Fabrication of beam resonators from hot-wall chemical vapour deposited SiC

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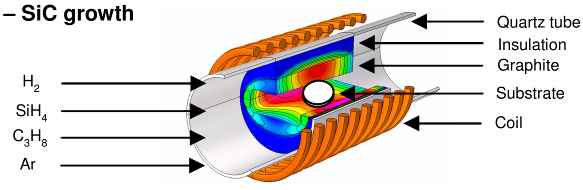
Introduction

Silicon Carbide (SiC) micro electromechanical systems (MEMS) are promising devices for high efficiency radio frequency (RF) applications. The high value of the Young's Modulus and the relatively low mass density of SiC permit to achieve high resonant frequencies.

Single crystal and polycrystalline 3C-SiC have been grown on Si wafers and cantilever resonators have been fabricated. The resonators have been actuated mechanically and the Young's Modulus has been calculated from the measured resonant frequencies.

3C – SiC growth



Hot-wall CVD reactor

Growth conditions

Different growth conditions give single crystal or polycrystalline layers:

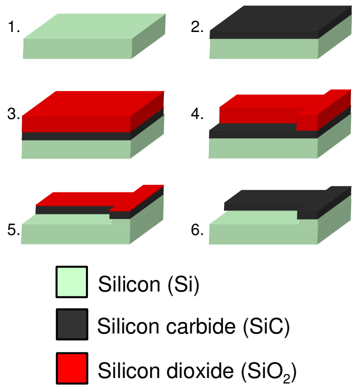
Single crystal SiC:

- T_g = 1350 °C
- P = 300 mbar
- C_3H_8 introduced at 600 °C
- SiH_4 introduced at T_g

Polycrystalline SiC:

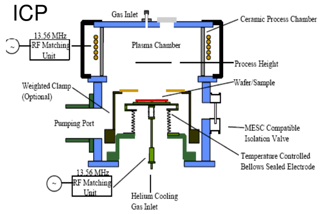
- T_g = 1280 °C
- P = 400 mbar
- C_3H_8 introduced at T_g
- SiH_4 introduced at T_g

Resonator fabrication

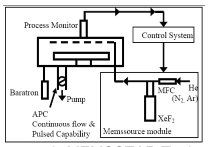


SiC etching and release

ICP



XeF_2

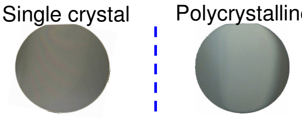


A. O'Hara *et al.*, MEMSSTAR Technology, Semicon (2005)

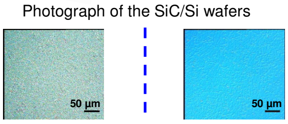
1. 4'' p-type Boron-doped (100) Silicon wafers used as substrate
2. Silicon Carbide growth in hot-wall CVD reactor
3. SiO_2 PECVD deposition for SiC masking
4. RIE etching of masking SiO_2 to define beam shape
5. ICP etching and release of SiC with additional XeF_2 chemical etch to release wider beams
6. Removal of possible residuals of SiO_2

Grown SiC

Single crystal / Polycrystalline

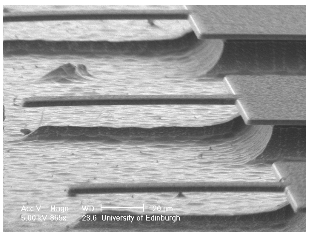


Photograph of the SiC/Si wafers



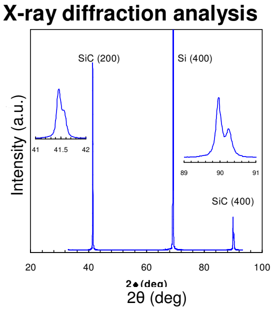
Surface morphology observed with optical microscope

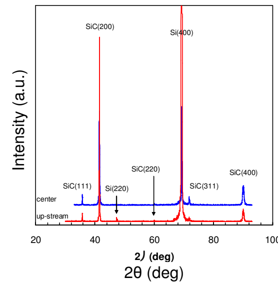
Fabricated devices



SEM image: cantilevers fabricated from single crystal SiC

X-ray diffraction analysis





Single crystal SiC:

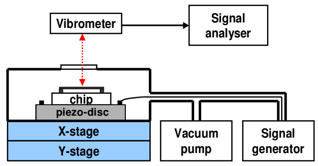
- SiC (100) orientation
- Doublets caused by the multiple Cu peaks are observed

Polycrystalline SiC:

- SiC (100) orientation
- SiC (311)
- SiC (111)
- SiC (220)

Resonator testing

The resonators have been actuated mechanically with a piezoelectric disc and the resonance detected with a laser vibrometer.



Laser vibrometer measurement system

Young's Modulus calculation

$$f = 0.162\sqrt{\frac{E}{\rho}}\frac{t}{L^2}$$

L = cantilever's length
t = cantilever's thickness
E = Young's Modulus
ρ = mass density

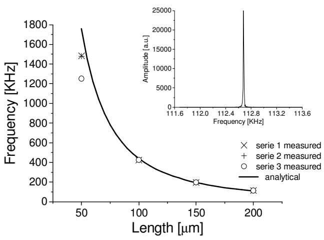
Considerations

- Resonant frequency not dependent on the stress.
- Use of different beam lengths leads to a more accurate estimation.

Results

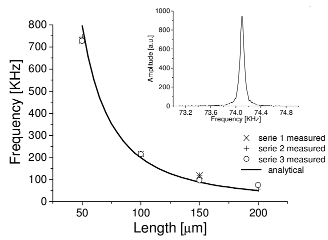
Single crystal SiC

E = 446 ± 26 GPa



Polycrystalline SiC

E = 246 ± 40 GPa



Resonant frequency as a function of electrode length and resonant peaks of 200 µm long cantilevers

- L ≥ 100 µm: good agreement between experimental data and analytical values.
- L < 100 µm: discrepancies observable probably due to the impact of the undercut at the cantilever's anchor.

Conclusions

Single crystal and polycrystalline 3C-SiC films have been grown in a hot-wall CVD reactor. Resonators have been fabricated and actuated mechanically. The measured natural resonant frequencies have been used to calculate the Young's Modulus. Values of 446 ± 26 GPa and 246 ± 40 GPa for single crystal and polycrystalline layers have been obtained, respectively. Due to its high crystal quality and the relatively high Young's Modulus, the grown single crystal 3C-SiC is a good candidate for RF-MEMS applications.

Acknowledgements

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