Heat Transfer by Surface Phonon Polaritons in Silicon Carbide Nanowires

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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.

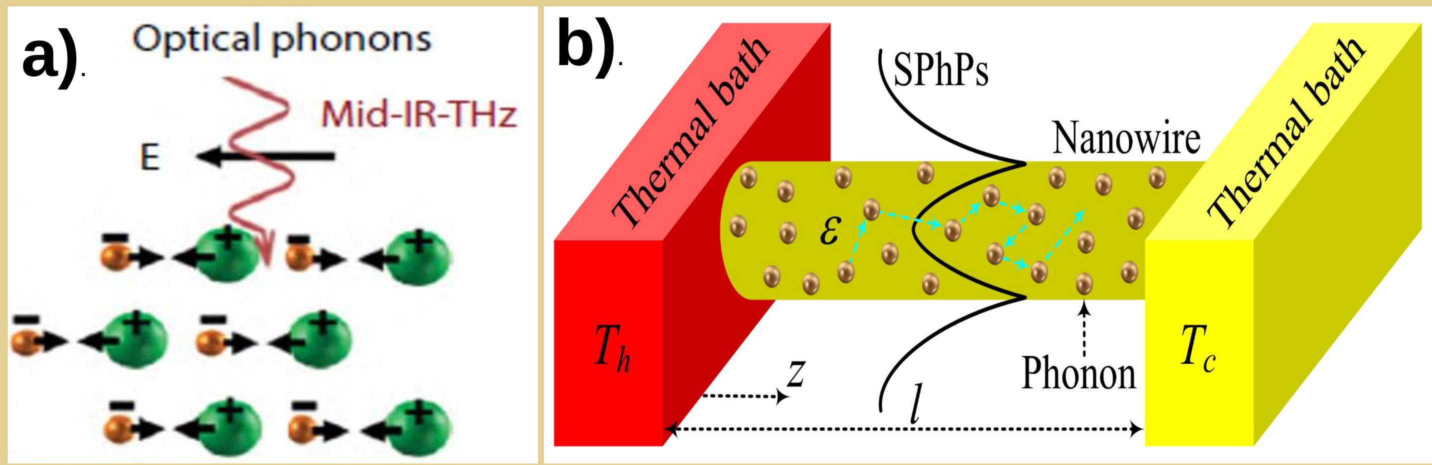

Figure 1: (a) Coupling between optical phonons and surface electromagnetic waves leads to SPhPs **(b)** Schematic diagram of SPhPs contributing to thermal transport in a polar nanowire.

Sample Preparation

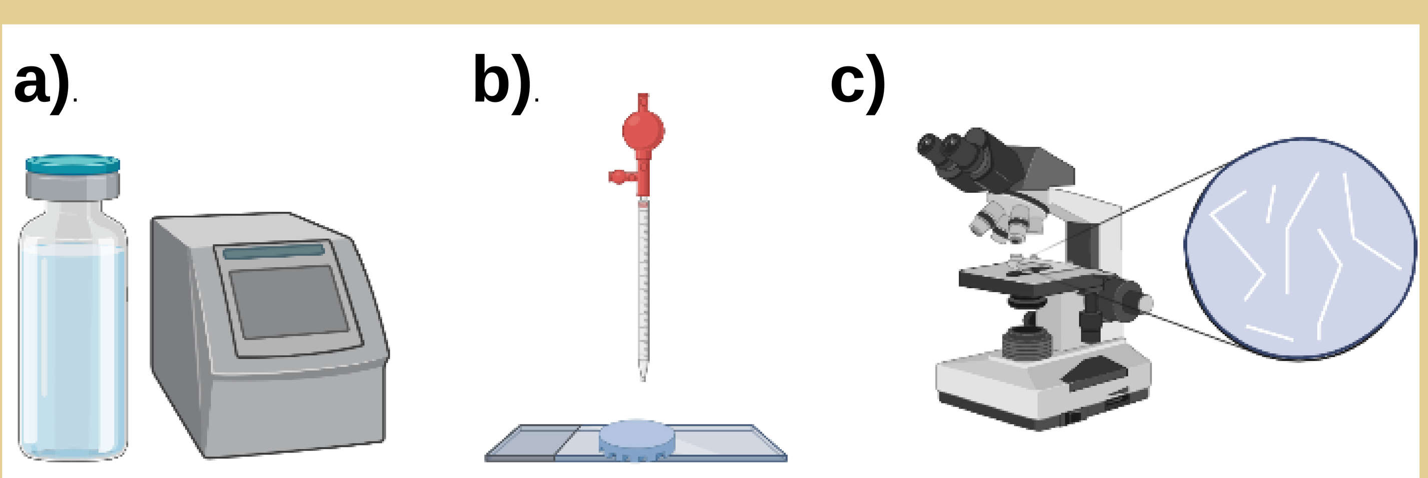

Figure 2: (a) Sonication to generate SiC suspension **(b)** Drop-casting SiC nanowire onto a PDMS surface **(c)** Nanowire sample preparation using a built-in micromanipulator.

