주름진 다결정 3C-SiC 마이크로-빔 공진기의 설계

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Design of polycrystalline 3C-SiC micro beam resonators with corrugation

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Abstract : This work has suggested corrugation beam as a new structure for mechanical resonators. Micro beam resonators based on 3C-SiC films which have two side corrugations along the length of beams were simulated by finite-element modeling and compared to a flat rectangular beam with the same dimension. With the dimension of 36x12x0.5 μm^3, the flat cantilever has resonant frequency of 746 kHz. Meanwhile, this frequency reaches 1.252 MHz with the corrugated cantilever which has the same dimension with flat type but corrugation width of 6 μm and depth of 0.4 μm. It is expected that mechanical resonators with corrugations will be very helpful for the research of sensing devices with high-resolution, high-performance oscillators and filters in wireless communications as well as measurement in basic physics.

Key Words : corrugated, resonator, 3C-SiC, cantilever

1. INTRODUCTION

Mechanical resonator is one of the important components in communications applications and sensor techniques. Among them, micro beam resonators are especially interested because their dimension can be reduced to micro or even nano size so that they are comfortably integrated on application chips. Furthermore, it's micro-size or even smaller makes it possible to detect infinitesimal object such as gas, cell, DNA etc in sensor application [1]. Oscillators and filters based on mechanical resonators have higher frequency selectivity characteristics than those of conventional active RC filter [2].

The popular structures of micro beam resonator are cantilever, doubly clammed beam and free-free beam which they are distinguished by the constraint condition at the ends. From the Euler-Bernoulli Beam Equation, beam's resonant frequency is:

$$f = \frac{\beta^2}{2\pi L^2}\sqrt{\frac{EI}{\rho A}} \qquad (1)$$

Where β is the eigenvalues of the equation of beams that depend on their boundary conditions at specific mode (cantilever:β=4.73, doubly clammed beam β=1.875 [3]), E is the Young's modulus, I is the inertia moment, ρ is the mass density, A is the cross section area of the beam.

Among materials that usually used in MEMS, silicon carbide, SiC is one of the highest Young's modulus materials [4]. This is the important factor that drives resonant frequency up as seen in Eq. 1. There are many types of SiC but this resonator is studied based on polycrystalline SiC. It is the most attractive material because it overcomes defects of single crystalline such as large residual stress, cracks and large lattice mismatch (20%). Moreover, this type is expitaxially grown on many types of substrates such as crystalline, insulating materials, non crystalline etc. at lower temperature (1000^0C-1200^0C) [5].

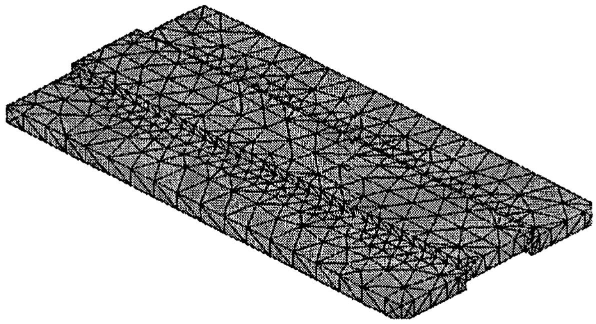

Fig. 1. Smart mesh for corrugated 3C-SiC beam.

Fabricating resonators based on 3C-SiC is one of the efforts to put up resonant frequency. This paper suggested changing mechanical structure of resonators as another method. Corrugated resonators as shown in Figure 1. is a such new structure of resonator that increases the resonant frequency by changing moment I in Equation 1.

2. MODEL'S GEOMETRY AND MESHING

This wok has used finite element method to analyze the affects of corrugation depth and width on vibration properties. Figure 1 also presents the structure of meshed 3C-SiC corrugated micro beam resonator by the element SOLID187 in ANSYS. APVCD deposition process is carried out to gain the thickness of silicon carbide up to 1 μm. In this simulation, the model thickness is 0.5 μm or 1 μm. With corrugated resonators, because the corrugation depth is much smaller than other dimension of the beam, the element sizes were chosen smaller near the corrugation edges and lager at the surface of the beam.

3 RESULTS AND DISCUSSION

The modal analysis at the first mode gives the vibration properties of corrugated structure. This paper presents the vibration properties of cantilevers. The doubly clammed beam has the same structure with cantilever but different boundary conditions.

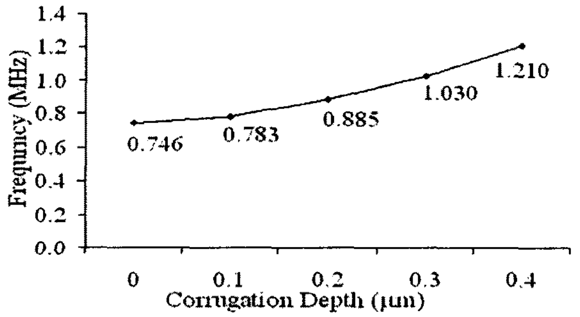

Fig. 2. Resonant frequency of cantilever (36x12x0.5 μm^3) with changing corrugation depth.

Fig. 2 shows the effect of corrugation depth on 4 cantilever when comparing with the cantilever. Their all dimensions are of 36x12x0.5 μm^3 but have different corrugation depth. All corrugations have the width of 4μm but the depth of 0.1, 0.2, 0.3 and 0.4 μm respectively and flat cantilever has the depth of 0 μm. This Figure has proved the fact that the resonant frequency is improved by increasing the corrugation depth. With the corrugation depth of 0.4 μm, the frequency reached 1.2 MHz. This frequency approximately increased 60% when compared to that of flat type resonators whose frequency is 0.746 MHz.

Corrugation width is also other important parameter that has affect on characteristics of resonator. Twelve corrugated cantilevers which all have the same dimensions of 36x12x0.5 μm^3 were analyzed. In this case, the corrugation depth was fixed at 0.2 μm for all cantilevers but their width varied from 1 μm to 12 μm.

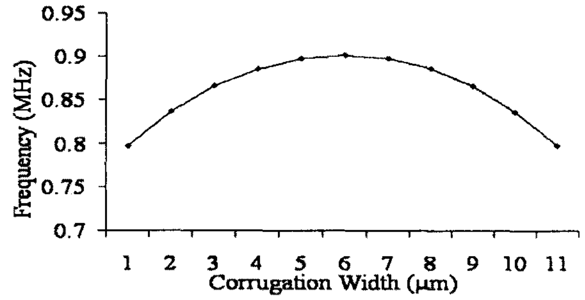

Fig. 3: The effect of corrugation width.

Fig. 3 presents the influence of the corrugation width. All their resonant frequencies are higher than that of flat type resonator. The maximum frequency occurs at width of 6 μm, a half of resonator width. At this point the resonant frequency is 901 kHz while the flat cantilever has this frequency of 746 kHz

4 CONCLUSION

From these results, corrugation depth and width are two crucial parameters in improving resonators. the design was based on 3C-SiC because of its high Young's modulus and several advantageous properties. In designing, optimum corrugated resonator that has dimension of 36x12x0.5 μm^3, the corrugation has the width of 6 μm, a half of resonator's width and the depth is chosen at 0.4 μm. With this structure the resonant frequency is 1.252 MHz. which 68% lager than that of flat type, 746 kHz.

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