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Nanowire devices bend and flex

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Scientists from Harvard University, US, have used nanowires to make electronic devices on glass and plastic surfaces. The researchers made silicon nanowire field-effect transistors on both glass and plastic, and a light-emitting diode on a plastic substrate that used silicon and gallium nitride nanowires.


Nanowire solution

"Our work suggests that nanowires can be readily incorporated into next-generation macroelectronics, such as lightweight display, mobile computing and information storage applications," Mike McAlpine told *nanotechweb.org*. "Most interestingly, the high performance and ruggedness of these devices opens exciting doors for futuristic gadgets such as throw-away computers and flexible colour displays you can wear on your clothes or might be integrated into contact lenses."

To make the devices, the team grew single-crystal nanowires under optimum conditions. Then they made suspensions of the nanowires and deposited them onto the desired substrate by solution-based assembly.

"The philosophical breakthrough was the realization that we have the ability to synthesize high-quality single-crystal semiconductor nanowires at high temperature, but can then disperse these wires into solution and assemble them onto low-cost glass and flexible plastic substrates," said McAlpine. "The high-temperature requirement for achieving single-crystal semiconductors is what traditionally limits the quality of electronics on alternative substrates, since plastics melt at those temperatures. In our case, the separation of the high-temperature growth and room-temperature assembly processes allowed us to realize our goal of high-performance electronics on low-cost glass and plastic."

A p-type silicon nanowire field-effect transistor made in this way on a glass substrate had a hole mobility of 365 $cm^2 V^{-1} s^{-1}$. For a device on a flexible plastic substrate, the mobility was 135 $cm^2 V^{-1} s^{-1}$. According to the researchers, these mobilities are comparable to or better than the highest values reported for p-channel polycrystalline silicon transistors on nonalkali glass, and at least two to three orders of magnitude larger than typical values seen for amorphous silicon and organic transistors on glass and plastic substrates. Silicon nanowire/plastic devices also retained good characteristics when they were bent to a radius of curvature of 0.3 cm, exhibiting only a small drop in current.

McAlpine and colleagues also made crossed nanowire light-emitting diodes on plastic substrates. They used n-type gallium nitride nanowires and p-type silicon nanowires, which they deposited by sequential orthogonal fluid-directed assembly. Under forward-bias, the p-n junctions where the two types of nanowires intersected emitted ultraviolet light. Such devices could have applications in flexible self-emitting displays.

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"The next big step is to combine this approach with recent advances in our group towards fabricating large arrays of nanowire transistors, in order to reliably make thousands to millions of high-performance nanowire devices over an entire glass or flexible plastic substrate," said McAlpine. "The generality of the approach offers a flexible pathway for the bottom-up assembly of virtually any nanowire material into hierarchically organized devices for integrated information storage and display applications."

The scientists reported their work in *Nano Letters*.

About the author

Liz Kalaugher is editor of *nanotechweb.org*.

E-mail to a friend

Tel +44 (0)117 929 7481 | Fax +44 (0)117 930 1178 | E-mail info@nanotechweb.org