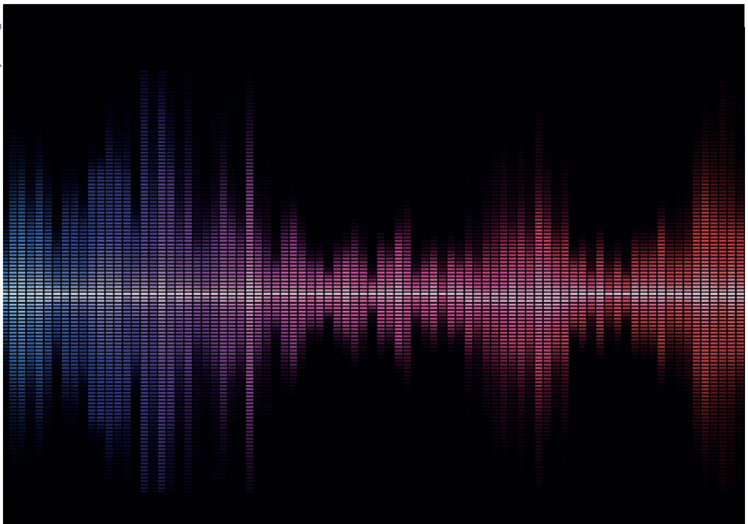
Nature Reviews Materials | Published online 27 Jun 2017; doi:10.1038/natrevmats.2017.47



iunewind/Getty Images

ACOUSTIC METASURFACES

Ultrathin sound diffusers

Sound diffusers based on acoustic metasurfaces can be one order of magnitude thinner than conventional diffusers while retaining comparable performance, Yun Jing and colleagues report in *Physical Review X*.

Sound diffusers scatter sound waves in all directions, avoiding undesired echoes and reflections, but preserve sound energy (unlike sound absorbers). They are used to improve the quality of sound in recording studios, concert halls and auditoria, but can also find application as noise reducers in urban streets. A common type of commercial diffuser, first introduced in the 1970s, is the Schroeder diffuser. These diffusers are composed of a series of wells of different depths that are designed to scatter sound in a predictable way. However, Schroeder diffusers can be very bulky: for low frequencies, such as the frequency of human voices or traffic noise, they can be as thick as 70 cm, which limits their applicability.

The researchers addressed the need for thinner sound diffusers by incorporating the concept of metasurfaces in the device design. Metasurfaces are composed of building blocks — known as meta-atoms — that are engineered to give the material unusual properties that are not observed in conventional materials. "I have been working with metasurfaces for a few years now, and although their physics is very interesting, I wanted to find a practical problem for which they could really help," says Jing. "I have a background in architectural acoustics and am aware of the limitations of conventional sound diffusers; thus, after discussing with Jianchun Cheng and Bin Liang from Nanjing University, who are experts in acoustics, we decided to work together on this project." Rather than wells, which are the basis of conventional Schroeder diffusers, the metasurface-based devices are composed of meta-atoms that are shaped as parallelepipeds with a square base, a height that is only 5% of the wavelength of the target sound wave and a square opening on top. The width of this opening is the only tunable parameter of the system and allows the acoustical response to be controlled. The material of choice for the devices, which are 3D printed, is plastic.

A combination of numerical simulations and experiments has demonstrated that the performance of these new systems is comparable to that of Schroeder diffusers. However, the basic design suffers from a relatively narrow bandwidth, which stems from the resonant nature of the meta-atoms, a problem that Schroeder diffusers do not have. To overcome this limitation, the researchers produced hybrid structures with meta-atoms that operate at different frequencies. This broadband version of the device has a performance as good as that of Schroeder diffusers but is an order of magnitude thinner, so that diffusers that are only a few centimetres thick can efficiently scatter low-frequency sound.

"Our ultimate goal is to commercialize these diffusers," says Jing. "Our structure is simple and relatively easy to manufacture. Right now, the main challenge is the bandwidth; in particular, we need to improve the high-frequency performance." These ultrathin sound diffusers are poised to improve architectural acoustics, and might be the first step on the way to real-life applications of metasurfaces.

Giulia Pacchioni

> “I have been working with metasurfaces for a few years now, and although their physics is very interesting, I wanted to find a practical problem for which they could really help”

ORIGINAL ARTICLE Zhu, Y. *et al.* Ultrathin acoustic metasurface-based Schroeder diffuser. *Phys. Rev. X*, **7**, 021034 (2017)
FURTHER READING Cummer, S. A., Christensen, J. & Alù, A. Controlling sound with acoustic metamaterials. *Nat. Rev. Mater.* **1**, 16001 (2016)