Low-Temperature Thermal Conductivity of thin-film MoSi for SNSPDs

Jacopo Piantanida Chiesa[1], Tom Q. Post[1], Shuhul Mujoo[1,2], and Michiel J.A. de Dood[1]

[1] *Leiden University, Niels Bohrweg 2, 2333 CA Leiden, The Netherlands*

[2]*Thomas J.Watson Sr. Laboratory of Applied Physics, 1200 E Calfornia Blvd, Pasadena, CA 91125, USA*

Superconducting Nanowire Single Photon Detectors (SNSPDs) are a key technology for quantum information applications, due to their low timing jitter and high detection efficiency [1]. The reset time of a single nanowire, limited by electronic and thermal reset times, is around 50 ns, well below generation rates of state-of-the-art single photon sources.

Thermal reset time in an SNSPD is governed by Joule heating and thermal conductivity. Heat is generated by the current carrying nanowire when a photon is absorbed and breaks superconductivity creating a measurable voltage. Dissipation of this heat into the thermal bath limits the detector's reset time. Electro-thermal models of this process have been proposed and evaluated [2], but rely on assumptions for the value of the superconductor's thermal conductivity κ. While this allows qualitative simulations of the reset dynamics of an SNSPD, it fails to give a numerical value regulating the thermal exchanges in the process. This makes it difficult to predict the effects of a change of materials on the heat dynamics and reset times of a device.

We present direct measurements of the thermal conductivity κ of thin-film MoSi in the 2-300 K temperature range using the 3ω method [3]. Most importantly, we access the behavior of κ across the superconducting phase transition. The 3ω method uses a wire (Pt or ZrN in our case) deposited on top of a stack that includes the thin-film MoSi layer. When driven by an AC current at frequency ω, the wire acts both as a heater and as a thermometer and generates a voltage component at frequency 3ω that is proportional to the thermal conductivity of the substrate. We apply the method to MoSi thin films deposited via diode RF sputtering, with a bulk critical temperature $T_C \simeq 7.40$K. The value of κ for the thin film is directly proportional to the offset between a measurement on a stack including the MoSi film (~ 90 nm) and one without it (see Fig.1). To allow thermometry at the lowest temperatures in our experiment, we use reactively sputtered ZrN wires [4] to overcome the limitation of Pt wires below 20 K.

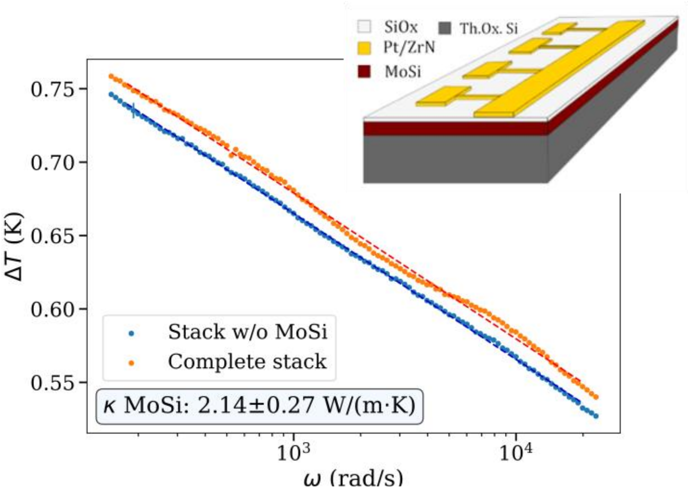

Fig. 1: *Room temperature 3ω measurement for a 90 nm MoSi film on a substrate (see inset). The temperature difference ΔT between top and bottom of the stack is proportional to the 3ω voltage. The value of κ for MoSi follows from the offset between the two lines.*

Our results will allow for a better understanding of thermal reset dynamics of SNSPDs, exploring how these properties are influenced by choice of substrate and capping materials.

References

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