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Calibrating Resistance Measurements in Conductive Probe Atomic Force Microscopy: development of the first universal standard sample

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As technological advances keep pushing the limits of devices' fabrication to incredibly smaller scales, a commensurate development of measuring tools and methods is inevitably required. Conductive probe atomic force microscopy (C-AFM) is a scanning probe microscopy method designed to measure nanoscale currents and resistances. It has witnessed a recent rise in popularity owing to the versatility of its application in mainstream technologies, such as memories, photovoltaics, and semiconductors.

Despite the considerable contributions of C-AFM to understanding materials and devices' properties, measurements have remained prone to an arsenal of artifacts-inducing factors. No universal referencing approaches have been addressed so far, which has hindered the applicability of C-AFM in the development of fabrication and synthesis processes.

In this communication, we present the development of the first standard reference sample for the multi-resistance calibration on C-AFM measurements covering the range between 100 Ω and 100 G Ω . We discuss a set of measurement protocols using resistance mapping and current-versus-voltage (I-V) spectroscopic approaches to comprehend the quantitative measurement of resistances in C-AFM. For this, we address various factors involved in accurately evaluating the complete C-AFM setup resistance, including experimental, instrumental, and environmental factors.

Our findings show that using the multi-resistance wide-range resistance standard sample developed in this work allows a universal calibration of C-AFM measurements applicable to all available systems and with a 1% achievable relative uncertainty level. Further developments are underway to improve the measurement's accuracy of the lowest resistances (from 100 Ω to 10 k Ω) and expand the resistance range to 1T Ω or higher.

This new development paves the way for reliable quantitative measurements of resistances and currents at the nanoscale, which is expected to propel the understanding of the nano-electric properties at the level of individual devices and components.

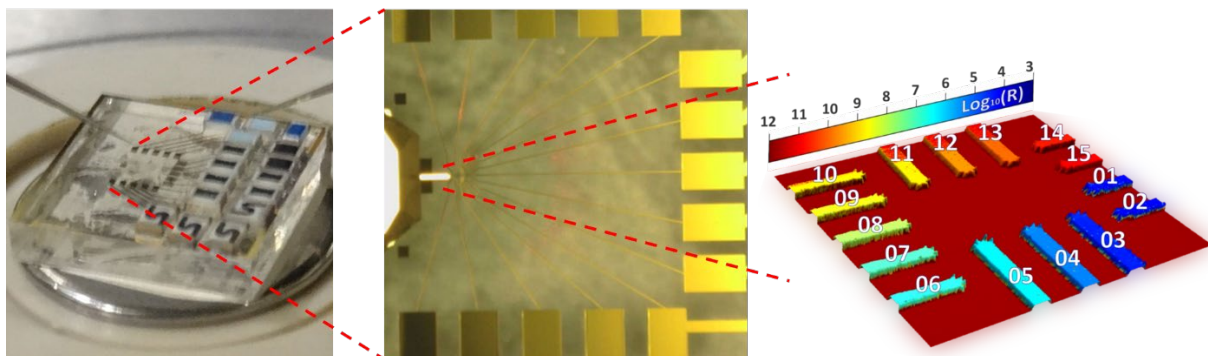


Figure 1. (left to right) Photograph of the developed resistance standard sample, top-view of the large and small measurement electrodes showing a conductive AFM probe, and a 3D map of resistances obtained from a C-AFM scan over 15 electrodes covering the range between 100 Ω and 100 G Ω .

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