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The heat is off

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Researchers at Cambridge University have made a breakthrough in the manufacture of carbon nanotubes. They claim it heralds the beginning of the end for the silicon industry and the start of a new era of carbon nanotube-based miniaturised electronic applications.

The team from the university's engineering department has developed a way of growing single-wall carbon nanotubes at far lower temperatures than was previously believed possible.

The benefits of using carbon nanotubes in electronics has been known for some time. As one of the strongest materials known, they exhibit incredible strength, and their unique properties mean they can theoretically withstand an electrical current density more than 1,000 times greater than silver or copper.

For this reason carbon nanotubes are seen as the future of the electronics industry and according to Cambridge researcher Dr Mirco Cantoro, nanotubes will eventually replace silicon as the dominant electronics technology. He believes his team's work is the first big step towards this.

Temperature hurdle

Until now, the biggest challenge in integrating carbon nanotubes into current complementary metal-oxide semiconductor (CMOS) technology has been that of temperature. To create carbon nanotubes using the method known as chemical vapour deposition (CVD) the substrate must be heated to temperatures often approaching 700ºC.

But it is impossible to integrate carbon nanotubes on to semiconductors at temperatures greater than around 400ºC as the inter-metal dielectrics become damaged and much of the chip's processing capability is lost, thus nullifying the benefit of the nanotubes.

Cantoro and his colleagues have experimented using CVD to closely control the development of the thin films of nanotubes and were able to reduce the temperature at which the nanotubes grow from 700ºC to 600ºC and finally to the breakthrough temperature of 350ºC. Cantoro describes 350ºC as being a 'technologically relevant number' as it means that the integration of nanotubes into semiconductors can now begin.

'Thin-film technology has been known for a long time but the role of pre-treatment of the catalyst or growth conditions was never really understood before,' said Cantoro. 'The key is that if you pre-treat the catalyst then you can lower the temperature at which you can grow the nanotubes. Growing them at lower temperatures also means you can have much greater control over their growth and their properties.'

Cantoro admits there are a number of technical obstacles to overcome before carbon nanotubes can begin to usurp silicon for electronics supremacy. These include the ability to closely design the conductive properties of the nanotube and the difficulties inherent in growing a nanotube from one point to another, said Cantoro.

Huge step forward

He said: 'Dealing with the temperature issue is a huge step forward towards integration of nanotubes into silicon devices. Once nanotubes are used in electronics, devices will be able to operate at much higher speeds and applications that we cannot even conceive at the moment will

become possible.'

Cantoro said the current trend of squeezing circuits and semiconductors into smaller and smaller spaces means there is a much greater current density on the circuits. As nanotubes are better able to withstand high current density than silicon, they could open up a whole new world of powerful miniaturised electronics, he says.

The team's next step is to work on integrating the carbon nanotubes fully with silicon semiconductors.

Cantoro claimed that by early 2010 the first commercial circuits and semiconductor chips based entirely on carbon nanotubes will be in development.