Spatially resolved thermometry of micro- and nano- devices using scanning thermal microscopy

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Self-heating and localized temperatures play an important role in the principle of operation of nano- and micro-scale devices. On the one hand, heating in transistor devices affects the mobility of the carriers, limiting device performance and lifetime. On the other hand, energy dissipation in memory devices is connected to some drawbacks, like reliability and energy efficiency. Understanding the energy dissipation mechanisms is therefore essential for the evaluation, design and optimization of our electronic devices.

Optical techniques, like infrared (IR) or Raman thermometry, can be used to obtain thermal maps of devices but their spatial resolution is diffraction limited, i.e., ~5 µm and ~0.5 µm respectively. Scanning thermal microscopy (SThM) is a scanning probe microscopy technique that allows thermal maps of devices with nanoscale resolution (~50 nm). Therefore, SThM is a promising tool for determining local hot spots and self-heating of different types of devices.

In this work, we show how SThM can be employed for the characterization of heat dissipation in nanoelectronics. Our SThM uses a thermo-resistive probe whose electrical resistance varies with temperature. This probe can be used as a nanoscale sensor to map the temperature of devices locally. First, we present challenges associated with the calibration of this probe, which are key to obtaining quantitative measurements of device temperatures. Second, we show how a calibrated SThM system can be used to gain knowledge of the energy dissipation of memory devices. We focus on resistive random access (RRAM) and phase change (PCM) memory devices, which show promise for applications such as non-volatile memory and neuromorphic computing. The SThM thermal maps show the filamentary heating from RRAM devices as well as the Joule heated PCM device, displaying local temperature features. These maps provide insights into device operation, showing how the energy dissipates and offering new routes for developing more efficient switching mechanisms.