Heat Transfer by Surface Phonon Polaritons in Silicon Carbide Nanowires

Nicholas Pugh[1,2], Zhiliang Pan[2], Deyu Li[2]

[1]Department of Mechanical Engineering, University of Maryland, Baltimore County, Baltimore, MD 21250

[2]Department of Mechanical Engineering, Vanderbilt University, Nashville, TN 37235

Introduction

Understanding thermal transport at the nanoscale level is crucial for maintaining the safe operation of modern electronic devices.

It is well-established that electrons and phonons are the major energy carriers for thermal transport in metals and semiconductors/insulators, respectively.

There is a possible third energy carrier contributing to thermal transport, i.e. surface phonon polaritons (SPhPs), originating from coupling between surface electromagnetic waves and optical phonons.

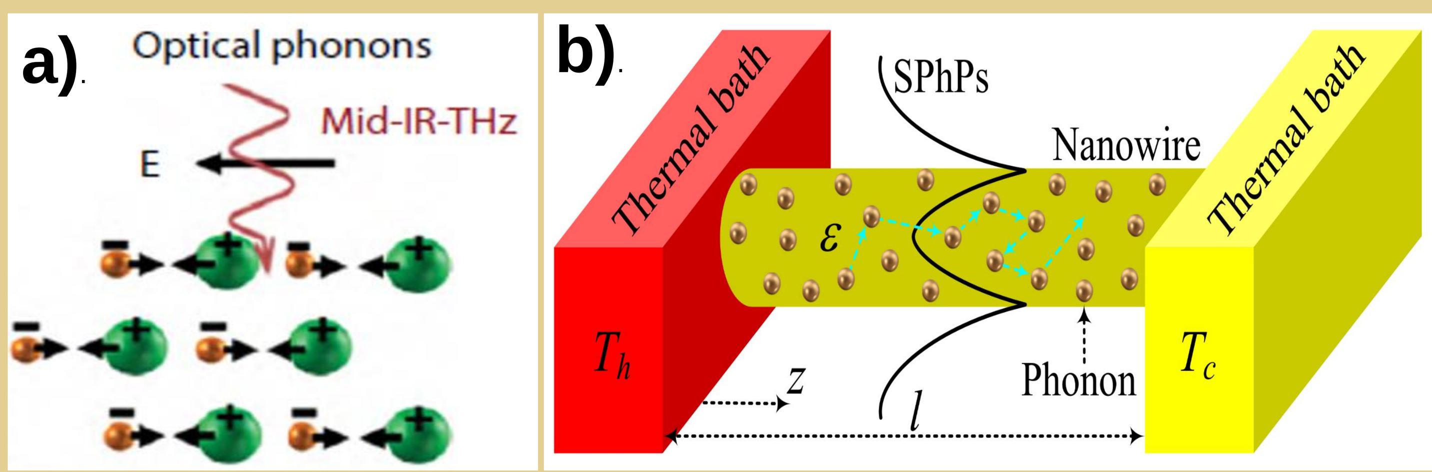

Figure 1: (a) Coupling between optical phonons and surface electromagnetic waves leads to SPhPs **(b)** Schematic diagram of SPhPs contributing to thermal transport in a polar nanowire.

