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SiC micro hot wires for flow measurement in harsh environments

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Summary

The present study deals with an integrated effort in the process of fabricating a silicon carbide-based micromachined device for measuring turbulent airflow in harsh environments, involving SiC etching and silicon substrate under-etching to create the MEMS structure. These SiC-based MEMS structures have been electrically and thermally characterized, with resistance and TCR measurements *vs.* temperature.

Keywords: MEMS, silicon carbide, thermal flow sensors, harsh environments.

Background, Motivation an Objective

There is an increasing need to measure turbulent airflow in harsh environments: high temperature, high flow speeds and reactive gases [1]. Silicon carbide is a promising material, already used for power electronic applications [2] and in MEMS for its high bandgap, mechanical robustness, thermal and chemical stability [3], [4]. The semiconductor nature of the material enables to control the dopant concentration, making it suitable as an active element in MEMS devices, exploiting the piezoresistive and thermoresistive effects [5]. The usage of SiC enables these effects to be used in sensor designs for harsh environments applications [6]. In this work we will focus on the demonstration of proof of concept of SiC-based hot-wire sensors, for measurement of hot and high-Reynolds turbulent airflow.

Design and realisation

This work introduces a micromachined device aimed for thermal flow measurement in harsh environments, made with a double-clamped micro-wire structure.

Epitaxial 3C–SiC thin films have been deposited onto a silicon substrate using Chemical Vapor Deposition (CVD) process. N-type doping of the SiC film has been achieved by introducing nitrogen in the CVD reactor. A negative 2×10^{18} cm^{-3} level of doping has been measured on Van der Pauw structures using a Hall effect characterisation setup. Structure patterning was achieved using Reactive Ion Etching (RIE) with a / mixture, followed by an under-etch process.

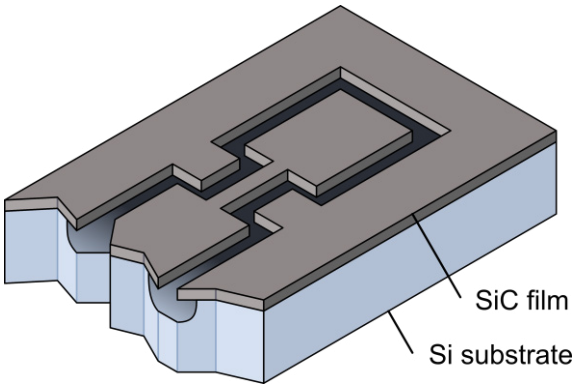

Fig. 1. Schematic view of the sensor micro-wire.

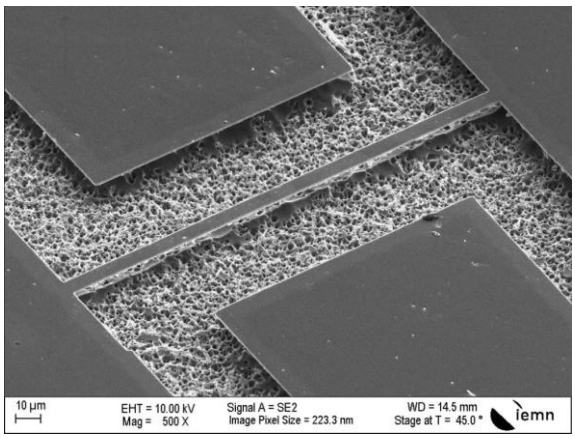

Fig. 2. SEM view of the sensor micro-wire.

Characterisation

First thermal and electrical characterisations of the device have been conducted, including current-voltage (I–V) curves to measure the electrical resistance of the micro-wire, as well as measurement of the Temperature Coefficient of Resistance (TCR) *vs.* the temperature. Emphasis is placed on the sensitivity evaluation for thermal sensors using SiC as an active layer. These measurements have been carried on temperatures ranging from 25 to 500 °C. A maximum TCR of 20000 ppm/K has been measured on a 180 °C overheat working point, which is much higher than what is typically obtained with metal-based hot wires (2000 – 4000 ppm/K).

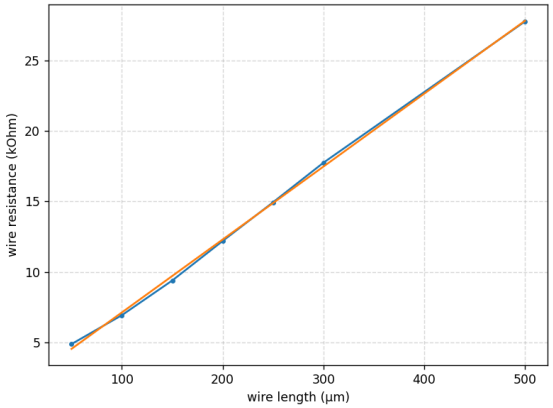

Fig. 3. Wire electrical resistance vs. *length.*

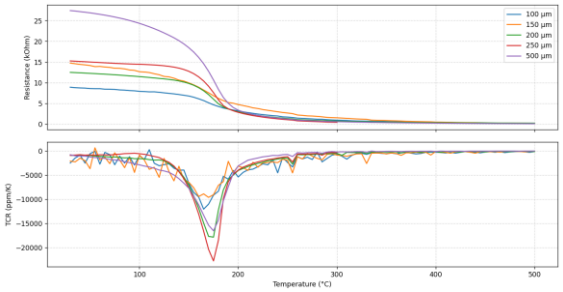

Fig. 4. Resistance and TCR measurements vs. *temperature.*

Conclusion

In conclusion, this study presents a proof of concept utilising SiC for the development of hot-wire sensors capable of measuring airflow in harsh environments. Through the fabrication and characterization of a SiC-based micro-wire structure, this study highlights the potential advantages of the material, making it a promising candidate for applications requiring thermal sensing in harsh environments.

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