Tuning lasers at the nanoscale

NANOTECHNOLOGY

By creating semiconductor nanowires surrounded by multiple concentric quantum wells, researchers at Harvard University and the Georgia Institute of Technology have succeeded in fabricating tunable miniature lasers [Qian *et al*, Nature Materials (2008) doi:10.1038/nmat2253].

These nanowires are long, thin rods, with diameters of just a few hundred nanometers but lengths of several micrometers. They can be synthesized through self-assembly, and they demonstrate electronic properties that are not present in the bulk material.

To date, most nanowires have consisted of a single material, leaving little possibility to vary the properties directly. When applied to lasing, for example, the material choice determines both the optical gain of the medium and the dimensions of the cavity, making it difficult to tune the emission wavelength.

In their study the researchers addressed this limitation by starting out with a single gallium-nitride core, but surrounding it with alternating layers of indium-doped material. While these layers (quantum wells), have thicknesses of just a few nanometers and alter the structure very little, they strongly impact its electronic properties. For the miniature lasers, it means that the properties of the gain medium can now be adjusted nearly independently from the optical cavity itself.

A composite, pseudocolor image showing light emission from MQW nanowire lasers with different compositions (Courtesy of Charles Lieber).

This approach is not limited to lasing, however, as Charles Lieber of Harvard University says. "These Multi-Quantum Well (MQW) nanowires go far beyond the compositional variation demonstrated in previous experiments, and enable new or enhanced properties associated with quantum confinement".

By changing the composition of the shell layers, the researchers were able to tune the lasing wavelength from 365 to 494 nm. "However, these lasers are only an example of what is possible with this new approach," Lieber continues. "The ultimate goal of this research is to develop electrically-driven, multicolor, low-threshold nanolaser arrays, and to apply them to integrated optical-electronic chips. We are actively pursuing this goal in two directions, including optimization of the MQW structure to achieve lower laser thresholds (based on optical pumping studies), and electrical excitation of MQW lasers through complementary doped core/shells."

Peter Dedecker

Building a better gecko

BIOMATERIALS

Walking effortlessly across vertical surfaces, or hanging comfortably from the ceiling, gecko lizards are capable of performing feats we haven't quite figured out how to replicate yet. The adhesive strength of gecko feet is higher than that of most artificial adhesives, and can latch onto almost any surface.

Attempts to design a mimetic system have met with little success. Until recently, that is, as a collaboration between different US research groups has now produced a material with remarkable properties [Qu *et al*, Science (2008) doi:10.1126/science.1159503].

At the core of this material are vertically-oriented carbon nanotubes with a twist: the ends of the tubes consist of a coiled and entangled segment, which can engage in strong interactions due to its efficient side contact.

"These designs match the structure of real gecko feet, which have microscopic hairs that branch off in different directions," explains Liming Dai of the University of Dayton. "For the first time, they also demonstrate anisotropic adhesion forces: while the strong shear adhesion force (about 100 N/cm^2) keeps the nanotube adhesive attached very strongly to the vertical surface, the normal adhesion force is only about 10 N /cm^2, so it can be easily removed by pulling away from the surface in a normal direction. The very strong shear binding force is about ten times stickier than natural gecko feet, and three times stickier than any other gecko-inspired glues."

The key to this mechanism lies in the alignment of the nanotube ends, Liming continues. "When the adhesive is pulled in a direction parallel to its surface, the tangled portion of the nanotubes aligns with the substrate, drastically increasing the sticking interaction. In contrast, when lifting in a direction normal to the substrate surface, as one would peel off a piece of Scotch tape, the nanotubes lose contact point by point, minimizing the normal adhesion force."

The applications could range from low-tech fridge magnets to electronics or even airplane parts. For instance, rather than soldering components into electronic devices, using these adhesives would make the parts easy to remove and replace. As a dry adhesive, the carbon nanotube material would also have many uses in space, where the vacuum causes traditional adhesives to dry out. More futuristic applications might include climbing robots, super-grip tires and rapid-repair systems.

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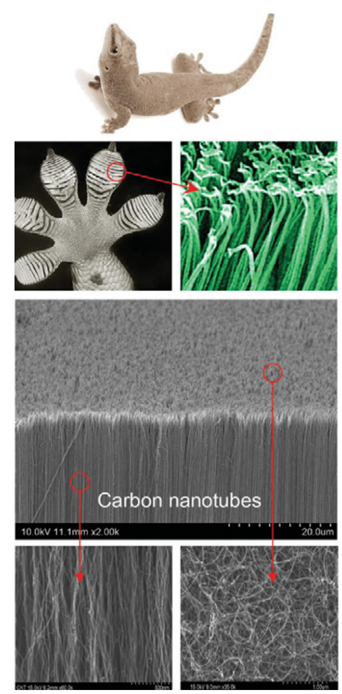

Thanks to US researchers and gecko lizards, traditional adhesives are in for some strong competition from an artificial system made out of carbon nanotubes.