Sample Preparation

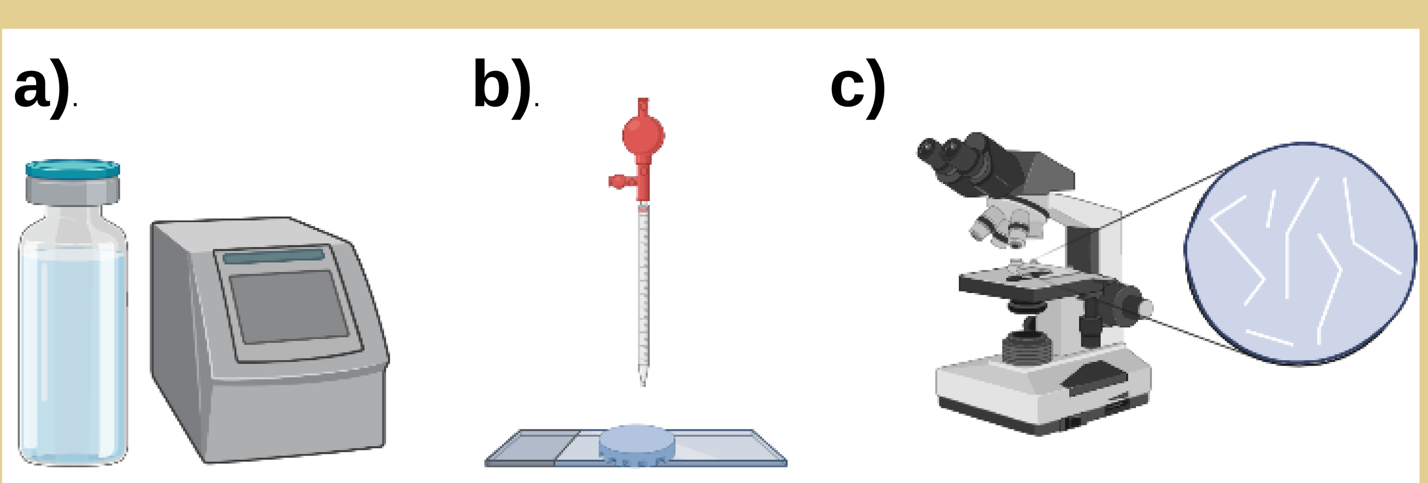

Figure 2: (a) Sonication to generate SiC suspension **(b)** Drop-casting SiC nanowire onto a PDMS surface **(c)** Nanowire sample preparation using a built-in micromanipulator.

Figure 3: Optical image of SiC nanowires dispersed on a PDMS surface and a probe mounted on a micromanipulator.

Micro-Thermal Bridge Method

Baseline Test | **EBID Coated Sample** | **Sample Cross-Section**

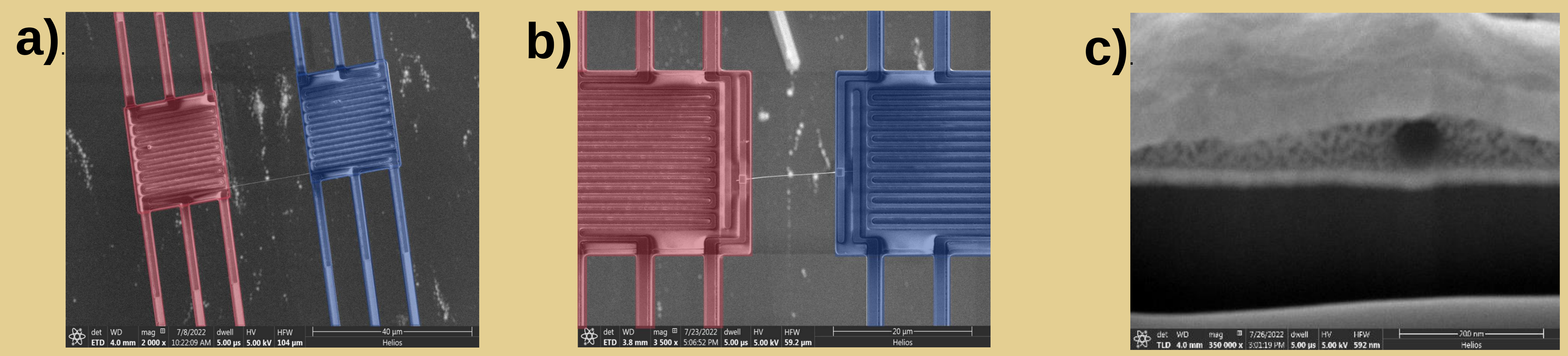

Figure 4: (a) Scanning Electron Microscope (SEM) image of a SiC nanowire on a device without EBID **(b)** SEM image of the nanowire with EBID coating **(c)** SEM image of the cross-section for the EBID-coated SiC nanowire. The image was taken at a tilted angle (52°).

