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Fabrication of completely free-standing pyrolytic carbon string resonators

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Here, we present a novel method for fabrication of carbon string resonators obtained by pyrolysis of suspended SU-8 micro strings in inert atmosphere at high temperature. The fabricated strings were characterized by optical readout to get the resonance frequencies and quality factors. We analyzed the resonance behavior of the optimized string resonators and performed a first proof-of-concept of mass sensing using polystyrene micro particles.

In the pass few decades, Micro Electro-Mechanical Systems (MEMS) sensors have become increasingly attractive for a wide range of applications such as pressure sensors, accelerometers and gyroscopes due to the high sensitivity, small size and low costs. Among all those sensors, MEMS resonators with high sensitivity and short response time show promising applications. For MEMS resonators such as cantilevers (single-clamped beams), strings (double-clamped bridges) and membranes, the working principle is based on the frequency shift due to external stimuli such as changes in mass [1] or temperature [2]. Recently, carbon MEMS (C-MEMS) was introduced as a method to fabricate microstructures in pyrolytic carbon. The main advantage of the pyrolytic carbon as a resonator material is that its properties can be tailored due to the possibility to modify the pyrolysis parameters [3]. Additionally, pyrolytic carbon is electrically conductive which potentially can be used for actuation or readout. In our previous work [4], pyrolytic carbon string resonators were fabricated. However, the gap between the strings and the underlying substrate was very small and the proximity of the substrate made it impossible to deposit and analyse samples such as micro particles. For this purpose, new pyrolytic carbon string resonators fully separated from the substrate and placed over a through-wafer hole are needed.

In this work, the new fabrication process for fully free-standing pyrolytic carbon string resonators is presented (Figure 1). The fabrication process starts with n-type double side polished Si wafer. Then, 200nm of low-stress SiN was grown on both sides. Next, the opening window is patterned from the backside followed by dry etching step. The strings were patterned on the front side by photolithography with SU-8 photoresist. The SiN layer underneath of SU-8 then is etched from the backside. Finally, the SU-8 strings were converted into pyrolytic carbon strings by pyrolysis process at 700oC. A 300x30µm fully free-standing pyrolytic carbon string resonators is shown in Figure 2. After fabrication, the fully free-standing pyrolytic carbon string resonators were characterized with a Laser Doppler Vibrometer system. Figure 3 shows the resonance frequencies and quality factors of the string resonators with three different lengths.

Micro particles based on polystyrene which have 10µm in size were dispersed in liquid. The deposition on fully free-standing pyrolytic carbon string resonators is done by nebulizing the solution using jet nebulizer. After drying, the string resonators were characterized again to track the frequency shift. Figure 4 shows the resonance frequency of the 300x30µm free-standing pyrolytic carbon string resonator after sampling. The results show that the resonance frequency decreased compared to the original frequency due to the particles adhering to the string.

In conclusion, we fabricated the fully free-standing pyrolytic carbon string resonators suitable for sampling. The results indicate that the fully free-standing pyrolytic carbon string resonators can work as mass sensor.

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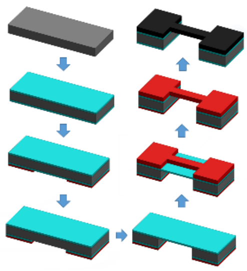

Figure 1. Fabrication process of free-standing pyrolytic carbon string resonators.

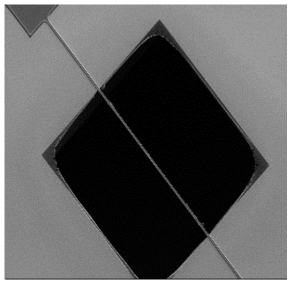

Figure 2. SEM image of free-standing pyrolytic carbon string resonator.

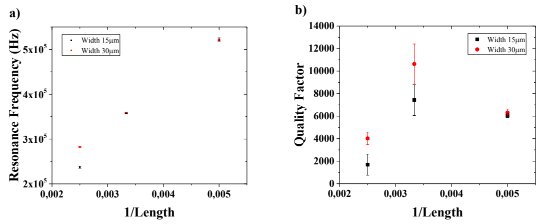

Figure 3. Resonance frequencies (a) and quality factor (b) of free-standing pyrolytic carbon string resonators.

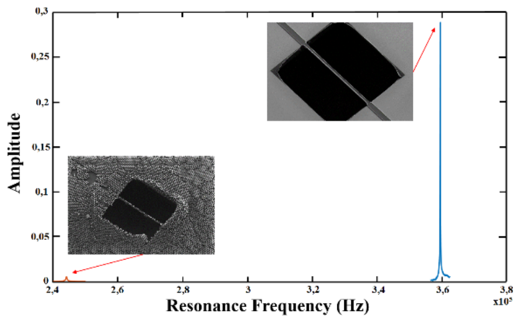

Figure 4. Frequency shift of free-standing pyrolytic carbon string resonator.