Nanotunes

CARBON nanotubes have been all the rage in chemistry over the past decade, but actual applications are thin on the ground. The tubes (cylinders a few billionths of a metre across, whose walls are made of carbon atoms) have found their way into tennis racquets and bicycles' handlebars, where they provide strength and stiffness. But Lilliputian nanoradios, nanomotors and the like have, so far, been confined to the laboratory.

With luck, that fate will be avoided by the latest addition to the list. Carbon nanotubes, it turns out, can be used to make paper-thin loudspeakers. As they report in a forthcoming issue of *Nano Letters*, a group of researchers led by Jiang Kaili of Tsinghua University in Beijing have developed a transparent film made of nanotubes. When electrodes are attached to the ends of this film, and a signal-carrying current is passed through it, the result is a sound that matches the signal. Carbon-nanotube speakers play music with a fidelity similar to that of conventional loudspeakers. What is more, they continue to play even while they are being bent and stretched.

A conventional "moving coil" loudspeaker—like the one in your stereo—is made of a bulky permanent magnet, a coil of copper wire and a flexible diaphragm, housed in an enclosure. When a varying electrical current is passed through the coil it creates a varying magnetic field that interacts with the field of the permanent magnet. The diaphragm moves back and forth in response to this interaction, causing pressure waves to form in the air in front of it. The listener perceives these waves as sound.

Nanotubes produce sound by a different mechanism, known as the "thermoacoustic effect", which is also responsible for the thunderclap that follows a burst of lightning. Lightning is created when an electrical arc jumps between clouds, or between clouds and the ground. The arc heats the air surrounding it and causes that air to expand rapidly, producing a shock wave that is heard as thunder. With the nanotubes, variations in the electrical current cause the air surrounding the tubes to heat up (and thus expand) or cool (and thus contract), which produces pressure waves that register as sound. The beauty of generating sound this way is that no bulky magnets or moving diaphragms are needed.

In fact, the thermoacoustic effect has been employed in a similar way before. In the 19th century, a device called a thermophone, which used metal sheets to generate sound, was developed. But the effect was so weak that the thermophone never took off. Dr Jiang says nanotubes produce a bigger thermoacoustic effect than metal because carbon has a lower heat capacity. More of the converted electrical signal thus ends up in the air.

Potential applications of flexible and stretchable carbon-nanotube loudspeakers include speakers on clothing, windows, flags, and video and laptop screens. It helps that nanotube films continue to produce sound if torn, unlike a torn diaphragm in a conventional loudspeaker. Earphones and hearing aids might also benefit from the new approach.

There is some way to go before the technology can be commercialised. The biggest task is devising a way to create the necessary films in industrial quantities. But if that can be done, the next generation of loudspeakers may be almost invisible. The speaker-banks at rock concerts will never be the same again.

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