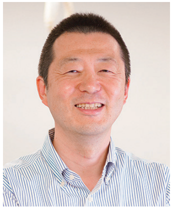
Development of New Methods for Analyzing Surfaces and Interfaces Using Scanning Probe Microscopy

Instrument Center



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Analytical methods based on surface and interface sciences provide crucial information for understanding physical properties and reaction mechanisms with high precision. Scanning probe microscopy (SPM) enables the analysis of geometric structures, mechanical properties, electronic properties, magnetic properties, and reaction mechanisms at surfaces and interfaces with extremely high resolution and sensitivity. We have applied SPM to energy conversion systems, such as rechargeable batteries.[1,2)]

In applying SPM to analyze surface and interface phenomena, it is essential to extract meaningful information from the data. However, the characteristics of SPM data can often be challenging to interpret. To address this, we have developed a new method to recognize specific structures and extract positional correlations in local structures from experimentally obtained SPM data. We have demonstrated that this method is applicable to mirror structures (Figure 1) and molecules adsorbed on metal surfaces, revealing specific characteristics in the positional correlations of molecular adsorption.[3)]

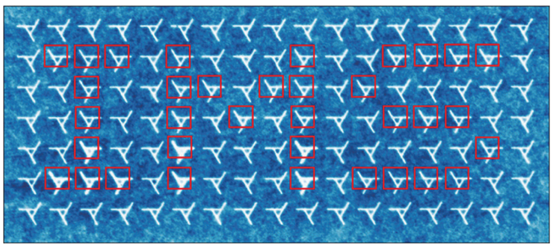

Figure 1. Recognition results for mirror structures in the scanning probe microscopy image. The red squares indicate the locations where specific structures were identified.[3)] © 2024, *Appl. Phys. Express*, CC By 4.0.

We have also developed methods to analyze new physical properties of water. The wetting phenomenon of solid surfaces by water is common in everyday life, yet its detailed mechanisms remain not fully understood. Previous research suggested that as humidity increases, water molecules adsorb uniformly, leading to the formation of a water film. However, the latest studies using nonlinear spectroscopy have shown that water adsorption at low humidity is non-uniform. We have developed an experimental system that directly observes the microscopic wetting behavior on glass surfaces under different humidity levels. By using atomic force microscopy, we achieved the clarification of the change of adhesive force in nano-droplet of water.[4)]

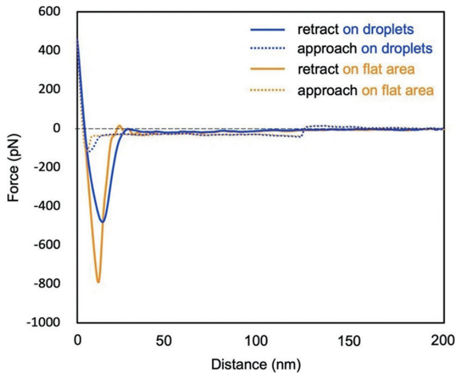

Figure 2. Force curves obtained from peak force tapping measurements at 80% humidity. The average of 10 force curves was acquired on nanometer-sized water droplets (blue) and on flat areas (orange), respectively. The dotted curves represent the approach curves, while the solid curves represent the retract curves.[4)] © 2024, *Sci. Rep.*, CC By 4.0.

Additionally, we have developed an experimental system to study the physical properties of ice in liquid. While detailed studies of ice surfaces under ultra-high vacuum conditions have been reported, their true nature in liquid has not been fully clarified. We successfully observed atomically flat ice surfaces in alcohol and demonstrated changes in surface structure due to reactions with the alcohols.[5)]

References

1) T. Minato and T. Abe, *Prog. Surf. Sci.* **92**, 240–280 (2017).
2) T. Minato, K.-i. Umeda, K. Kobayashi, Y. Araki, H. Konishi, Z. Ogumi, T. Abe, H. Onishi and H. Yamada, *Jpn. J. Appl. Phys. (Review)* **60**, SE0806 (2021).
3) S. Tsubokura, S. Kawano, Y. Imai, T. Ueda, K.-i. Nakamoto, H. Noma, H. Hioki and T. Minato, *Appl. Phys. Express* **17**, 035003 (2024).
4) Y. Araki, T. Minato and T. Arai, *Sci. Rep.* **14**, 10693 (2024).
5) R. Yanagisawa, T. Ueda, K.-i. Nakamoto, Z. Lu, H. Onishi and T. Minato, *J. Chem. Phys.* **161**, 024702 (2024).