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Strain measurement in 6H-SiC under external stress

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6H-SiC was chosen to measure the strain by external stress using micro-Raman scattering. Under various external stress conditions, our experiments showed that the top part of 6H-SiC was under a tensile stress while the bottom part of 6H-SiC was under a compressive stress. When it was bent more and more, the stress was increased at both top and bottom. This data is very helpful in understanding the mechanical properties of a 6H-SiC cantilever which is very promising in SiC micro electro mechanical system (MEMS) applications in harsh environments.

Key words: Stain, 6H-SiC, Stress, Raman, MEMS.

Introduction

There is increasing demand for devices that can operate in harsh environments such as in high temperatures well above 300 ^{o}C [1-3]. The applications of such devices are in the automotive, space, oil and combustion industries, which have been looking for alternatives to silicon. SiC has been considered as a semiconductor with exceptional chemical and electrical properties [4]. For other applications, SiC is also very promising in micro electro mechanical system (MEMS) technology in various sensor and actuator applications [5-8]. In a SiC-MEMS, a cantilever actuator or cantilever resonator working at high temperature is under strain. Therefore, it is very important to know how much stress the SiC cantilever is under when operating, and also helpful to understand the failure mechanism of the devices.

Raman scattering is a noncontact and non-destructive technique for semiconductor characterization. The spatial resolution of the micro-Raman scattering technique is typically ≤ 2 micrometer. Considering that the phonon frequencies are sensitive to the sample stress and temperature, Raman spectroscopy allows us to measure directly the device stress. To measure the stress induced by bending, a pivot pin was employed, then both sides were pressed down by an aluminum plate. Then, the effect of bending of the 6H-SiC template was characterized by micro-Raman scattering.

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Experiments

Figure 1 illustrates the setup to apply the stress and measure the effect of the external strain on the Raman scattering of 6H-SiC. As references, 3 points from top to bottom in the cross-sectional view were chosen, then measured without external strain. Then, both sides of the square 6H-SiC template were pressed by a standard press screw (Fig. 2(A), 2(B)).

Micro-Raman scattering measurements were performed on 6H-SiC in a back scattering geometry with the 488 nm line of an Ar-ion laser. The laser spot size was ≤ 5 mm and the laser power at the sample was ~0.5 mW. The bandgap of 6H-SiC is larger than the incident photon energy, which minimizes possible laser-induced heating. Because of the higher relative intensity at this scattering geometry, and its sensitivity to stress, we selected the E_2^2 phonon as a probe to monitor the film stress. Three points (A, B, and C) were measured without external strain, then the three points were measured again with the external force applied to find the effect of external strain. After the data was acquired, Lorentzian fitting was employed to find the phonon frequencies.

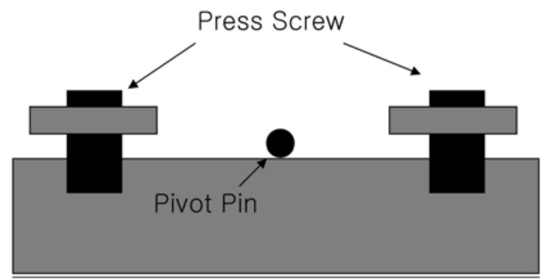

Fig. 1. Schematic diagram of the package for application of external strain.

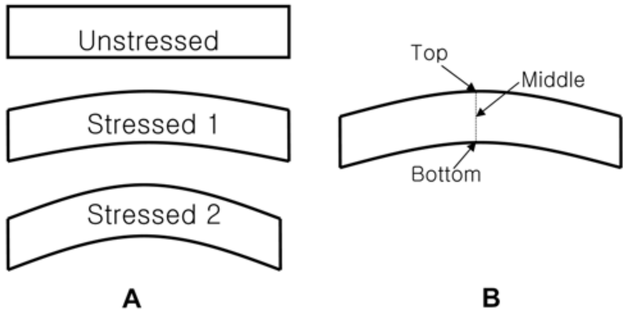

Fig. 2. (A) The direction of stress when bent (B) Postions to be measured.

Table 1. Value of ($\Delta\omega_{\text{each position}}$-$\Delta\omega_{\text{reference}}$) at each point on 6H-SiC held under stress

	Unstressed	Stressed 1	Stressed 2
Top	0	−0.32	−0.38
Middle	0	~0	0.03
Bottom	0	0.14	0.26

Results

Micro-Raman Spectroscopy was successfully employed to find the effects of external strain. As shown schematically in Fig. 2(B), each lattice length among each lattice would be reduced when the film was under a compressive stress, which causes $\Delta\omega$ to move to higher frequency. However, we would expect the top of 6H-SiC to be under a tensile stress when an external strain is applied on the template using a pivot pin. With the film under a tensile stress, each lattice length would be increased, which should result in a shift to a lower frequency in $\Delta\omega$. Since the biaxial stress is proportional to ($\Delta\omega_{\text{each position}}$-$\Delta\omega_{\text{reference}}$), it is straightforward to say that there was more stress when the plate was bent more (Fig. 2(A)).

Table 1 summarizes the results of strain in the 6H-SiC without stress under less stress (less bending) under more stress (more bending). At the top of 6H-SiC template, ($\Delta\omega_{\text{each position}}$-$\Delta\omega_{\text{reference}}$) was −0.32 cm^{-1} with less bending and −0.38 cm^{-1} with more bending, where a negative sign means tensile stress (Fig. 3). In the middle of 6H-SiC, there was not much shift in ($\Delta\omega_{\text{each position}}$-$\Delta\omega_{\text{reference}}$). Theoretically, at the center of 6H-SiC, the stress should be zero, but there was a small offset from the center, which resulted in 0~0.03 cm^{-1} of offset. At the bottom of the 6H-SiC, ($\Delta\omega_{\text{each position}}$-$\Delta\omega_{\text{reference}}$) was 0.14 cm^{-1} with less bending, and 0.26 cm^{-1} when bent more, where a positive sign means a compressive stress (Fig. 3). The reason that the absolute value of stress is different is that the crystal quality of the top layer is better than that of the bottom layer because this is the growth direction and the defect desnity and crystal quality changes with layer thickness.

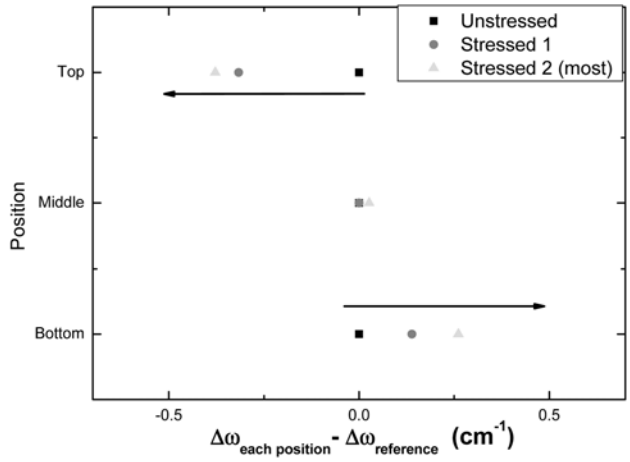

Fig. 3. ($\Delta\omega_{\text{each position}}$-$\Delta\omega_{\text{reference}}$) at top, middle and bottom.

Summary and Conclusion

In conclusion, we have demonstrated the effects of the external strain on 6H-SiC templates by micro-Raman scattering. Micro-Raman scattering was found to be a simple and non-destructive tool to characterize the stress in the film. Also, this technique will be very useful to understand the mechanical properties and failure mechanism of SiC-MEMS cantilevers.

Acknowledgements

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