

Enrico Mastropaolo¹, Rebecca Cheung¹, Anne Henry² and Eric Janzén²

¹ The University of Edinburgh, Scottish Microelectronics Centre, UK (contact e.mastropaolo@ed.ac.uk)

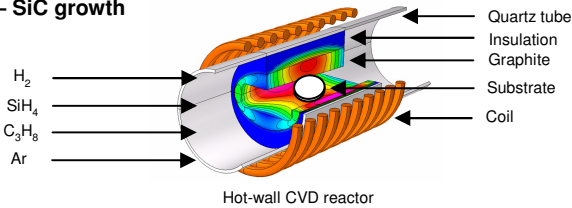
² Linköping University, Department of Physics, Chemistry and Biology, Sweden

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



Growth conditions

Different growth conditions give single crystal or polycrystalline layers:

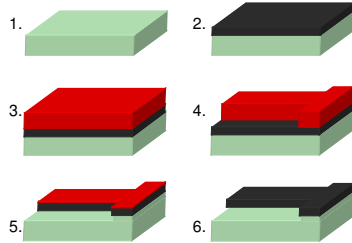
Single crystal SiC:

- $T_g = 1350\text{ }^\circ\text{C}$
- $P = 300\text{ mbar}$
- C_3H_8 introduced at $600\text{ }^\circ\text{C}$
- SiH_4 introduced at T_g

Polycrystalline SiC:

- $T_g = 1280\text{ }^\circ\text{C}$
- $P = 400\text{ mbar}$
- C_3H_8 introduced at T_g
- SiH_4 introduced at T_g

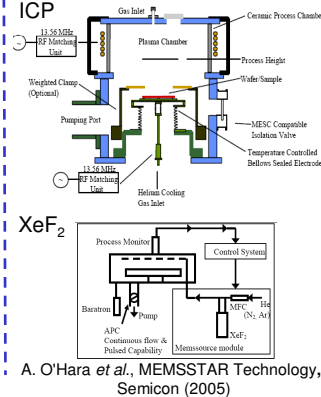
Resonator fabrication



- Silicon (Si)
- Silicon carbide (SiC)
- Silicon dioxide (SiO₂)

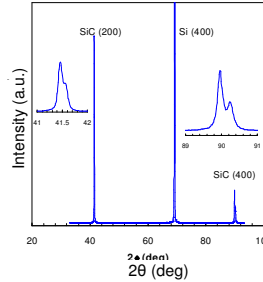
1. 4" p-type Boron-doped (100) Silicon wafers used as substrate
2. Silicon Carbide growth in hot-wall CVD reactor
3. SiO₂ PECVD deposition for SiC masking
4. RIE etching of masking SiO₂ to define beam shape
5. ICP etching and release of SiC with additional XeF₂ chemical etch to release wider beams
6. Removal of possible residuals of SiO₂

SiC etching and release



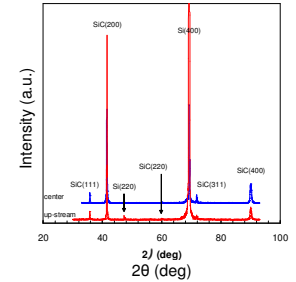
A. O'Hara et al., MEMSSTAR Technology, Semicon (2005)

X-ray diffraction analysis



Single crystal SiC:

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

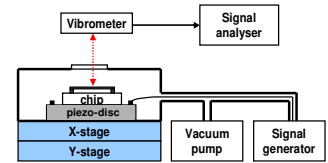


Polycrystalline SiC:

- 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

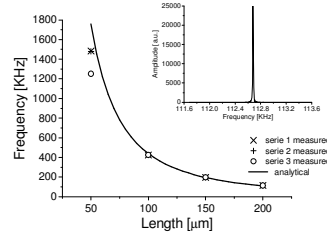
Considerations

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

Results

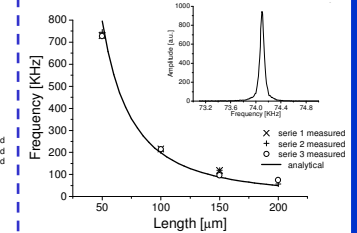
Single crystal SiC

$$E = 446 \pm 26\text{ GPa}$$



Polycrystalline SiC

$$E = 246 \pm 40\text{ GPa}$$



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

- $L \geq 100\text{ }\mu\text{m}$: good agreement between experimental data and analytical values.
- $L < 100\text{ }\mu\text{m}$: discrepancies observable probably due to the impact of the undercut at the cantilever's anchor.

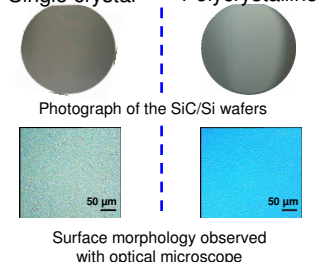
Conclusions

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 $446 \pm 26\text{ GPa}$ and $246 \pm 40\text{ GPa}$ 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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Grown SiC



Fabricated devices

