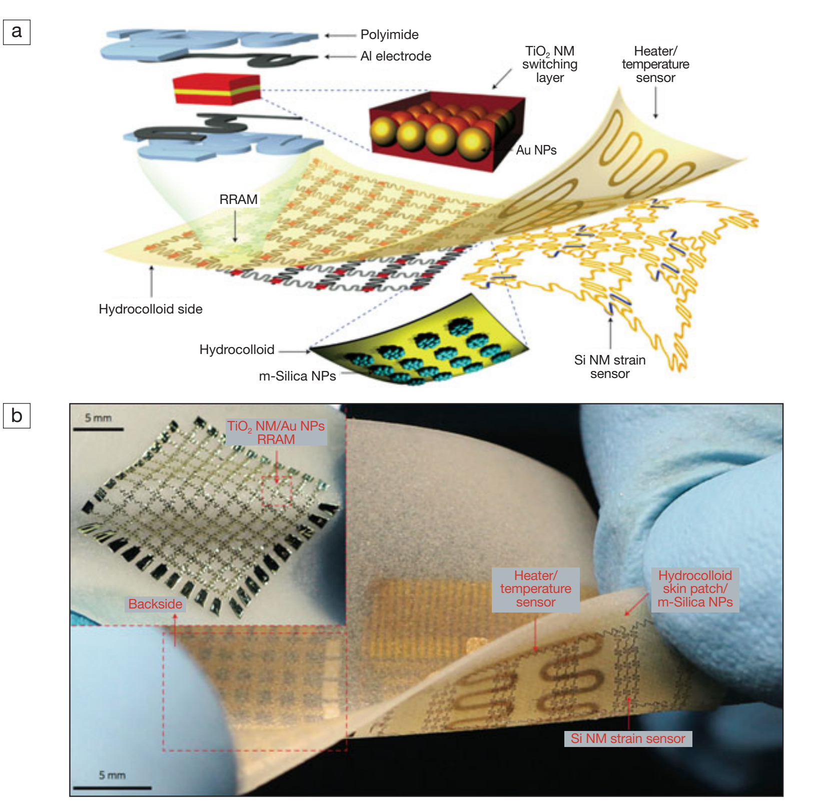
Bio Focus

Healthcare-on-a-patch: Responsive wearable materials

As widely commercialized personal wristbands that count our footsteps and monitor our sleeping patterns gradually gain a cultural foothold, some materials scientists are forging a new future for wearable bio-diagnostics through the clever application of nanotechnology. Industrial nanotechnology already enables wide-scale production of complex and useful tools (accelerometers in wristbands, for example), but seamless integration of such tools with the human body, an attractive prospect, is ripe with challenges. For example, brittle nanostructures at the heart of most electronics often require rigid encasements (e.g., metals or hard plastics) as protection from moisture and mechanical stress. This can make such structures uncomfortable bedfellows with the squishy, sweaty skin of the human body. Requisite physical robustness often amounts to sacrifices in ideal features for smart medical devices, such as robust electronic performance during long-term intimate skin contact.

Can sensing, responsiveness, and comfort be integrated into a single wearable device? A team of researchers based at Seoul National University in South Korea, along with collaborators at the University of Texas–Austin and flexible electronics company MC10 (based in Cambridge, Mass.), would surely say yes, having made an important recent contribution to body-tailored wearable electronics. Lead author D. Son of Korea and colleagues report their findings in the May issue of *Nature Nanotechnology* (DOI: 10.1038/nnano.2014.38; p. 397).

In an advance over previous systems, the researchers report construction of a resistive random access memory (RRAM) device that is integrated into a wearable polymer (hydrocolloid) patch for potential diagnostics and drug delivery applications.



A schematic overview of a wearable diagnostic and drug-delivering device. RRAM is resistive random access memory. Reproduced with permission from *Nature Nanotech*. **9** (2014), DOI: 10.1038/nnano.2014.38; p. 397. © 2014 Macmillan Publishers Ltd.

The device maintains its memory functionality when immersed in an aqueous buffer and also when stretched up to 25% strain. This flexible functionality is due in part to the use of thin serpentines as an important structural design feature (see Figure).

A key material component of the memory system is comprised of gold nanoparticles that are laid down neatly, a monolayer at a time, using Langmuir–Blodgett assembly. This assembly step is performed at a fabrication midway point, ultimately resulting in a nanoparticle sandwich, with nanomembranes of TiO_2 and Al on either side of the gold layer. A polymer further sandwiches the mineral layers to afford mechanical symmetry while enabling device lift-off from a Si substrate. The gold nanoparticle layer reduces current through the oxide at a given voltage applied to the metal, thereby yielding enhanced power efficiency of the skin-adhering resistive memory system.

In addition to a novel RRAM architecture, the researchers highlight relevant nanocomponents that could be integrated toward achieving a multifunctional wearable device. Signals indicating physiological changes (e.g., muscle contractions), as measured by Si-nanomembrane strain sensors, can be stored in the patch's RRAM. If a given physiological state is activated (e.g., intense, rapid muscle contractions), the patch can recognize the activity and respond by delivering drug-carrying mesoporous silica nanoparticles into the skin. A simple demonstrated delivery method involves activating a heating element on the multifunctional patch, which drives transdermal silica nanoparticle delivery through thermal diffusion. In this way, the researchers propose the overall wearable system could provide feedback therapy for treatment of muscle disorders.

With such important applications ahead, and with promising demonstrations at hand, further development of the technology awaits the introduction of battery and signal processing capabilities into a wearable format as well. Based on this recent study, though, future progress of wearable electronics is bound to be memorable.

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