Microelectronics and Microsystems
Advanced Microfabrication

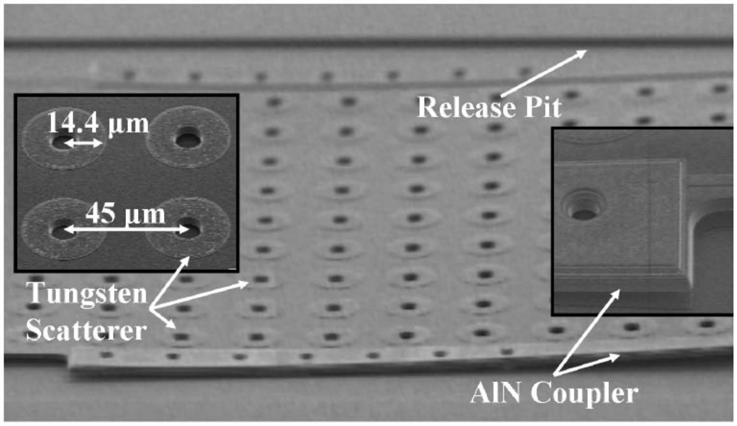

Figure 1: SEM image of a suspended 67 MHz acoustic crystal.

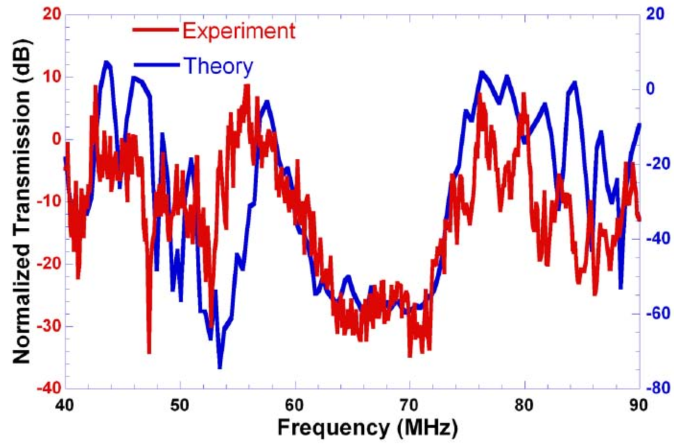

Figure 2: Measured and theoretical acoustic transmission.

Synthetic Acoustic Bandgap Materials

New microfabricated materials offer unique capabilities to control acoustic wave propagation and frequency distribution.

An acoustic bandgap (ABG) is the acoustic wave equivalent of an electronic or photonic bandgap, where a wide range of frequencies are forbidden to exist in a structured material. ABGs thus offer the unique capability to control the propagation and distribution of acoustic waves or phonons. This, in turn, provides a new research tool for studying phonon interactions, and is applicable to acoustic devices such as radio frequency (RF) resonators and filters, ultrasound, and thermal management. The majority of applications and novel physics enabled by ABG materials require solid, low loss structures operating in the 10 MHz to 100 GHz regime with length scales ranging from 100 µm to 10 nm. Prior ABG work has been limited to large, hand-assembled structures operating at frequencies below 1 MHz. Now, Sandia researchers are utilizing advanced microfabrication and modeling capabilities to scale ABG devices to submicron length scales and to frequencies in excess of 1 GHz, where the full potential of this technology can be realized.

Shown in Figure 1 is a scanning electron microscope (SEM) image of a micromachined acoustic crystal. The micro-ABG is comprised of a lattice of high acoustic impedance tungsten scatterers in a low acoustic impedance silica medium. Interrogation of the ABG is accomplished by aluminum nitride piezoelectric couplers, integrated on both sides of the bandgap material, that generate and detect acoustic waves. The measured and theoretical transmission of phonons though the ABG material versus frequency, normalized to the phonon transmission through a solid piece of silica, is shown in Figure 2. A wide bandgap is observed between 63 and 72 MHz, where acoustic transmission is attenuated by greater than 25 dB.

Micro-ABGs are very useful for acoustic isolation of microfabricated devices such as RF resonators and sensors. They can also be fabricated in ways to create novel devices in the acoustic crystal. For example, defects in the micro-ABG lattice through removal of W rods (Figure 3) have already been used to realize miniature acoustic waveguides that have applications in ultrasound and signal processing. In the future, defected acoustic crystals will be used to realize "mirrors" for micro-cavities, thus providing higher frequency selectivity than competing technologies. As the ABGs are scaled to even smaller sizes operating at higher frequencies, applications in thermal management and engineering the thermal noise distribution of a material become feasible.

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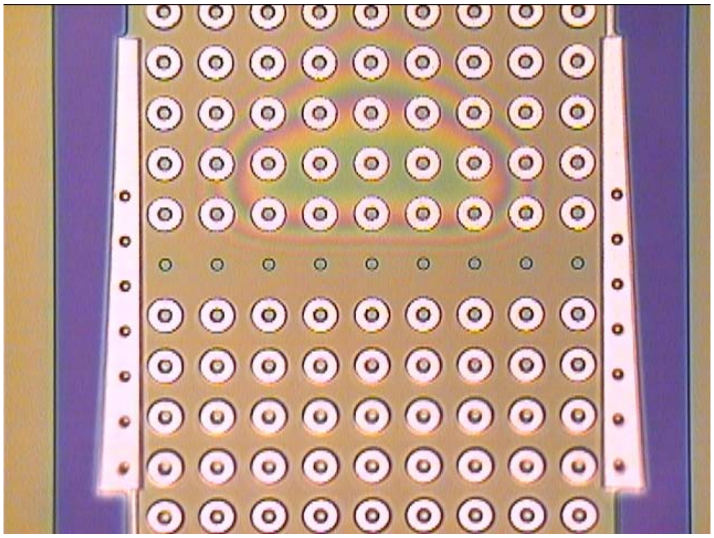

Figure 3: W1 acoustic waveguide realized by removing a single row of W rods from the acoustic crystal.

Publications

R. H. Olsson III, I. F. El-Kady, M. F. Su, M. R. Tuck, and J. G. Fleming, "Microfabricated VHF Acoustic Crystals and Waveguides," *Sensors and Actuators A: Physical*, In-Press.

R. H. Olsson III, J. G. Fleming, I. F. El-Kady, M. R. Tuck, and F. B. McCormick, "Micromachined Bulk Wave Acoustic Bandgap Devices," *International Conf. on Solid-State Sensors, Actuators, and Microsystems*, pp. 317-321, June 2007.

J. G. Fleming, R. H. Olsson III, I. El-Kady, and M. Tuck, "CMOS Compatible, Electrically Transduced, Acoustic Bandgap Structures," *International Symposium on Photonic and Electromagnetic Crystal Structures*, April 2007.

I. El-Kady, J. G. Fleming, R. H. Olsson III, and T. S. Luk, "Modeling of Micromachined Acoustic Bandgap Structures and Devices," *International Symposium on Photonic and Electromagnetic Crystal Structures*, April 2007.

Patent Applications

R. H. Olsson III, J. G. Fleming, I. F. El-Kady, and F. B. McCormick, "*Microfabricated Bulk Wave Acoustic Bandgap Device*," United States Patent Application, 11/748,832, May 2007.

Sandia National Laboratories

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