Bimaterial electro-mechanical systems for audio frequency applications

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Since late 1980s, researchers have turned their attention on biomimetics as a new way of discovering unconventional designs and materials both for creating new device concepts and solving engineering problems[1]. In our research, we aim to implement an adaptable MEMS acoustic sensor inspired by the behavior of the human ear. The human ear represents an excellent tunable acoustic sensor able to perceive sounds with relatively wide pitch and frequency range (20 Hz – 20 kHz). The inner ear acts as a transducer for the acoustic input signal that is transformed from mechanical to electrical domain, filtered and decomposed into different frequency bands[2,3]. Few works have reported on the physical modeling of the cochlea using microfabrication technology[2,4]. Thus far, the MEMS microphones developed and used in the market suffer from limited tunability and directionality. In our system, we propose an array of MEMS resonant gate transistors (RGTs) to sense and filter acoustic signals in the audible frequency range (Fig. 1). The MEMS structures are to be connected to a neuromorphic auditory analog circuit that provides feedback to the resonant gates in order to adjust the gain (sensitivity) and frequency (selectivity) of the system and consequently enable complete tunability of the device[5]. In the past, aluminum (Al) and tantalum (Ta) have been used successfully for manufacturing RGTs[6]. However, the fabrication of relatively long and straight beams requires the ability of controlling precisely the film stress during deposition. In this work, in order to address the critical aspects of the structures' design and fabrication, we demonstrate the use of silicon nitride (SiN) as a suitable material for precise tuning of the film stress during plasma enhanced chemical vapor deposition[7].

In this paper, we report on the design and fabrication of SiN/Al resonant gate pFETs (RG-pFETs). The gates are designed as double-clamped beams with lengths in the range 1000 – 5800 μm and widths of 10 μm and 20 μm. Fig. 2 and Fig. 3 show the schematic process flow for the fabrication of the SiN/Al structures on top of pFETs and a scanning electron micrograph of one of the fabricated bridges. The process developed allows the fabrication of planar structures with length up to 5800 μm and distance to the substrate controllable in the range 0.8 – 3 μm. Fig. 4 shows the distance to the substrate measured along the length of some of the fabricated beams. A maximum deflection of 300 nm has been measured showing a relatively straight profile for beams with a length/width ratio up to 580. From finite element analysis (FEA), the fabricated devices are expected to resonate in the audible range 5 – 20 kHz. Fig. 5 shows the I-V characteristic of one of the fabricated RG-pFETs. The details of the design and fabrication of the SiN/Al RG-pFETs will be presented. The influence of the structural materials' internal stress on the deflection and sensitivity of the beams will be discussed. The FEA mechanical results will be compared to the measurements performed on the fabricated devices.

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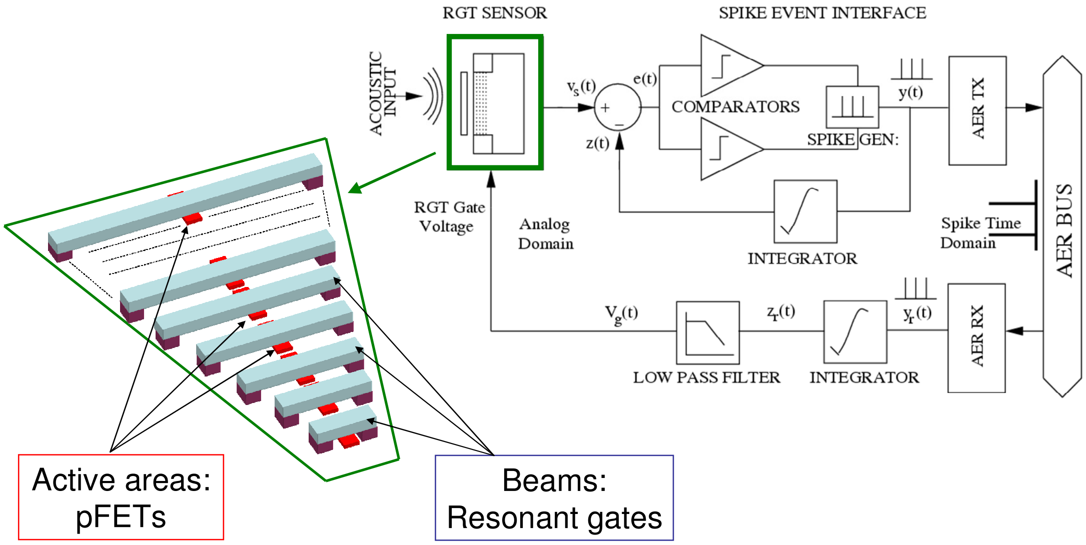

