Nano-machining of silicon carbon nitride resonators using low voltage electron beam lithography and cold development

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Nanoelectromechanical resonators are increasingly being used for a wide variety of applications in signal processing, nanofluidics, ultrasensitive mass detection and analysis, etc. Initially, the usage of silicon dominated this field; however, in an effort to improve the performance, other materials have now started to appear such as SiC and Si_3N_4. A relatively new entrant in this field, silicon carbon nitride (SiCN), has shown significant promise by exceeding the *fQ* product of previously reported silicon resonators [1] and has achieved mass sensitivity in the attogram range.[2] In this work, we apply our theoretical and experimental methodologies of finding optimum exposure and development conditions [3] in electron beam lithography (EBL) to fabricate SiCN resonators at a significantly smaller scale than was previously achieved [1,2,4] for improving the mass sensitivity. For this purpose, a unique set of exposure, development, and metallization conditions was combined with an existing fabrication process.[2] A combination of 3 keV electron exposure and -15°C MIBK:IPA 1:3 development was used to obtain structures in polymethyl-methacrylate (PMMA) with large undercuts for etch mask deposition and liftoff without the use of bi-layer resists. This process enabled us to fabricate SiCN doubly-clamped resonators as narrow as 20 nm and up to 15 μm long (Fig. 1). Figure 2 shows the resonance response of a 25 nm wide, 50 nm thick and 15 μm long doubly-clamped resonator. The device had a resonant peak at 11.112 MHz and displayed a quality factor of ~ 1000. A detailed investigation of the resonant properties of these devices is under way. Further studies are being conducted to refine the fabrication process. These include reduction of the clamping losses by numerically modeling the edge interface profile (Fig. 3) and fine tuning the process conditions to minimize the overhang, as well as further reduction of the dimensions of the resonator by using negative tone resists such as hydrogen silsesquioxane (HSQ).

[1] L. M. Fischer et. al., J. Vac. Sci. Technol. B 25(1), 33 (2007)
[2] L. M. Fischer et. al., Sensors Actuators B: Chem. 134, 613 (2008).
[3] M. A. Mohammad et. al., Microelectron. Eng. (2009), doi:10.1016/j.mee.2009.11.047 (In press)
[4] L. Sekaric et. al., Sensors Actuators A: Phys. 101, 215 (2002).

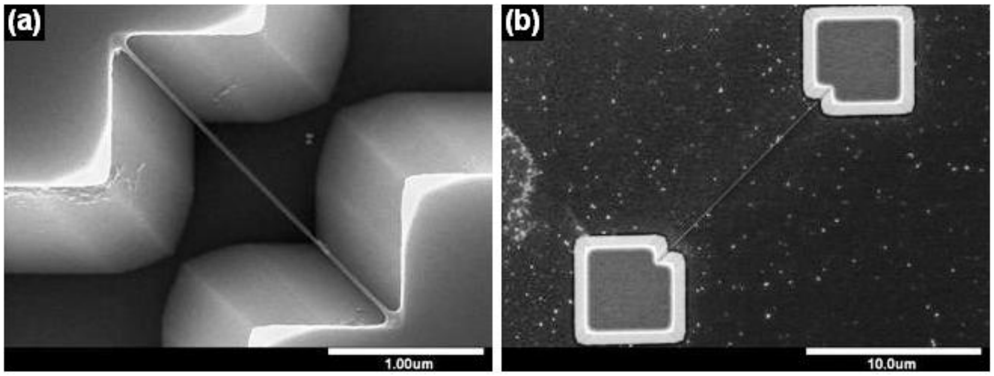

Fig. 1. SEM images of (a) 2.8 μm long, and (b) 15 μm long, doubly-clamped SiCN resonators with 20 nm width.

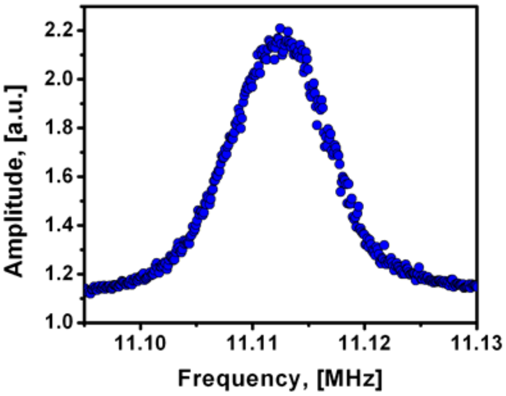

Fig. 2. Typical resonance curve for a 25 nm wide, 50 nm thick and 15 μm long resonator. From the FWHM of the peak a *Q*-factor of ~ 1000 is obtained

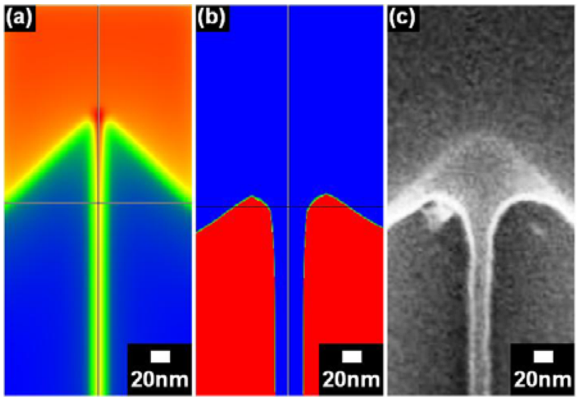

Fig. 3. Comparison of a (a) computed probability of scission profile, and a (b) computed dissolution profile, with an (c) SEM image of clamping point, representing a major source of energy loss.