While working under ambient conditions, Scanning Probe Microscopy (SPM) techniques face up to a liquid meniscus when the probe gets into contact with the sample. The meniscus is formed due to the capillary condensation of the ambient environment. This meniscus could be a barrier and prevents exploiting the performed measurements or an advantage for some applications like the “Dip-Pen Nanolithography”. In the case of some applications where BioMEMS or NEMS/MEMS are involved, the meniscus problem is referred as to the stiction. In our case, the stiction is the large lateral force required to initiate relative motion between the probe and the sample. In order to find out a solution to this problem, we present an investigation of the volume and the radii of the water meniscus at different temperatures of the probe. The probe is mounted on an atomic force microscope (AFM) for its 3D positioning and displacement and for controlling the force between the probe and the sample. A resistive element is located at the tip apex and serves to heat the probe depending on the electrical current. The probe temperature is verified through a Wheatstone bridge and is maintained constant during the approach of the probe to the sample. The variations of the capillary forces are measured at different probe temperatures on different hydrophilic and hydrophobic samples. The measurements as a function of the probe temperature show a progressive evaporation of the meniscus. Moreover, and simultaneously to these variations, the heat conductance to the sample is measured. A correspondence between the thermal signal and the capillary forces is evidenced as shown in Figure 1. Based on theoretical models found in the literature, the meniscus interaction radius is evaluated from the capillary forces. Afterwards, the heat conductance at different probe temperature levels is linked with the evolution of the capillary forces, e.g. the meniscus volume. The experimental results obtained with different probes are compared and in accordance with literature values. The effect of roughness on the capillary forces is shown for different samples. For each used probe, we introduce a model that takes into account all the heat transfer mechanisms that operate simultaneously between the probe and sample. The transposition of these results could be interesting for many related applications such as BioMEMS and NEMS/MEMS.
Fig. 1: An example of the correspondence between the pull-off forces and the heat flux ratio as a function of the probe mean temperature ($T_m$). The measurements shown here are between a Pt/Rd microprobe and a Ge sample. (IT) and (DT) stand up for increasing temperature and decreasing temperature respectively.