SIC AS A PROMISING MATERIAL FOR MEMS/NEMS: A REVIEW

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Abstract - SIC has excellent mechanical and electrical properties that make it very promising material/candidate for MEMS/NEMS. This paper highlights some of the SiC properties that makes it more suitable, over conventional Si, for MEMS/NEMS applications. These applications include; high frequency resonators, RF MEMS, electrothermal actuators, and harsh environment applications. The aim of the paper is to review some of the very promising results which demonstrate that SiC as a potential material for each of the aforementioned applications.

Keywords – Micro Electromechanical Systems, Electrostatic Actuation, Electro Thermal Actuators, RF MEMS, high frequency, Resonators.

INTRODUCTION

With the advancement in SIC micro fabrication together with its excellent mechanical and electrical properties, SIC is becoming more promising for Micro/Nano electromechanical systems (MEMS/NEMS) applications such as micro sensors, micro actuators, switches, RF mixers. Actuation of SIC MEMS devices were attempted with commonly applied principles; electrostatic, piezoelectric, and electro thermal actuation [1-5]. A limited focus was given for the electro thermal actuation of SiC micro devices and MEMS applications in general. The main drawback that caused the limitation of electro thermal actuation is the low thermal time constant that makes electro thermal actuation only useful for DC and low frequency applications. In the past, devices were mainly fabricated from Silicon due the well established Si micro fabrication techniques. But now, there is a continuous advancement in SiC micro fabrication [6]. SiC proved to have excellent mechanical and electrical properties that makes it good candidate for MEMS devices [7]. Electrostatically actuated MEMS devices are more common that electro thermally actuated ones. The first SIC microcantilever reported was in 2006 [8] and it was actuated at resonance of 117 kHz. The highest reported resonance frequency for electro thermal SiC microcatilever was 112 MHz but in the longitutinal (extensional) mode[9], and the volume of the cantilever was 1.5 μm^3.An I-shape electro thermal resonator made of single crystal silicon and footprint size of 110 1.5 μm^2 and thickness of 0.34 µm was reported to have frequency in the range of 112 – 176 MHz [10]. The aim of this paper is present review the work in which the author was involved in to demonstrate the potentiality of SiC as a promising material for MEMS/NEMS applications.

SiC for harsh environment applications

MEMS/NEMS devices can be used in harsh environment (e.g. high temperature,high pressure, and erosion media in automotive industry and industrial processes), and therefore the device material should withstand such environment without losing its mechanical and electrical properties. 3C-SiC has shown little degradation in the Young's Modulus as result of increasing temperature. A silicon carbide micro cantilever was successfully actuated electrostatically at different temperatures (up to 312 ^oC) with little decrease in the resonance frequency (from 64.81 kHz at room temperature to a value of 64.03 kHz at 312 ^oC). Figure.1 shows the change in the resonance frequency as a result of increasing temperature.

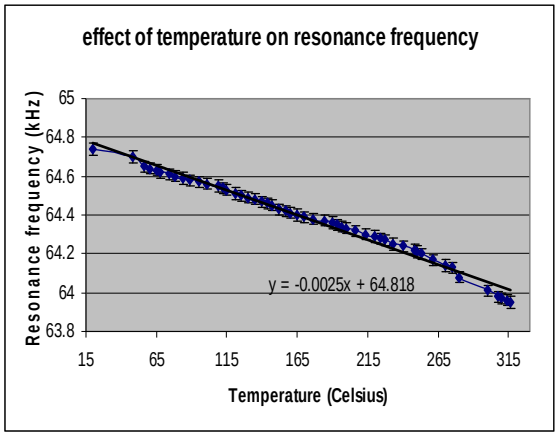


Figure 5.20 effect of temperature on the resonance frequency.

SiC for high frequency resonators

Resonators (e.g. micro/nano cantilevers or bridges) are very useful devices in MEMS/NEMS as microsensors that could perform at high accuracy and precision. Producing microsensors with high resonance frequency will improve the accuracy even better. Down scaling is not the only way to achieve high resonance frequency since the resonance frequency also depends on the Young's Modulus to density ratio. 3C-SiC has high such ration that makes it very useful to high frequency resonators specially when they are down scaled to nano level.

