Piezoelectrically Transduced Silicon Carbide MEMS Double-Clamped Beam Resonators

B. Sviličić[a,b], E. Mastropaolo[a], T. Chen[a], R. Cheung[a]
[a]*Institute for Integrated Micro and Nano Systems, University of Edinburgh, West Mains Road, Edinburgh EH9 3JF, United Kingdom*
[b]*University of Rijeka, Studentska ulica 2, 51000 Rijeka, Croatia, svilicic@pfri.hr*

Microelectromechanical system (MEMS) resonant devices are considered increasingly to replace filter[1] components and quartz crystals[2] in systems requiring timing and frequency control functions in order to solve power consumption and miniaturization issues. One of the most promising materials for high efficiency MEMS resonant devices is silicon carbide (SiC) because of its excellent mechanical properties[3]. Electrostatic and piezoelectric transductions are leading techniques for the electrical actuation and sensing of the resonators' mechanical vibration. However, the complex fabrication process associated with achieving an electrode-to-resonator gap spacing in the nanometric scale in electrostatic transduction motivates the use of piezoelectric transduction. Recently, 3C-SiC has been integrated with lead-zirconium-titanate (PZT) ports allowing electrical actuation[4] and sensing[5] of flexural 3C-SiC resonators. Moreover, electrothermal tuning on similar devices has been demonstrated[6]. On the other hand, previous studies have reported the influence of DC bias on the complex material coefficients[7], electromechanical coupling parameter[7,8] and frequency tuning of piezoelectrically actuated MEMS resonators[9,10].

In this paper, we investigate the influence of DC bias on the resonant frequency of piezoelectrically transduced 3C-SiC double-clamped beam MEMS resonators. The devices have been fabricated with beam lengths in the range of 75 μm - 200 μm and with the beam width of 50 μm, and they operate between 1 MHz and 2.3 MHz. The SEM image and the schematic of the designed devices are shown in Fig. 1. Fig. 2 shows the transmission frequency response of a 100 μm-long device actuated with the input signal power of 10 dBm and DC bias in the range of 0 V - 5 V. A resonant peak has been measured in air at 1.816 MHz with a *Q* factor of 280 at a DC bias of 0 V. As the DC bias voltage is increased, increases in the transmission magnitude and resonant frequency have been measured. Moreover, the shift in resonant frequency has been observed to increase when the lengths of the actuating electrode (Fig. 3) and/or the beam (Fig. 4) are increased. Details of the design and fabrication processes will be presented. The effect of bias induced stress through the piezoelectric effect will be simulated and correlated with experimental data. The influence of the DC bias voltage, electrode and beam dimensions on the resonant frequency and transmission amplitude, including the impact of the voltage on the linearity of the frequency response, will be discussed.

Acknowledgment: One of us, B. Sviličić, acknowledges financial support of the Croatian Science Foundation.

---

[1] C.S. Lam, Int. Ultrason. Symp. Proc., 2008.
[2] C. T.-C. Nguyen, IEEE Trans. Ultrason. Ferroelectr. Freq. Control, 54, 2007.
[3] R. Cheung, "Silicon carbide micro electromechanical systems", Imperial College Press, 2006.
[4] E. Mastropaolo, I. Gual, G. Wood, A. Bunting, R. Cheung, J. Vac. Sci. Technol. B, 28, 2010.
[5] E. Mastropaolo, B. Sviličić, B. Flynn, T. Chen, R. Cheung, submitted to Microelectron. Eng., 2011.
[6] B. Sviličić, E. Mastropaolo, B. Flynn, R. Cheung, IEEE Electron Device Lett., 33 (in press), 2012.
[7] Q.M. Wang, T. Zhang, Q. Chen, X.H. Du, Sens. Actuators A, 109, 2003.
[8] J. Cho, M. Anderson, R. Richards, D. Bahr, C. Richards, J. Micromech. Microeng., 15, 2005.
[9] H. Chandrahalim, S.A. Bhave, R. Polcawich, J. Pulskamp, D. Judy, R. Kaul, et al., Appl. Phys. Lett., 93, 2008.
[10] P.B. Karabalin, M.H. Matheny, X.L. Feng, E. Defaÿ,G. Le Rhun, C. Marcoux et al., Appl. Phys. Lett., 95, 2009.

