surface chemistries lead to strong covalent bonds that spontaneously form between the material on the stamp and the surface of the substrate," said Rogers. A covalent bond forms when two atoms join by sharing one or more pairs of electrons.

Because the stamp material does not stick to gold, removing the stamp transfers the tiny pattern of gold that was on the raised regions of the stamp to the surface, he said.

Rogers' team used the stamps to make transistors and inverter circuits. Transistors are switches that control electrical signals in integrated circuits. They are the basic building blocks of computer processor and memory chips. Inverter circuits, or NOT logic gates, consist of a pair of transistors and convert digital 1s to 0s and 0s to 1s.

The researchers' stamps ranged in size from one square millimeter to ten square centimeters and the variety of patterns they produced included intersecting lines and arrays of holes as small as 100 nanometers, or one ten-thousandth of a millimeter, in diameter.

Although the process produces features smaller than today's commercial chipmaking processes, which currently makes features only as small as 130 nanometers, it is not possible to stamp entire computer chips because the stamps can't be positioned precisely enough, said Rogers. Computer chips are made of several layers of material, and these layers must be perfectly aligned.

The researchers are aiming to make devices that require fine features but that don't contain multiple layers, said Rogers. "The first applications that we are examining are in integrated optics and plastic electronics," he said. Integrated optics chips contain tiny channels for directing light beams.

The researchers are currently experimenting with several types of bonding chemistries that will allow them to print different types of materials, said Rogers.

They are also using the stamping process to build molecular electronics structures, he said. Molecular electronics involves using individual molecules as the components of electronic devices like transistors.

Nanotransfer printing could be used in practical applications in three to seven years, said Rogers. "We... have several examples of simple functional structures that we have printed with this method, but we are really just now beginning this line of research," he said.

Rogers' research colleagues were Yueh-Lin Loo, Robert Willett and Kirk Baldwin. They published the research in the July 15, 2002 issue of the journal Applied Physics Letters. The research was funded by Lucent Technologies.

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