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

Micro-Thermal Bridge Method

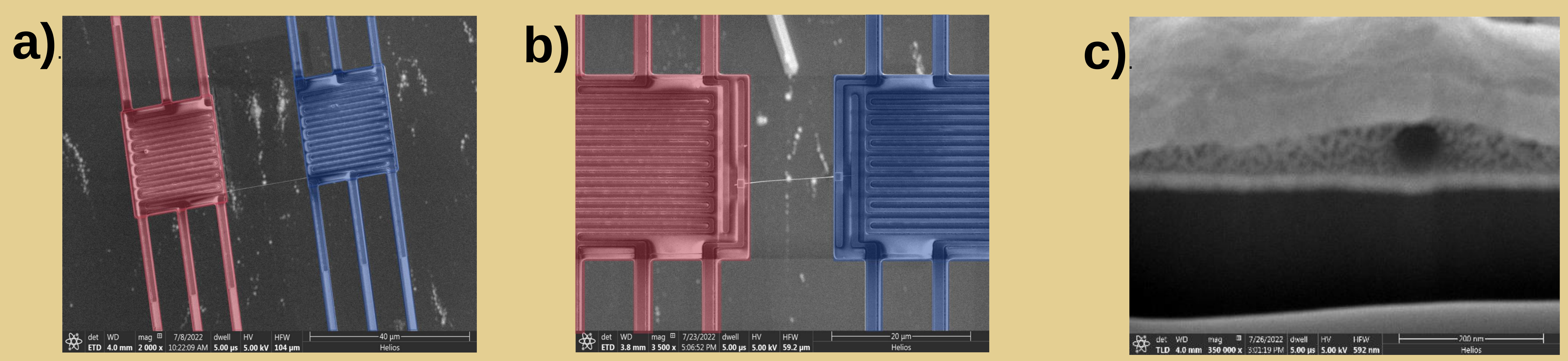

Figure 4: (a) Scanning Electron Microscope (SEM) image of a SiC nanowire on a device without EBID **(b)** SEM image of the nanowire with EBID coating **(c)** SEM image of the cross-section for the EBID-coated SiC nanowire. The image was taken at a tilted angle (52°).

Data Analysis

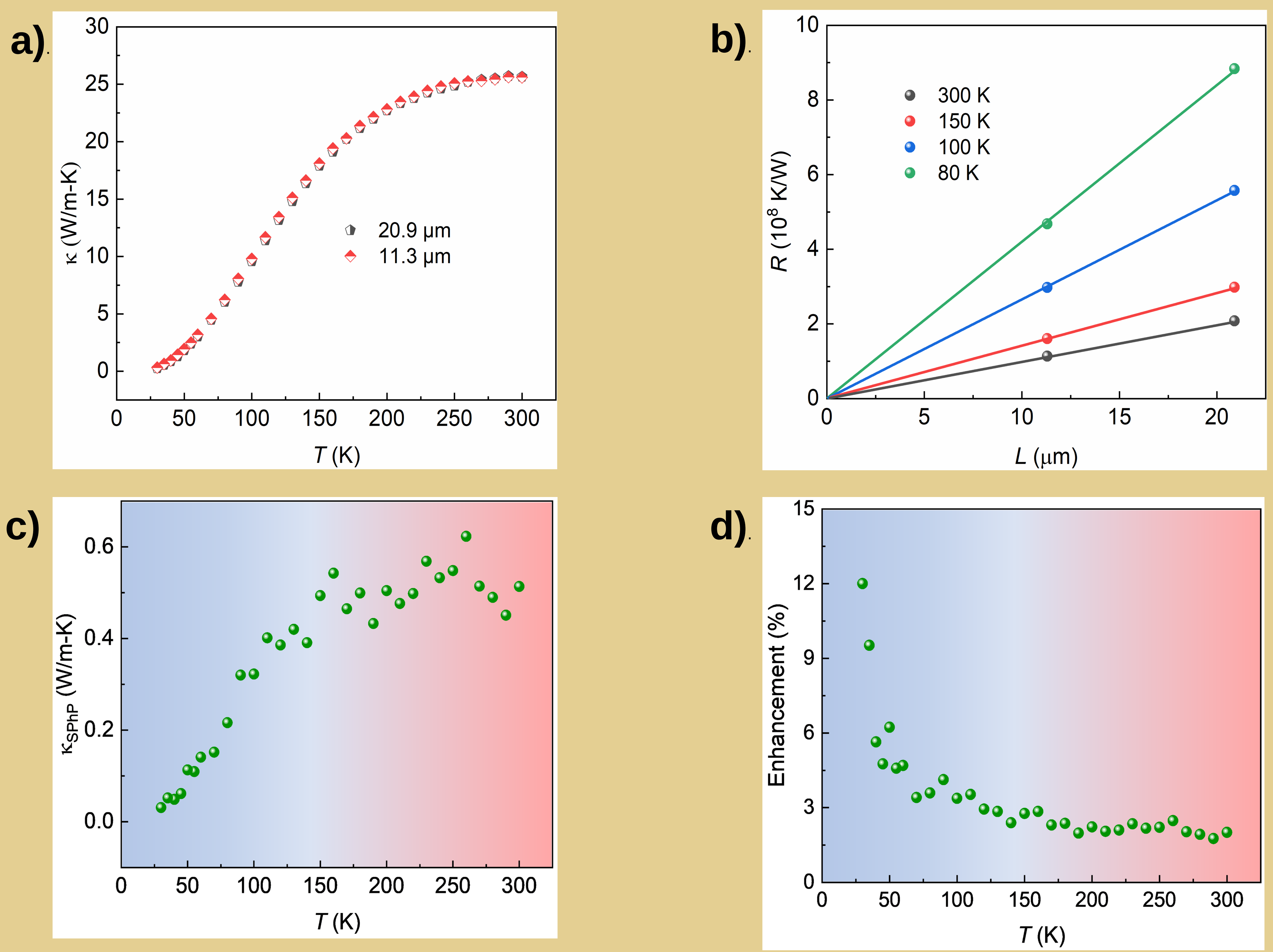

Figure 5: (a) Phonon thermal conductivity of a SiC nanowire with different suspended lengths **(b)** Thermal resistance with respect to sample length at different temperatures **(c)** SPhP thermal conductivity as a function of temperature **(d)** Thermal conductivity enhancement due to SPhPs.

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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