vapour–solid–solid growth in the branches of the same tree. The resulting Eshelby Twist offers a new type of nanoscale building block, with a unique chiral distribution of the branches.

After these first striking reports on the visualization of the effect, we can now expect that more observations will follow, and that further insights into the growth mechanisms and self-assembly of these exciting nanostructures will be uncovered. The work also raises a number of questions. As the coexistence of two different growth mechanisms has been demonstrated, are there further similar possibilities for assembling such wires? Do certain materials prefer certain growth mechanisms?

Moreover, the recent findings are made in lead sulphide and lead selenide, but nanowires have been synthesized in a vast array of materials. Thus, the sequential growth of epitaxial branches could perhaps be used with other materials to more easily reveal the Eshelby Twist. We can also look forward to better tailored nanomaterials, and the use of such helical brushes in, for example, complex three-dimensional networks of functional nanowires for sensor applications, or the realization of solid-state-based artificial neural networks[9].

References

1. Bierman, M. J. *et al. Science* **320,** 1060–1063 (2008).
2. Zhu, J. *et al. Nature Nanotech.* **3,** 477–481 (2008).
3. Eshelby, J. D. *J. Appl. Phys.* **24,** 176–179 (1953).
4. Frank, F. C. *Discuss. Faraday Soc.* **5,** 48–54 (1949).
5. Drum, C. M. *J. Appl. Phys.* **36,** 816–829 (1965).
6. Veblen, D. R. & Post, J. E. *Am. Mineral.* **68,** 790–803 (1983).
7. Wagner, R. S. & Ellis, W. C. *Appl. Phys. Lett.* **4,** 89–90 (1964).
8. Persson, A. I. *et al. Nature Mater.* **3,** 677–681 (2004).
9. Dick, K. A. *et al. Nano Lett.* **6,** 2842–2847 (2006).

SMART TEXTILES

Tough cotton

Cotton is an important raw material for producing soft textiles and clothing. Recent discoveries in functionalizing cotton fibres with nanotubes may offer a new line of tough, wearable, smart and interactive garments.

Alba G. Avila and Juan P. Hinestroza
are at the Textiles Nanotechnology Laboratory, Department of Fiber Science and Apparel Design at Cornell University, Ithaca, New York USA.
e-mail: jh433@cornell.edu

Despite the many high-performance synthetic polymers used in the textile industry today, cotton is still preferred because it is soft, does not irritate the skin and is cool to wear in warm climates. Cotton is the soft fibre that grows around the seeds of the cotton plant and the fibres consist primarily of a natural polymer known as cellulose. Evidence of cotton being grown, spun and woven into cloth can be traced as far back as 3,000 BC in the valleys of the Indus and Nile rivers of Pakistan and Egypt. The invention of the cotton engine (also known as the cotton gin) by Eli Whitney is perhaps one of the most tangible outcomes of the American industrialization spirit of the 18th century[1]. Recent advances in materials chemistry and surface functionalization are about to revolutionize the use of cotton for load-bearing, ballistic and abrasion-resistance applications and as a wearable platform for biosensors and electronics.

Writing in the *Journal of Materials Chemistry*, Yuyang Liu, John Xin and colleagues[2] at the Hong Kong Polytechnic University and University of Minnesota, inspired by the configuration of commercial communication cables, have shown that cotton fabrics can be coated with carbon nanotubes for improved mechanical properties, flame retardancy, ultraviolet-blocking and water-repelling characteristics. The team first grafted a polymer, polybutylacrylate, onto the surface of the nanotubes and applied the modified nanotube emulsion as a finish to cotton fabrics via the traditional dipping, drying and curing procedure. The technique appears simple and scalable, and can be easily incorporated into existing textile manufacturing processes.

Scanning electron microscopy images show that the nanotubes form a crosslinked network (roughly 500 nm thick) around the cotton fibres as a reinforcement

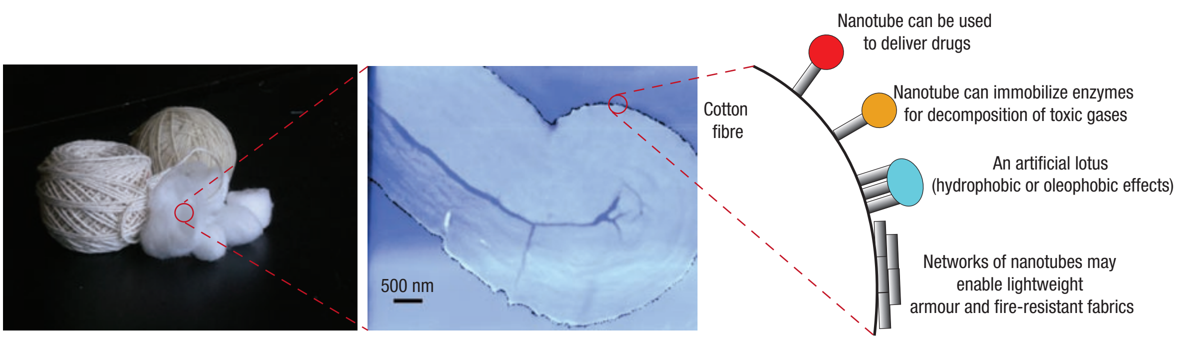

Figure 1 Possible applications of cotton. Cotton balls and yarn (left). Transmission electron micrograph of a single cotton fibre showing its characteristic bean-like shape (middle). The schematic (right) shows that carbon nanotube coatings on the cotton fibre can be modified in a variety of ways. Drugs can be encapsulated in the tubes for controlled delivery, enzymes can be immobilized for detoxifying dangerous gases, and intercalated tubes can form strong fire-resistant lightweight fabrics. Combining nanotubes with cotton offers fabrics with improved properties. © Textile Nanotechnology Laboratory at Cornell University.

and protective shell. The nanoscale and hydrophobic structures of the network enable the otherwise water-absorbing cotton to repel water nearly as efficiently as the lotus leaf. Furthermore, the treated fabrics are stronger and more resistant to tears. Nanotube concentrations of over 2% in the applied emulsion made it more difficult for the cloth to catch fire and prevented burning by forming a carbonaceous amorphous char on the surface of the cotton, which behaved as a heat shield. With just 0.25% of nanotubes, more than 90% of the harmful ultraviolet rays that would normally penetrate an untreated fabric could be blocked.

