Electrothermal actuation of silicon carbide ring resonators

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Recently, microelectromechanical systems (MEMS) have shown to be a challenging alternative to CMOS circuitry in radio frequency (RF) applications[1]. However, micro resonators made from beam designs suffer from frequency and dimensional limitations so that attention has been focused on new solutions and designs for achieving higher resonant frequencies[1,2]. In addition, beyond the frequency challenge, the importance of the actuation mechanism has increased in order to obtain high efficiency devices. Combining simple fabrication process and low power consumption[3], electrothermal actuation represents a promising alternative to the widely used electrostatic technique. Presenting excellent mechanical properties, silicon carbide (SiC) is a good candidate for high frequency MEMS with possible application in harsh environments[4]. In the last decade, great progress has been made in the fabrication of SiC MEMS due to the improvement of the epitaxial growth methods[5] and dry etching techniques for bulk and surface micromachining[6].

In this work, we report on SiC ring actuators to investigate the possibility of achieving higher resonant frequencies compared to beam actuators. In fact, for a given area, circular structures possess a higher natural frequency in the flexural mode (Fig. 1a). The resonators have been simulated, fabricated and tested. Fig. 1b shows the resonant frequency as a function of the ring radius ($20<R<200$ µm) for different hole radius ($h = 2, 10, 15$ µm). Simulating out-of-plane deflections, the resonant frequency has been found to increase when R decreases and h increases. Moreover, values in the MHz range have been obtained. For the fabrication of the ring resonators, single crystal SiC has been grown by hot-wall chemical vapour deposition (CVD)[7] on a silicon (Si) substrate. Aluminium (Al) electrodes have been patterned photolithographically and dry etched on top of the SiC epilayer. After, circular holes have been etched through the SiC and then the Si underneath released with XeF_2 chemical etching. Fig. 2 shows the characterized release rate (Fig. 2a) and area release rate (Fig. 2b) as a function of the etching time for different holes' radius at etching pressures of 1 and 2 Torr. Fig. 3 shows some of the released structures. The fabricated devices have been actuated mechanically with a piezo-disc and afterwards electrothermally by applying an AC voltage across the electrodes. Two of the measured resonant peaks at ~1.661 and 3.149 MHz are shown in Fig. 4. Details of the fabrication process and characterization of the ring resonators will be presented.

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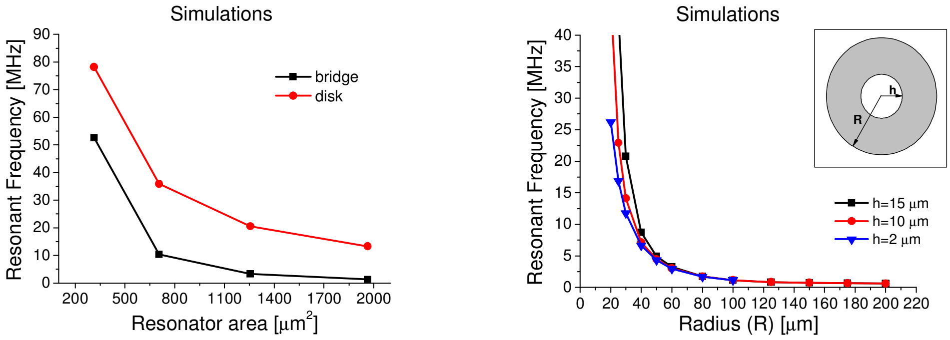

Fig. 1a Fig. 1b

Fig. 1: Simulated resonant frequency as a function of resonator area (Fig. 1a) and release radius for different hole dimensions (Fig. 1b) (inset: schematic of the ring resonator)

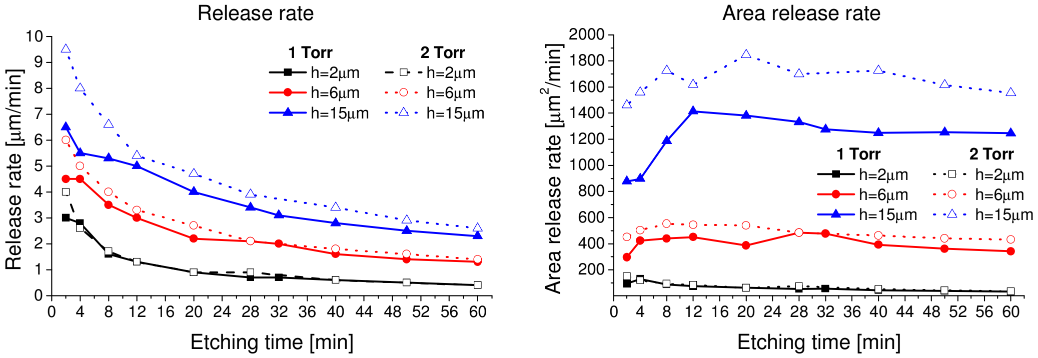

Fig. 2a Fig. 2b

Fig. 2: Release rate (Fig. 2a) and area release rate (Fig. 2b) as a function of etching time for different hole radius

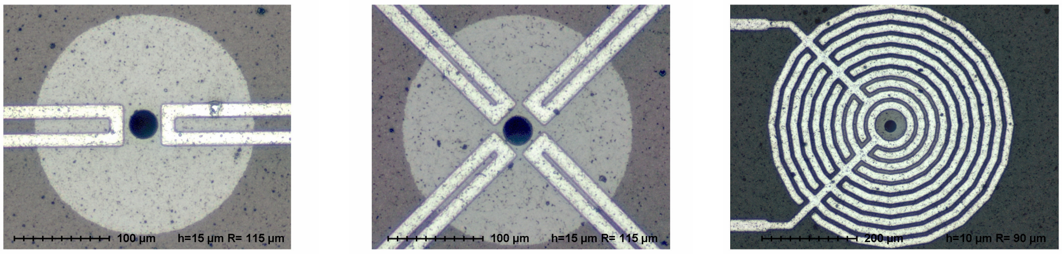

Fig. 3: Optical micrographs of SiC ring resonators with Al electrodes on top

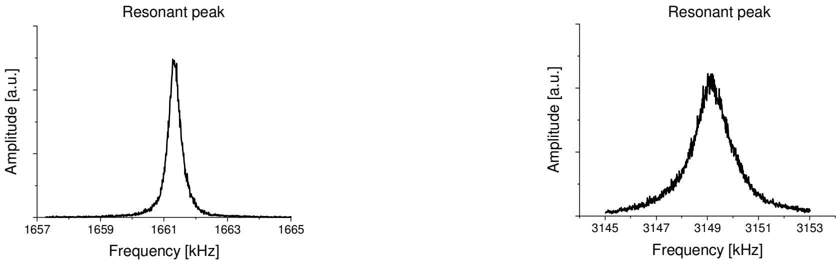

Fig. 4a Fig. 4b

Fig. 4: Resonant peaks of electrothermally actuated SiC ring resonators