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Modeling of Quantum Tunneling in Terahertz Scanning Tunneling Microscopes

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The tip-sample bias of a Scanning Tunneling Microscope (STM) is modulated by coupling THz pulses to the tip in order to get high transient tunneling current. This non-linear tunneling current and its parametric dependence need to be studied thoroughly to achieve efficient imaging of the sample surface. In this theoretical study, we investigate the basic scaling of rectified electrons in a THz-STM junction. We use a self-consistent quantum model [1-3] that includes both space charge potential and exchange-correlation potential, which were ignored in previous studies. Among these two important effects, the exchange-correlation potential, in particular, become crucial in THz-STMs since they are operated at high transient voltage in field emission regime [1][2]. We validate our calculation with recently reported experimental data and study the rectification property of the tip-sample junction for different parameters. We find that the time dependent tunneling current and the electron transport can be manipulated by varying the d.c. bias voltage (polarity, amplitude), incident THz field (polarity, shape, peak amplitude), work functions of STM tip and sample - especially their difference ΔW, and the tip-sample separation. Our study provides an important framework to characterize, control, and improve probing techniques at nanometer scale over subpicoseconds time periods.

[1] S. Banerjee and P. Zhang, AIP Adv., 9, 085302 (2019), [2] P. Zhang, Sci. Rep. 5, 9826 (2015), [3] S. Banerjee and P. Zhang, J. Vac. Sci. Technol. A 40, 030802 (2022), [4] S. Banerjee and P. Zhang, "Scaling of time-dependent tunneling current in terahertz scanning tunneling microscopes", under review, 2022.

Topic

Field Emission

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