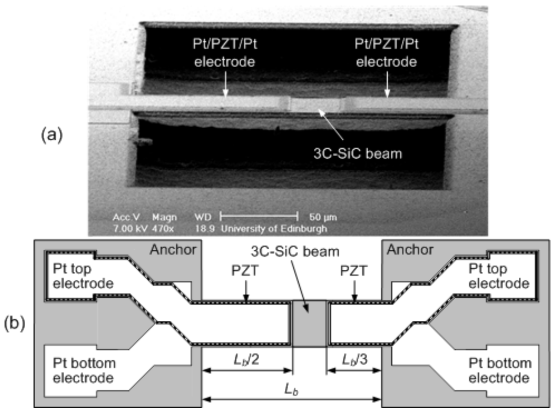

Figure 1: (a) SEM image of one of the fabricated double-clamped beam resonant device with Pt/PZT/Pt electrodes on top of the 3C-SiC beam. (b) Schematic of the designed device with the beam length L_b and electrodes lengths relation.

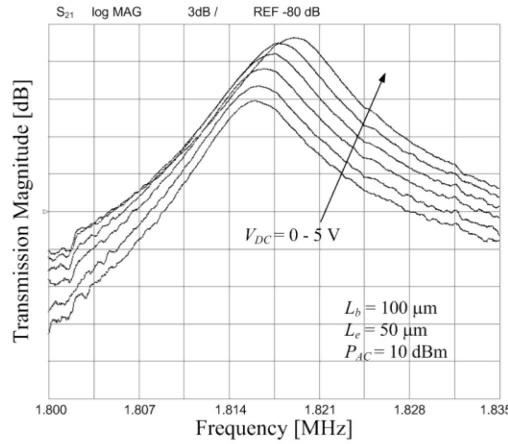

Figure 2: Transmission magnitude plots of the 100 µm-long device for different DC bias voltages V_{DC}. The device has been actuated using the long electrode ($L_e = L_b/2 = 50$ µm).

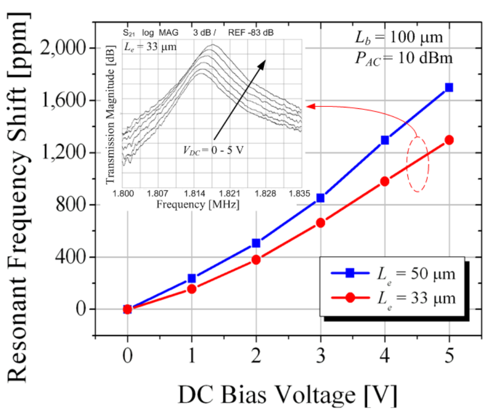

Figure 3: Measured resonant frequency shift versus tuning DC bias voltage with the input electrode length L_e as a parameter. The inset shows transmission magnitude plots of the device actuated using the short electrode ($L_e = L_b/3 = 33$ µm) for different DC bias voltages.

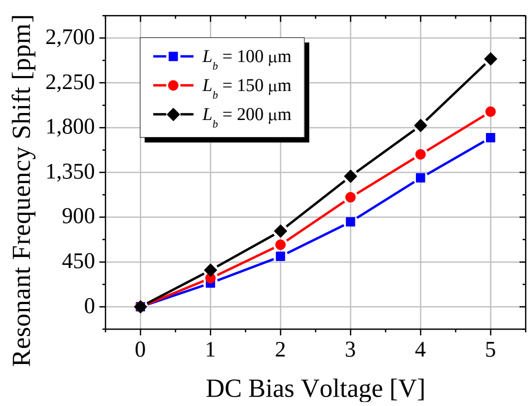

Figure 4: Measured resonant frequency shift versus tuning DC bias voltage with the beam length L_b as a parameter.