Surface Characterization of Thin-Layer Materials for Potential Applications in Physical Unclonable Functions

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Two-dimensional (2D) materials and **thin semiconductor films** exhibit unique properties that make them attractive for applications in electronics, sensing, and information security [1,2].
Here, we investigate selected layered systems to explore their potential for **physical unclonable functions (PUFs)**, focusing on characteristic nanoscale features revealed by **Raman spectroscopy, AFM, and SEM**.

Continuous $PtSe_2$ films covered with gold nanoparticles were studied using surface-enhanced Raman spectroscopy (SERS), revealing enhanced vibrational signatures [3,4]. Additionally, AFM measurements confirmed low roughness at the nanoscale morphology. Exfoliated ZrS_2 flakes were analyzed by conventional Raman spectroscopy and AFM techniques, highlighting thickness variations and different degrees of surface oxidation properties that appear highly specific to the sample [5,6]. Finally, chemically modified InSb layers examined with AFM and SEM showed surface roughness variations and etching-induced morphological changes.

These results demonstrate that intrinsic disorder, film morphology, and surface modifications can generate unique and irreproducible features. The combined use of SERS, Raman spectroscopy, AFM, and SEM provides a comprehensive framework for evaluating the suitability of thin-layer materials as candidates for secure PUF schemes [1,2].

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