Data Analysis

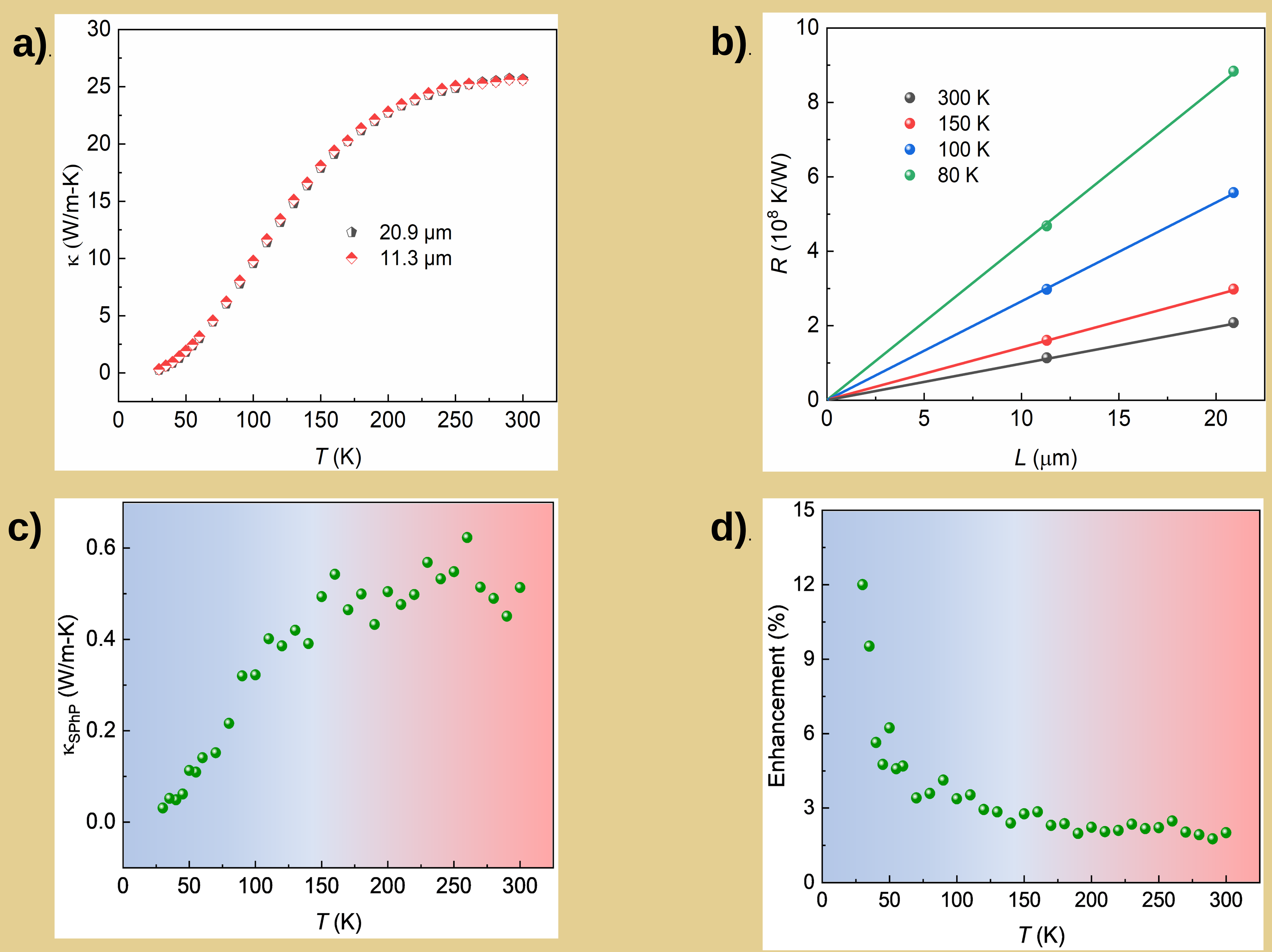

Figure 5: (a) Phonon thermal conductivity of a SiC nanowire with different suspended lengths **(b)** Thermal resistance with respect to sample length at different temperatures **(c)** SPhP thermal conductivity as a function of temperature **(d)** Thermal conductivity enhancement due to SPhPs.

Conclusion

- Contact thermal resistance is negligible in the baseline measurement and the intrinsic phonon thermal conductivity is extracted.
- Room temperature thermal conductivity of the nanowire is 25.6 W/m-K, much lower than the bulk value, as a result of enhanced phonon-boundary scattering in nanowire samples.
- Thermal conductivity enhancement of ~2% at 300 K, increasing to ~12% at ~30K
- The enhancement due to SPhPs is temperature dependent due to propagation loss at elevated temperatures.

Future Work

- Perform the EBID without the platinum layer on the bottom to achieve better thermal contact between the wire and device.
- Measure the thermal conductivity with a higher concentration of platinum in EBID mixture to explore the effect of different launching conditions.

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