SiC for fast electrothermal actuators

There are many advantages of electrothermal actuation over its counterparts (e.g. electrostatic and piezoelectric actuation). A larger force could be produced with electrothermal actuation at lower applied voltage. These advantages makes electrothermal actuation a very promising technique for micro/nano actuators. The main disadvantage of electrothermal actuation that hinders its use in high frequency applications, is the low thermal time constant. 3C-SiC as a material with high thermal conductivity has shown very promising results for thermal actuation not only in kHz but also in MHz range. A 1.89 MHz electrothermal actuation was achieved as shown in Figure.2.

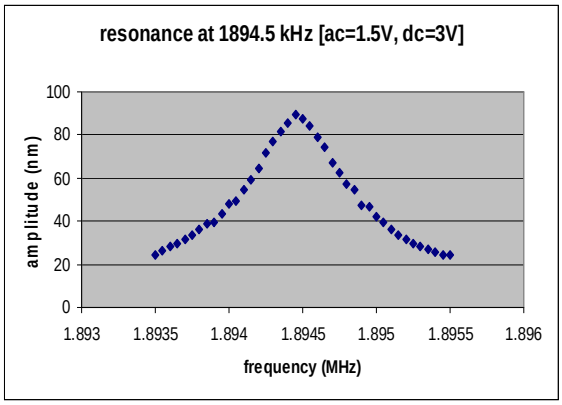


Figure 6.24 Resonance at the third mode using electrothermal actuation.

SiC for RF MEMS

Since 3C-SiC demonstrated excellent capapbility to be driven electrostatically and electrothermaly, it has made it also suitable for designing signal mixers for RF applications. Both electrostatic and electrothermal actuated SiC cantilevers were successfully applied to frequency mix two signals and the difference as well as the sum of two signals were used to actuate the cantilever at resonance as shown in Figure.3.

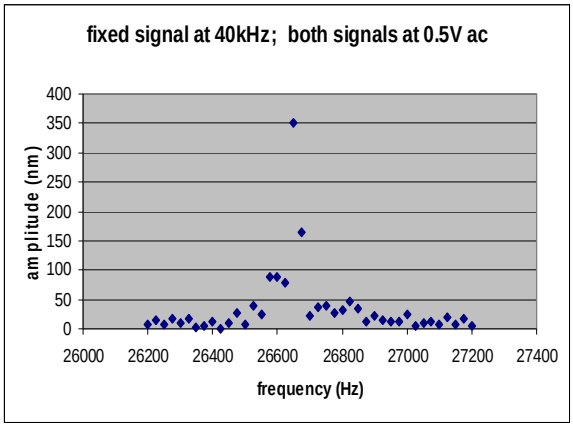


Figure 7.3 Electrostatic actuation used for signal multiplication; multiplying two signals to drive beam into resonance..

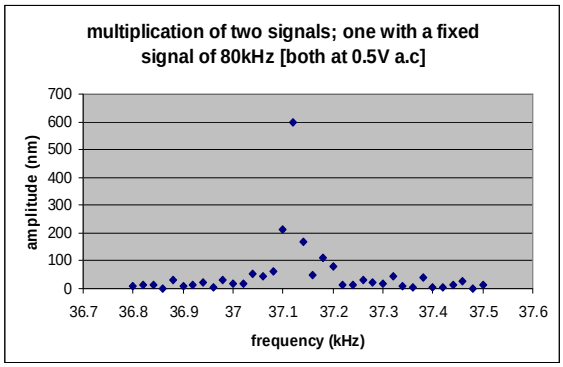


Figure 7.6 Electrothermal actuation used for signal multiplication; multiplying two signals to drive beam into resonance.

CONCLUSION

This paper reviewed some of the promising applications of SiC in different areas of microelectromechanical systems. These areas includes; the ability to achieve relatively high resonance frequency with an electrothermal microactuator, achieving Gigahertz frequency with nano electromechanical SiC resonator, as well as the capability of SiC to sustain high temperatures without much degredation in its mechanical properties. Finally, with all these advantages, SiC MEMS frequency mixers can replace the conventional electronic mixers and filters.

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