doi:10.1017/S1431927616000209
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Scanning Thermal Microscopy: Nano-localized Thermal Analysis and Mapping of Surface and Subsurface Thermal Properties

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Determining and acting on thermo-physical properties at the nano-scale is essential for understanding/modelling heat distribution in micro/nanostructured materials and devices with ever decreasing dimensions (few hundreds of nm) produced by electronic, optoelectronic, thermoelectric, and sensing micro/nanotechnologies [1]. Such miniaturization claims for thermal nano-characterization techniques to address issues (e.g. localized self-heating and high operation temperatures) which compromise device performance [2]. Scanning Thermal Microscopy (SThM) is a probing technique based on an atomic force microscope (AFM) that uses a specialized heated thermal nano-probe designed to act as thermometer and resistive heater which achieves the desired high spatial resolution [3-4]. Combined with AFM capability this contact technique can be pivotal in this context. Enabling direct observation and mapping of thermal properties such as thermal conductivity, temperature and thermal contact resistance between dissimilar materials, SThM has become a powerful tool with a leading role in diverse fields of science and engineering. Simultaneous collection of surface topography and thermal data is possible due to the independent nature of both mechanisms in the equipment [4].

We present the contribution of SThM (XE7 Scanning Probe Microscope, Park Systems) [5] in three relevant research topics: i) the study of thermal conductivity contrast in graphene monolayers deposited on different substrates. SThM proves itself a reliable technique to clarify the intriguing thermal properties of graphene which, due to its high efficiency in heat conduction, is viewed as an important contributor to minimize performance issues ensuing from devices and materials downscaling (Fig. 1). ii) SThM's ability to perform sub-surface imaging, by presenting thermal conductivity contrast analysis of polymeric composites showing detailed sub-surface entwining of polymeric chains which eludes surface topographical analysis (Fig. 2). iii) an approach to induce and study local structural transition temperatures in ferromagnetic shape memory alloy Ni-Mn-Ga thin films (Fig. 3) by externally assisting the conventional localized nano-thermal mechanism consisting in locally heating the sample and obtaining local thermal response by means of identifying surface morphology changes which characterize structural transitions [6].

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https://doi.org/10.1017/S1431927616000209 Published online by Cambridge University Press

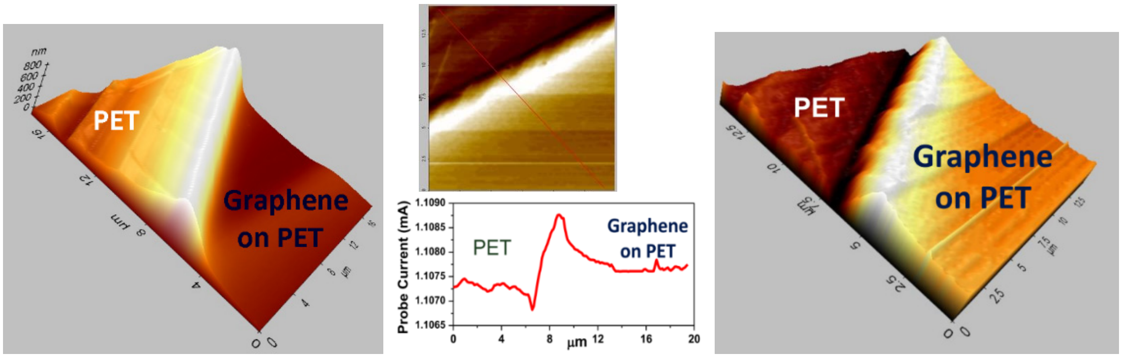

Figure 1. 3D images of topography (left) and thermal conductivity contrast (right) scans performed on a graphene/PET sample with line profile analysis.

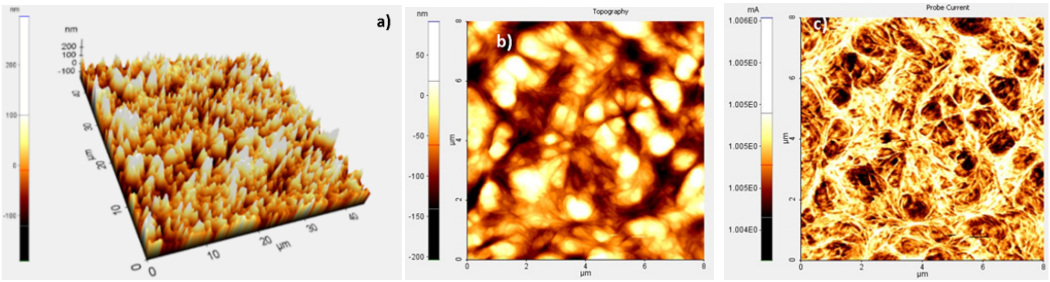

Figure 2. AFM topography scan (a) and SThM simultaneous topography (b) and thermal conductivity contrast (c) scans performed by SThM on a PLA membrane with 0.5% graphene oxide.

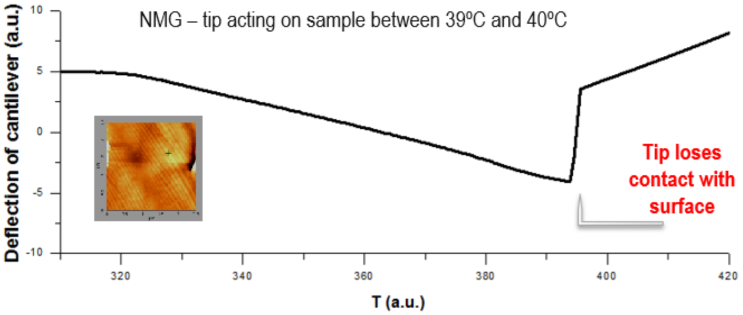

Figure 3. Cantilever deflection curve of a 400 nm Ni2MnGa film deposited on MgO when the sample is kept at a temperature safely below the beginning of the structural transition.

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