Strong fabrics with ultraviolet resistance and water-repellent properties may offer new alternatives to soft linings in marine and outdoor applications. Furthermore, cotton fabrics coated with nanotubes that are modified with enzymes capable of detecting and detoxifying chemical warfare agents could offer a new line of comfortable chemical protective clothing for the military and civilian first responders[3]. Textiles coated with nanotubes modified with other enzymes may also be used to make drug-impregnated gloves for arthritic patients or be used as a bed lining for transdermal drug delivery while a person sleeps on it.

The reported results are impressive and future studies using highly pure nanotubes with a specific set of well-characterized electrical, chemical and physical properties will offer a myriad of tailor-made applications. If the electronic properties of the nanotubes on the surface of the cotton can be harnessed, it will be possible to design wearable sensors or to build power generators and energy storage capabilities into the clothing.

For example, the piezoresistance properties of nanotubes may be used to detect variations of electrical conductance as a function of mechanical deformation of the fabrics. This could be used to monitor the motion of muscles and limbs for rehabilitative and telemedicine applications. Because chirality (or handedness) of nanotubes defines whether they are metallic or semiconducting, it is possible to engineer fabrics that are either insulating or conducting.

If a single layer of nanotubes can be deposited around the cotton fibre, the configuration of an insulating fibre located directly underneath a conductive layer may be exploited to fabricate flexible transistors[4]. Multilayering, on the other hand, may allow high rates of conduction with low rates of heat dissipation, making low-power wearable electronics a closer reality[5].

The reported results are of great interest and further studies are needed to understand the mechanisms responsible for the improved properties. The synergy between a flexible renewable natural substrate such as cotton and the increasing multifunctionality of nanotubes offers an endless number of possibilities. Perhaps one day it will allow us to dress like superheroes.

References

1. http://www.cotton.org
2. Liu, Y., Wang, X., Qi, K. & Xin, J. H. *J. Mater. Chem.* doi: 10.1039/b801849a (2008).
3. Wang, J. Timchalk, C. & Lin, Y. *Env. Sci. Technol.* **42,** 2688–2693 (2008).
4. Maccioni, M., Orgiu, E., Cosseddu, P., Locci, S. & Bonfiglio, A. *Appl. Phys. Lett.* **89,** 143515–143518 (2006).
5. Hyde, G. K., Park, K. J., Stewart, S. M., Hinestroza, J. P. & Parsons, G. N. *Langmuir* **23,** 9844–9849 (2007).

INSTRUMENTATION

Astronomers look to nanotechnology

A superconducting detector can count photons and measure their energy with an accuracy that could be good enough for space-based far-infrared telescopes.

Daniel E. Prober

is in the Department of Applied Physics, Yale University, New Haven, Connecticut 06520, USA.

e-mail: daniel.prober@yale.edu

Astronomers are greedy: they want to capture as much light as possible and extract every possible piece of information from even the faintest signal. A new detector[1] developed by researchers in the US now offers the possibility of unprecedented sensitivity at far-infrared wavelengths — a region of the electromagnetic spectrum that contains a wealth of information about the most-distant, and therefore the oldest, objects in the universe. This region of the spectrum has remained painfully elusive for astronomy to date, but a number of space-based telescopes, such as those of the SAFIR mission[2,3], are now being planned to explore the formation of galaxies, stars and planetary systems at far-infrared wavelengths.

Light from the most distant reaches of the universe is best detected in the far-infrared region, which runs from about 100 μm to 1 mm, because visible light is typically obscured by dust clouds in space. However, far-infrared light is absorbed by the Earth's atmosphere, which means that the most sensitive telescopes observing at these wavelengths need to be based in space. Another challenge is that far-infrared signals tend to be very weak, even by astronomical standards, because they have travelled extremely long distances.

Advances in far-infrared astronomy therefore depend on the development of much more sensitive detectors for photons at these wavelengths. On page 496, Michael Gershenson, Boris Karasik and co-workers[1] at Rutgers University, the Jet Propulsion Laboratory and the State University of New York at Buffalo combine recent advances in nanolithography, low-temperature physics and quantum detectors to make a bolometer — a device that can measure the energy of photons — that might offer the level of performance needed to detect single far-infrared photons.

For a century, ever since Einstein explained the photoelectric effect, it has been known that light comes in packets known as photons. The visible region of the spectrum runs from about 700 nm (red photons with energies ~1.6 eV) to about 400 nm (violet photons with energies ~3.0 eV). We do not experience the photon aspect of visible light in our everyday lives, but the quantum nature of radiation at X-ray wavelengths — where the photons have energies of 1,000 eV or higher — can be heard in the clicks of a Geiger counter, with each click corresponding to the absorption of an X-ray photon.

In a Geiger counter, every X-ray photon liberates a photoelectron, producing an electrical cascade that is then converted into a click. Modern solid-state detectors