obtained so far in bone repair by the 3D printing approach to be very encouraging, but not optimal. To overcome the difficulties related to scientific, clinical, and commercial areas, innovative developments are further proposed. In particular, new types of 3D advanced ceramic scaffolds based on OCP and plasmid DNA with the gene encoding vascular endothelial growth factor have been developed by us. We hope that these novel methodologies will truly represent a new product—and possibly a new gold standard—in the tissue engineering field of bone repair."

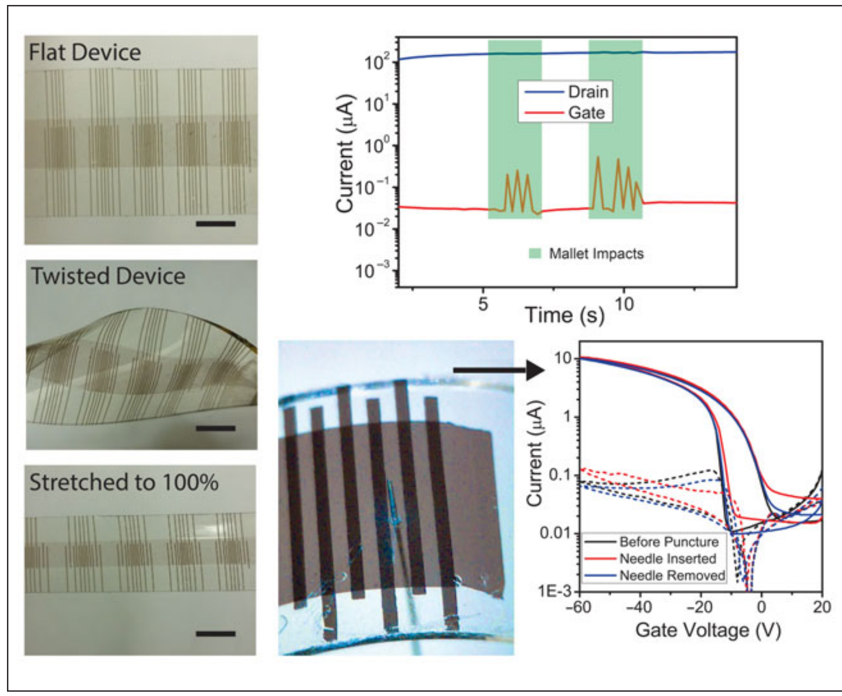
Yung Chan

Nano Focus

Stretchable carbon nanotube transistors are put to the test

The advent of wearable devices has signaled a modern trend toward higher levels of integrated technology. The natural progression of this field is a move from wearable technologies such as smartwatches or glasses to more cohesive or even implantable technology. However, current electronic transistors are typically made of stiff, brittle materials that make them unfit for applications that require flexibility or durability, such as in biomedicine or biosensing. In order for this evolution in personal technology to continue, significant strides must be achieved toward more adaptable electronics.

Interest in stretchable electronics has been growing rapidly in recent years and while numerous studies have demonstrated feasibility, they have yet to address the mechanical resilience of these devices. Alex Chortos and colleagues from Zhenan Bao's group at Stanford University and Samsung Electronics are setting the bar for mechanical robustness with a new study published in the July 14 issue of *Advanced Materials* (DOI: 10.1002/adma.201501828) on stretchable yet durable electronic transistors that can be easily interfaced with soft moving objects. The researchers developed a new type of flexible transistor using carbon nanotubes (CNTs) embedded in a tough, but flexible, biocompatible thermoplastic polyurethane. This was formed using a solution-processable sequential coating/transfer process which has the potential for high-throughput device fabrication. This durable polymer can be stretched and flexed without damage and, once punctured or cut, will even resist the propagation of a tear. When combined with CNTs, which independently possess a large tensile modulus, these durable transistors can be flexed and stretched, while still retaining the bulk of their electrical properties.



Photographs of the stretchable carbon nanotube transistor being twisted, stretched, and punctured. Accompanying graphs show electrical properties returning to normal after mallet impacts and needle punctures. Scale bars are 4 mm. Credit: Alex Chortos.

After fabrication, the stretchable transistors were put through a gauntlet of physical testing. The transistors were stretched to strain values up to 100% in directions both parallel and perpendicular to current flow. Stretching to 100% strain resulted in a negative shift in threshold voltage and a drop of nearly 50% in both ON and OFF current values. However, after the initial decrease with the first stretching cycle, these values remained relatively constant over 1000 more stretching cycles.

The researchers also tested how these transistors resist sudden impacts from both a rubber mallet and a metal hammer. They found that the gate current and ON current both increased at the time of impact, but returned to approximately the original value afterward.

Even after the transistors were punctured or cut, they still remained functional while strained and unstrained. However, the researchers say that there are still further tests to be made. "Eventually we'd like to test chemical stability and … environmental stability to see how that changes the performance of the device," Chortos says. The toughness of these transistors as well as their consistent performance while sustaining impacts, tears, and extensive stretching supports their potential use in the unpredictable and extreme environments of everyday life.

Ian McDonald

https://doi.org/10.1557/mrs.2015.206 Published online by Cambridge University Press