Multiphysics Simulation of Nanostructured Thermoacoustic Loudspeakers

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The recent advancements in the synthesis of solution-processed nanomaterials and the development of facile printing techniques allow the fabrication of nanostructures with unprecedented physical properties. The spray-coating deposition of solution-processed metallic nanowires enables for instance the fabrication of nanostructured layers, characterized by a low electrical resistance and an extremely low heat capacity [1]–[4], recognized as a promising solution for the development of efficient thermoacoustic (TA) loudspeakers [5]–[7]. The TA loudspeaker technology have long been studied but the models reported in literature are not fully adequate for the model-driven development of the technology, either lacking of a description of the device thermal behavior [8], [9], not accounting for the 3D geometry of the thermal and acoustic fields in air [10], [11], or neglecting the contribution of the heat losses due to convection and radiation [12]. In this work we present a multiphysics model of the TA loudspeaker transduction, overcoming the above limitations by considering the full electro-acoustic transduction as a sequence of two atomic processes: an electro-thermal transduction, describing all the involved thermal processes, and a thermo-acoustic transduction, accounting for the interaction between the thermal and acoustic fields. The model very accurately reproduces the response of nanostructured TA loudspeakers, providing a useful tool for further developing the technology.

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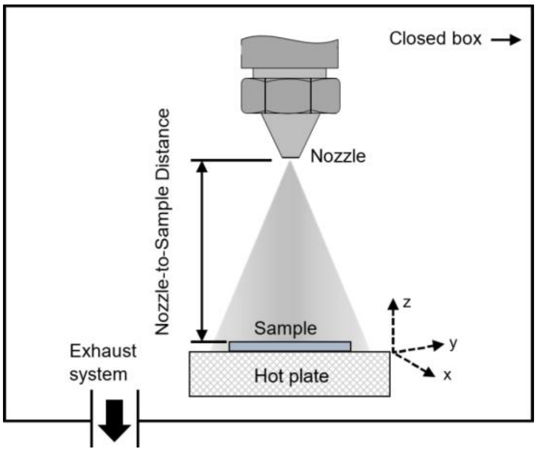

Fig.1: Schematic for a spray-coating setup that utilizes a spray gun, closed box, exhaust system and a movable hot plate.

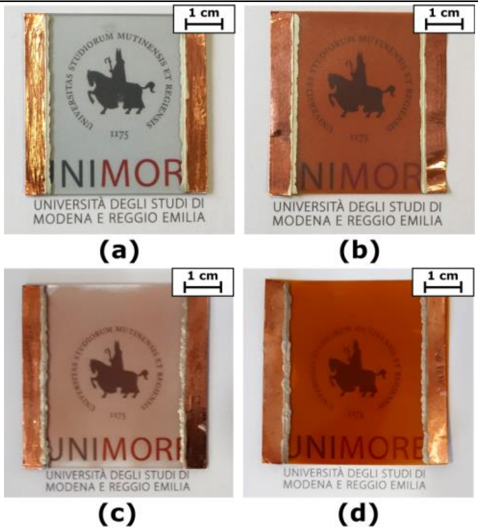

Fig.4: Thermoacoustic loudspeaker samples fabricated through spray coating of solution processed metallic nanowires: (a) silver nanowires deposited on glass; (b) silver nanowires deposited on Kapton; (c) copper nanowires deposited on glass; (d) copper nanowires deposited on Kapton.

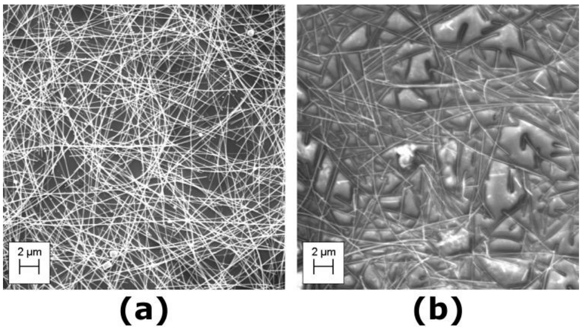

Fig.2: SEM-image of the conductive random network fabricated by spray-coating deposition of silver nanowires on glass (a) and Kapton (b).

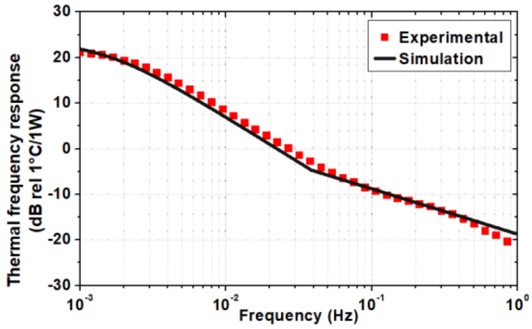

Fig.5 Experimental (colored symbols) and simulated (black solid line) thermal frequency response (power to temperature) of the TA loudspeaker sample made of silver nanowires on glass.

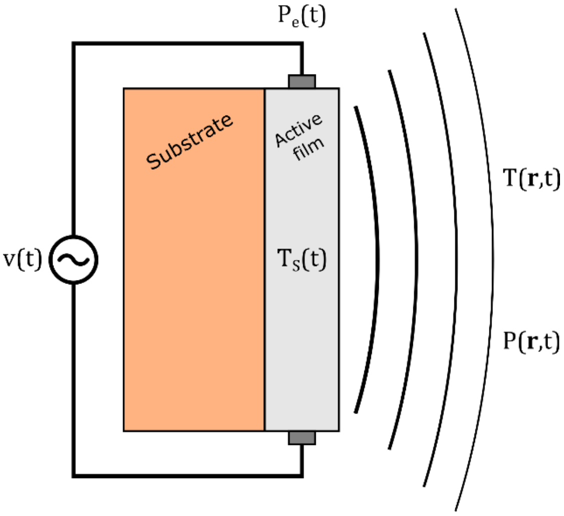

Fig.3: Structure of a solid substrate TA loudspeaker.

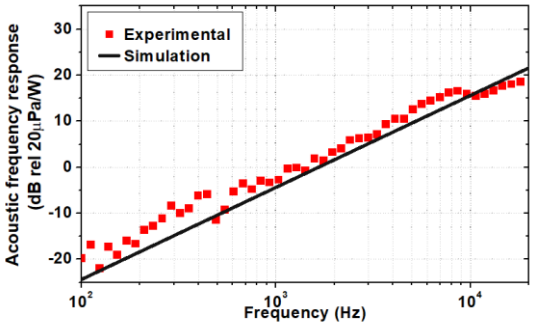

Fig.6 Experimental (colored symbols) and simulated (black solid line) acoustic frequency response (power to temperature) of the TA loudspeaker sample made of silver nanowires on glass.