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Thermoacoustic sound projector: beyond the fundamental efficiency of carbon nanotubes

The combination of smooth continuous sound spectra produced by a sound source having no vibrating parts, a nanoscale thickness of an active flexible layer and the feasibility of creating large projectors provoke interest in thermoacoustic phenomena. However, at low frequencies, the sound pressure level and the sound generation efficiency of open carbon nanotube sheets (CNTS) is low. In addition, the nanoscale thickness of fragile heating elements, their high sensitivity to the environment and the high surface temperatures practical for thermoacoustic sound generation are other drawbacks that merit the need for a protective encapsulation of freestanding CNTS in inert gases. However, the protective enclosure restricts the heat dissipation from the resistively heated CNTS and the interior of the encapsulated device. Here, the heat dissipation issue is addressed by short pulse excitations of the CNTS. An extended linear power dependence of the generated sound pressure and an increase of Carnot's cycle efficiency by more than three orders (from 10-5 to 0.1) using short pulse excitations were observed. The sound pressure level higher than 120 dB re 20μPa at 1 m in air and >170 dB re 1μPa @ 1m in water result from optimal signal processing and high exchange coefficient of chosen nanostructured materials. Using single pulse per period excitation with duty cycle of 10% at f=300 Hz we reached the sound pressure limit which ruptures the water (cavitation). We provide an extensive experimental study of pulse excitations in different thermodynamic regimes for freestanding CNTS with varying thermal inertias (single-walled and multi-walled with varying diameters and number of superimposed sheets) in vacuum and in air. The experimental observations are rationalized within a basic theoretical framework. The acoustical and geometrical parameters providing further increase in efficiency and transduction performance for open and closed resonant systems operating in air and underwater are discussed.

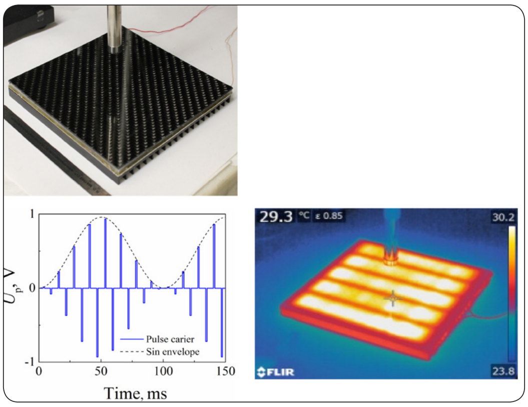

Figure 1: A picture of the TA projector with the microphone placed 3 cm above the projector. The right column shows a thermal image of the projector at an applied power of 20 W and the shape of optimal applied signal.

Recent Publications

1. Aliev A E, Perananthan S and Ferraris J P (2016) Carbonized electrospun nanofiber sheets for thermophones. ACS Appl. Mater. Interfaces. 8(45):31192-31201.
2. Aliev A E et al. (2015) Alternative nanostructures for thermophones. ACS Nano. 9(5):4743-4756.
3. Aliev A E et al. () Thermal management of thermo-acoustic sound projectors using a free-standing carbon nanotube aerogel sheet as heat source. Nanotechnology. 25(40):405704.
4. Aliev A E, Gartstein Y N and Baughman R H (2013) Increasing the efficiency of thermoacoustic carbon nanotube sound projectors. Nanotechnology. 24:235501.
5. Aliev A E, Lima M D, Fang S and Baughman R H (2010) Underwater sound generation using carbon nanotube projectors. Nano Letters. 10(7):2374-2380.

Biography

Ali E Aliev, Research Professor at Alan MacDiarmid NanoTech Institute, University of Texas at Dallas has earned his PhD and Doctor of Science Degrees at USSR Academy of Sciences (Uzbekistan) in 1984 and 1992, respectively. His scientific interests are in transport phenomena in nanoscale. He develops thermoacoustic projectors based on freestanding carbon nanotube sheets, graphene sponges and other alternative nanostructure for application in air and underwater.

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