Thermal contact resistance measurements on metal-semiconductor structures by scanning thermal microscopy and 3ω method

Carlos Acosta[1]
M. Brouillard[2], M. Dewitte[2], J.-F. Robillard[2], N. Horny[3], P.-O. Chapuis[1], S. Gomès[1]
[1]*CETHIL, UMR CNRS 5008, INSA Lyon, UCBL, Université de Lyon, 69621 Villeurbanne, France*
[2]*Univ. Lille, Junia, Univ. Polytechnique Haut-de-France, IEMN – UMR CNRS 8520, F-59000 Lille, France*
[3]*ITheMM, Université de Champagne Ardenne, 51100 Reims, France*
carlos.acosta@insa-lyon.fr

Reduced size of current electronic devices involves boundaries that play a crucial role in heat transfer inside such components. In particular, metal-semiconductor interfaces are widely present. Understanding the mechanisms of thermal transport undergone by energy carriers at the junction regions requires the determination of both thermal conductivities of materials in contact and thermal contact resistance between them [1].

We study experimentally metal-semiconductor structures by means of scanning thermal microscopy (SThM) and 3ω method. SThM is based on a self-heated metallic thermal sensor that is part of a movable AFM tip and enters in contact with the sample surface [2]. This technique allows to perform thermal imaging with a spatial resolution down to the nanometric scale, at sample temperature close to ambient. The 3ω method is based on the deposition of a metallic resistive wire on top of the sample and whose electrical resistance is measured as a function of an alternating power input [3]. In contrast to SThM, which is hardly able to be performed as a function of sample temperature, the 3ω method can provide thermal data over a wide temperature range through the use of a cryogenic system, while it does not allow for spatially-localised measurements.

Figure 1 shows an example of SThM image over a sample containing a silicon substrate on top of which two metallic nanolayers were successively deposited. In order to estimate the thermal boundary resistances involved in the sample, the obtained data are compared to FEM simulations. In addition, in order to better know the semiconductor thermal properties, we perform thermal conductivity measurements of thin layers deposited over silicon substrates by means of the 3ω method. In this case, a sensitivity analysis is detailed and the experimental results are compared to a semi-analytical model [4].

References

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Figures

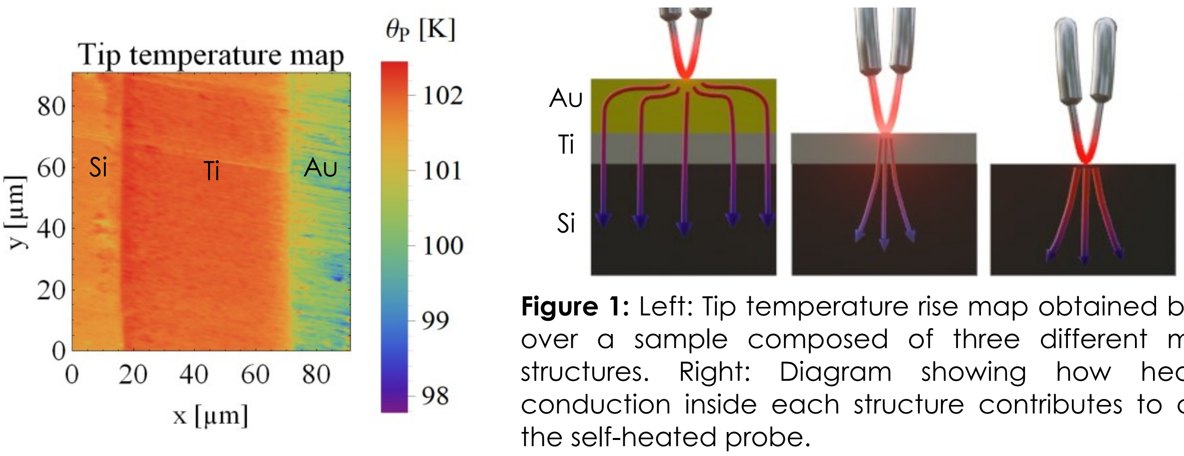

Figure 1: Left: Tip temperature rise map obtained by SThM over a sample composed of three different material structures. Right: Diagram showing how heat flux conduction inside each structure contributes to cooling the self-heated probe.

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