Bimodal intermodulation spectroscopy with an nc-AFM

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Kelvin probe force microscopy (KPFM) is a well-known variant of atomic force microscopy (AFM) that probes the electrostatic landscape of a sample at the nanoscale by measuring the contact potential difference. Since the early 1990s, various approaches have been implemented to enhance KPFM performance in terms of spatial, potentiometric, and temporal resolution. In 2012, amplitude-modulated heterodyne KPFM [1] was introduced, combining the advantages of FM-KPFM and AM-KPFM in terms of lateral resolution (operation based on a force gradient component) and sensitivity (signal demodulation at the second eigenmode). A few years later, Borgani and Haviland [2] demonstrated that measuring intermodulation products provides access to the Fourier spectrum of any time-periodic potential generated by electrical or optical pumping. In other words, an AFM can be used to perform time-resolved measurements by analyzing the modulated components of the electrostatic force. However, intermodulation spectroscopy is difficult to transpose to UHV conditions due to the limited bandwidth inherent in very high resonance quality factors. In this communication, we will show that the conversion frequency scheme which is at the basis of heterodyne-KPFM can be applied to implement a bimodal variant of intermodulation spectroscopy, namely dual heterodyne KPFM (DHe-KPFM). We will illustrate how this new open loop heterodyne KPFM [4] mode can be used to perform single-pass surface photovoltage mapping of solar cell materials and optoelectronic interfaces, as well as time-resolved measurements of the surface photovoltage (SPV) through a Fourier analysis of the spectral components of the time-periodic surface potential. Finally, we will look at the remaining challenges in terms of analytical description of the complex interplay between the cantilever eigenmodes in the heterodyne configuration, and our proposed approaches to map photo-excited states in molecular assemblies at the molecular/intramolecular scale [4].

REFERENCES

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