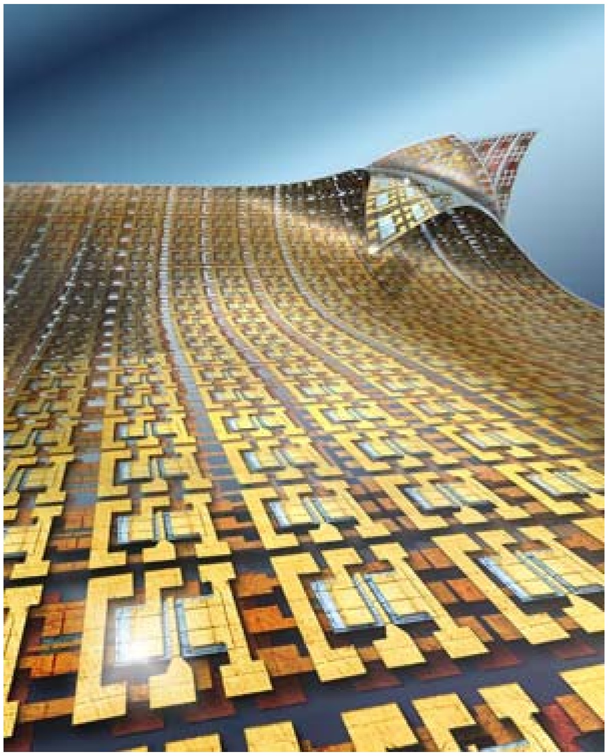
NEWS

3D heterogeneous systems are a key to the next generation of electronics



Researchers at the Frederick Seitz Materials Research Laboratory (FS-MRL) at Illinois have developed simple methods that allow the integration of wide ranging, dissimilar classes of transistors and other semiconductor devices on a single substrate, in two- or three-dimensional layouts. The approach uses specialized rubber “stamps” with functional “inks” consisting of high performance semiconductor materials in the form of micro and nanoscale ribbons, wires, tubes and bars. A printing operation delivers these materials to virtually any type of substrate, including lightweight, flexible plastic sheets. Circuits built in this way offer electrical and mechanical (e.g., bendability) attributes that would be impossible to achieve using conventional, wafer-based approaches to electronics.

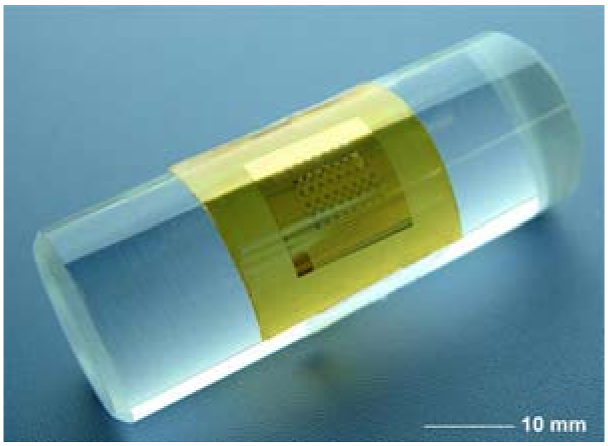
The invention of the transistor was considered by many to be one of the greatest inventions in modern history, ranking in importance with the printing press, automobile, and telephone. The research reported by the Illinois team seeks to exploit the power of transistors in new ways.

“Important new types of electronic systems will rely on the ability to mix and match wide ranging classes of devices in three dimensional configurations on unusual substrates,” explained John Rogers, a Founder Professor of Engineering at Illinois. “The circuits enabled by such approaches will open up interesting application possibilities that lie beyond the scope of existing single-material, wafer-scale electronics.” Examples include electronic eye imagers, advanced communication devices, large-area structural health monitors, and conformable sensor skins.

Rogers and his co-authors explain the fabrication processes together with the operation of the resulting devices and circuits in a paper, entitled, “Heterogeneously Integrated, Three Dimensional Electronics by use of Printed Semiconductor Nanomaterials,” which appears in the December 15, 2006 issue of *Science* magazine.

“We developed a simple approach to combine disparate types of semiconductor devices into heterogeneously integrated (HGI) electronic systems with two- or three-dimensional (3D) layouts,” added Rogers, who has appointments in the departments of materials science and engineering, chemistry, electrical and computer engineering, mechanical science and engineering, and is also a researcher at the Beckman Institute for Advanced Science and Technology.

The process begins with the synthesis of different semiconductor nanomaterials (e.g. single walled carbon nanotubes and single crystal nanowires/ribbons of gallium nitride, silicon and gallium arsenide) on separate substrates. Repeated application of an additive, transfer printing process that uses elastomeric stamps and these nanomaterials as ‘inks’ yields high performance 3D-HGI electronics that incorporate any combination of these (or other) semiconductors.



A key feature of the strategy is that it occurs at room temperature, thereby enabling the electronics to be placed on unconventional substrates such as thin sheets of plastic.

“This work shows that it is possible to liberate high performance electronic devices from semiconductor wafers and to integrate them onto surfaces and substrates that better serve important end applications,” explained Ralph Nuzzo, the William H. and Janet Lycan Professor of Chemistry and a professor of materials science and engineering, and a co-author on the paper.

The paper reports several demonstration systems that involve wide ranging types of devices, including silicon MOSFETs, GaN HEMTs, GaAs diodes and even transistors that use carbon nanotubes, formed in various combinations on rigid as well as mechanically flexible substrates in single and multilayer configurations. Besides these examples, the same methods enable integration of optical, sensing and micromechanical devices with these electronics to yield complete, multifunctional systems.

The *Science* article was co-authored by Jong-Hyun Ahn, a postdoctoral fellow, and co-workers Hoon-Sik Kim, Keon Jae Lee, Yugang Sun, Seokwoo Jeon, and Seong Jun Kang.

Supported by the U.S. Department of Energy, Division of Materials Sciences, the research was implemented with printing and nanomanufacturing approaches that are under development in the NSF Center for Nanoscale Chemical Electrical Mechanical Manufacturing Systems (NanoCEMMS). The work also benefited from the unique facilities at the University of Illinois at Urbana-Champaign including the FS-MRL Center for Microanalysis of Materials.

Contact: John A. Rogers, 217/244-4979, jrogers@uiuc.edu.

Writer: Rick Kubetz, Office of Engineering Communications, College of Engineering, 217/244-7716, rkubetz@uiuc.edu.

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