AI-equipped Scanning Probe Microscopy for Self-driving Measurements at room temperature

M. Abe, Z. Diao, and H. Yamashita

Graduate School of Engineering Science, The University of Osaka

abe.masayuki.es@osaka-u.ac.jp

We present an AI-equipped scanning probe microscopy system (AI-SPM) designed to autonomously conduct atomic-scale measurements. This advanced system can autonomously target specific atomic positions and perform atomic-precision tasks, including the acquisition of spectroscopic data and atom manipulation. A key feature of our AI-SPM is its inherent ability to identify and either circumvent or target areas with surface imperfections. The AI-SPM system effectively compensates for common experimental challenges such as thermal drift from target positions and atomic fluctuations at the tip apex. These implementations are critical for maintaining the fidelity of site-specific surface measurements and analysis. We validated our AI-SPM system under the harsh conditions of room-temperature experiments, where thermal drift and atomic fluctuations at the tip apex are ubiquitous. In room-temperature experiments on the Si(111)-(7×7) surface, the system autonomously distinguished areas free of adsorbates and defects, then automatically acquired thousands of current-voltage (I-V) spectroscopy measurements across four different adatom sites while compensating for thermal drift and monitoring probe apex conditions throughout the autonomous experiment. Additionally, we demonstrated Ag atom manipulation on the Si(111)-(7×7) surface. Such experiments generate large datasets with the statistical significance necessary for reliable material characterization, confirming the capabilities of our AI-SPM implementation for enhanced data collection. The incorporation of AI into the SPM field paves the way for more efficient, accurate, and reliable atomic-level surface analyses, potentially transforming our approach to material characterization.

Reference

[1] Z. Diao, et al. Small Methods **9**, 2400813 (2024).