# Piezo-electrically driven silicon carbide resonators

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In the last decade, silicon carbide (SiC) thin films have started to be employed for a wide range of electro-mechanical applications[1]. In particular, due to its unique mechanical properties, SiC is an excellent candidate for the implementation of high frequency MEMS with high Q-factors and good reliability[2]. Moreover, the possibility of integrating piezo-electric thin films into MEMS devices has attracted increasing attention in the actuators area[3], including interesting applications in the radio frequency field for the on-chip integration of filtering and frequency reference functions[4]. Thus far, the majority of the piezo-electric MEMS have been implemented using bulk materials or thin films grown on silicon (Si). For example, aluminum nitride (AlN), lead zirconium titanate (PZT) and zinc oxide (ZnO) films deposited on Si have been used for the implementation of SAW filters[5], accelerometers[6], electromechanical switches and resonators[7,8] and energy harvesting devices[9,10]. Recently, some attention has been focused on the use of piezo-electric AlN layers on SiC[11,12]. By integrating PZT films on SiC epilayers, the devices performance such as switching speeds, resonant frequency, actuation efficiency and reliability are envisaged to improve.

In this work, we report on the design, fabrication, simulation and testing of piezo-electrically actuated SiC cantilevers for MEMS applications. In particular, in order to perform piezo-electric actuation, an electrode made of Pt/PZT/Pt has been designed on top of the SiC, the same electrode is used for the electrical sensing of the structure's resonance. Fig. 1 and 2 show the process flow for the fabrication of the resonators and one of the fabricated devices. FEM simulations have been performed in order to study the devices' actuation mechanism and resonant frequency. Fig. 3 shows a simulation snapshot when a DC voltage is applied across the actuating electrode. The fabricated devices have been actuated piezo-electrically by applying an AC voltage across the top electrode. The actual resonant frequency has been detected by measuring the change in the magnitude and phase of the device impedance. Fig. 4 shows the detected magnitude and phase for one of the tested cantilevers resonating at ~ 192.5 kHz. The details of the design and fabrication of the piezo-electric electrodes integrated on the SiC cantilevers will be presented. Moreover, the influence of the electrodes' design and dimensions on the induced displacement and on the output voltage will be investigated. Simulations results will be compared to the measurements performed on the fabricated devices.

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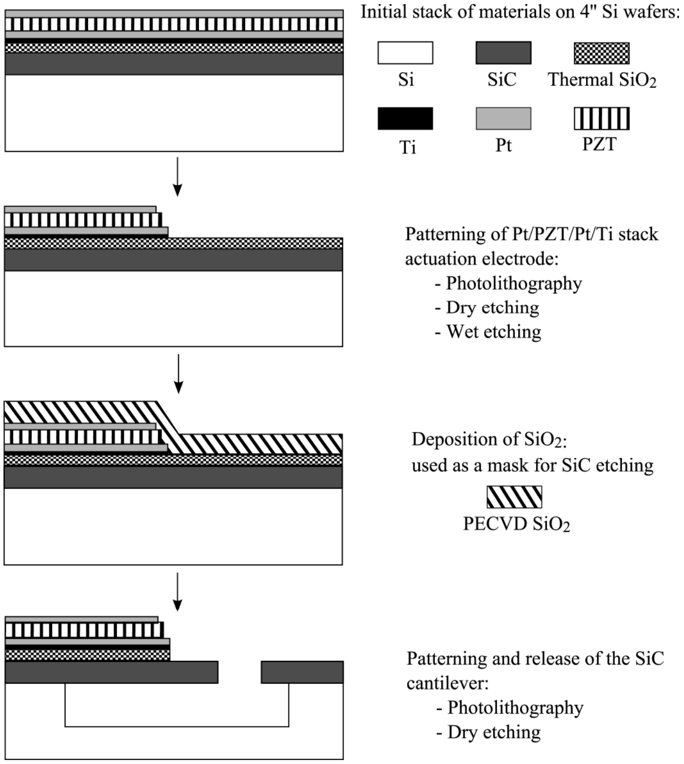

Initial stack of materials on 4" Si wafers:

Patterning of Pt/PZT/Pt/Ti stack actuation electrode:
- Photolithography
- Dry etching
- Wet etching

Deposition of $SiO_2$:
used as a mask for SiC etching

Patterning and release of the SiC cantilever:
- Photolithography
- Dry etching

Figure 1: Process flow for the fabrication of SiC cantilever with a piezo-electric electrode.

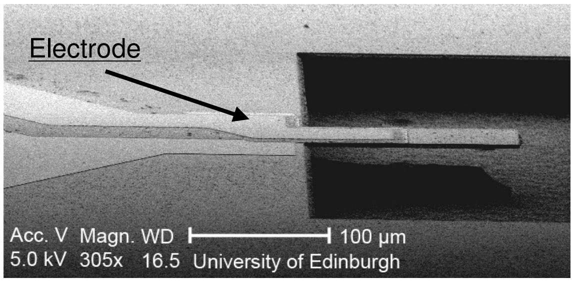

Figure 2: Scanning electron micrograph of one of the fabricated devices.

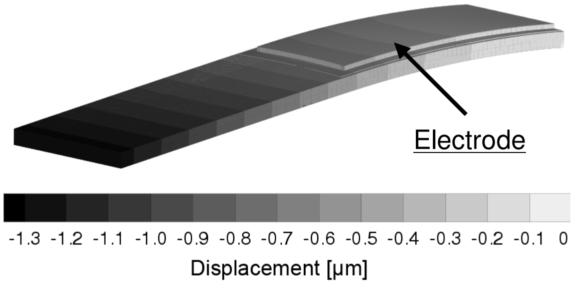

Figure 3: Simulation snapshot of a cantilever actuated piezo-electrically.

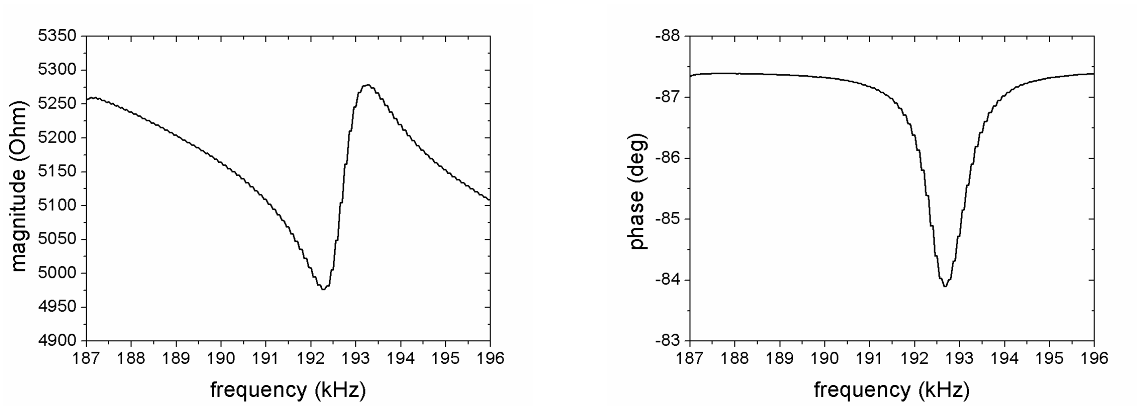

Figure 4: Measured impedance for a SiC cantilever actuated piezo-electrically resonating at ~ 192.5 kHz.