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Gutenberg + nanotechnology = printable electronics

(*Nanowerk Spotlight*) Nanoelectronics devices often are made by integrating dissimil semiconductors and various other disparate materials into one heterogeneous single primary modes of combining these materials - mechanical bonding and epitaxial grov place stringent requirements on the ultimate scale or constituent materials of circuits bonding, there is a limited ability to scale to large areas (i.e., larger than the wafers) (few stacking layers; incompatibility with unusual materials (such as nanostructured m temperature materials and substrates; challenging fabrication and alignment for the t electrical interconnects; demanding requirements for planar bonding surfaces; and b that can occur from mechanical strains generated by differential thermal expansion a disparate materials. Epitaxy avoids some of these problems but places severe restric and type of materials that can be grown. Using a process akin to the printing press, r managed to bypass the need for epitaxial growth or wafer bonding to integrate wide dissimilar semiconducting nanomaterials onto substrates for the purpose of construc three dimensional electronics.

Printed semiconductor nanomaterials provide new approaches to 3D heterogeneous systems that could be important in various fields of applications such as microfluidic integrated electronics, chemical and biological sensor systems that incorporate unus conventional silicon-based electronics, and photonic and optoelectronic systems that emitters and detectors of compound semiconductor with silicon drive electronics or m electromechanical structures. Furthermore, the compatibility of this approach with thi substrates may create additional opportunities for devices that have unusual form fac flexibility as key features.

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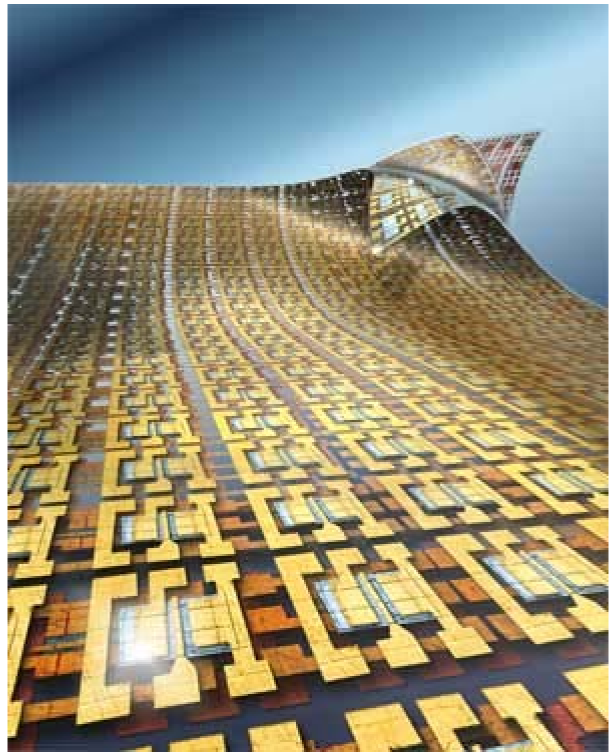

illustration based on confocal images of actual three layer stacks of transistors that ribbons of silicon for the semiconductor and a thin sheet of polyimide for the substra research group)

"Our approach, the combined use of semiconductor nanomaterials and printing techn quality electronics to be formed on diverse substrates, including nonplanar surfaces a sheets" John A. Rogers tells Nanowerk. "These capabilities, in particular the ability to component materials, all lie well outside of the range of things that can be achieved w wafer based approaches to electronics."

Rogers, a professor of chemistry, materials science and engineering at the University Urbana-Champaign, and his research group are trying to develop approaches that en performance electronics anywhere", i.e. they would like to extend semiconductor dev substrates other than the semiconductor wafer.

"Our goal is to invent methods that can allow interesting applications which cannot be conventional technologies, such as flexible displays, large area solar cells, conforma distributed structural and personal health monitors, curved surface imagers as electro Rogers. "Our belief is that inorganic semiconductor nanomaterials, delivered to a targ using printing techniques, forms an attractive way to achieve devices of these types."

The recent results by Roger's group show how dissimilar single-crystal inorganic sem as micro- and nanoscale wires and ribbons of GaN, Si, and GaAs) can be combined and also with other classes of nanomaterials (such as single-walled carbon nanotube the use of a scalable and deterministic printing method to yield complex, heterogene electronic systems in 2D or 3D layouts.

Specifically, the nanoscale semiconductor components are first fabricated, each on t substrate, through standard lithographic procedures, with ohmic contacts formed by d annealing. These components are then lifted from the source substrate by gentle var adhesion with an 'inking pad' made of polydimethylsiloxane, and then 'stamped' onto such as a sheet of polyimide.

After some additional processing – including deposition and patterning of gate dielec and interconnects – the transfer printing and device fabrication steps can be repeate spin-coating a new prepolymer interlayer on top of the previously completed circuit le

Rogers points out that this fabrication approach has several important features:

First, all of the processing on the device substrate occurs at low temperatures, therel differential thermal expansion and shrinkage effects that can result in unwanted defo multilayer stacked systems. This operation also enables the use of low-temperature | and interlayer materials, and it helps to ensure that underlying circuit layers are not tl by the processing of overlying devices.

Second, the method is applicable to broad classes of semiconductor nanomaterials, materials such as SWNTs.

Third, the soft stamps enable nondestructive contacts with underlying device layers; together with the ultrathin semiconductor materials, can also tolerate surfaces that ha topography.

Fourth, the ultrathin device geometries and interlayers allow easy formation of layer-t interconnects by direct metallization over the device structure. These features overcc disadvantages of conventional approaches.

The researchers demonstrated the capabilities of their printing process by fabricating stacks of high-performance metal oxide semiconductor field-effect transistors (MOSF mobility transistors (HEMTs), thin-film transistors (TFTs), photodiodes, and other con integrated into device arrays, logic gates, and actively addressable photodetectors oı flexible plastic substrates.

"We are now working to make these kinds of approaches realistic methods for manu Rogers. "We focus on (1) the development of tooling to automate the process, and (2 devices, i.e. electronic eye imagers, large area solar cells, and flexible displays), that utility of these approaches."

These findings have been published in a recent paper in the December 15, 2006 issu ("Heterogeneous Three-Dimensional Electronics by Use of Printed Semiconductor N

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