Fig. 1*:* Schematic of the adaptable MEMS microphone.

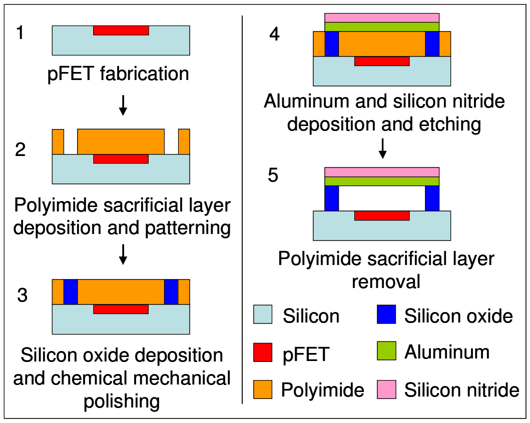

Fig. 2*:* Fabrication process flow for Al/SiN bridges.

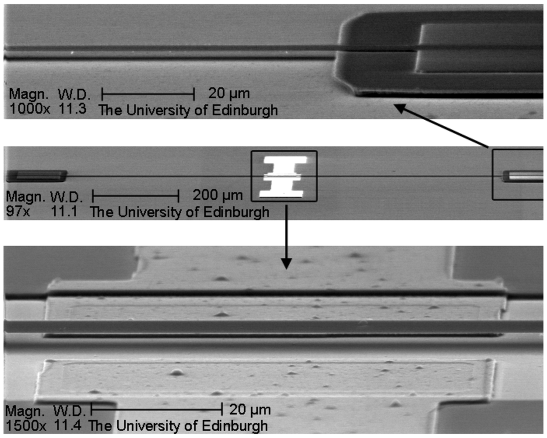

Fig. 3: Scanning electron micrograph of one of the fabricated structures.

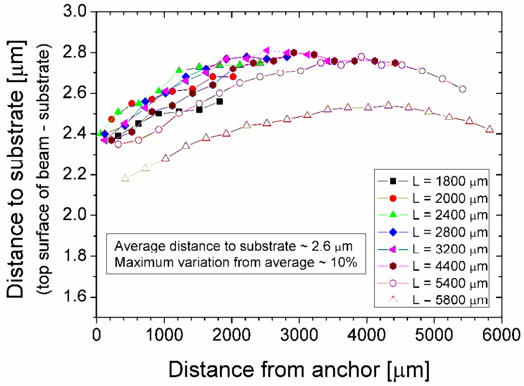

Fig. 4*:* Distance between beams and substrate measured along the beam length.

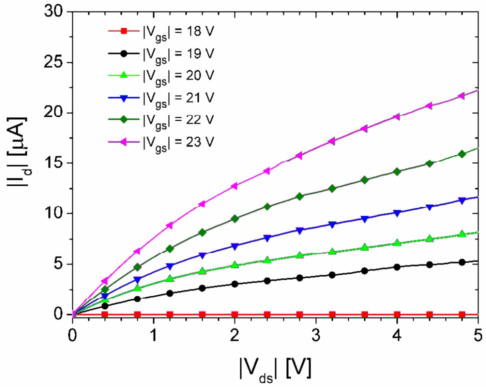

Fig. 5: I-V characteristic of one of the fabricated RG-pFETs.