Anomalous Potential-Dependent Friction on Au(111) Measured by AFM

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Abstract: We present an exploratory study of the tribological properties between an AFM probe and a Au(111) surface in an aqueous environment while subjected to applied surface potentials. Using a three-electrode setup, the electrical potential and interfacial electric field on a Au(111) working electrode are controlled. Lateral force microscopy is used to measure the friction forces between the AFM probe and the Au surface. As the AFM probe approaches the surface, normal forces are also measured to gain insight into the interfacial forces. When a positive potential is applied to the Au surface, the friction is found to rise sharply at a critical potential and levels off at a relatively high value. However, when a negative potential is applied, the friction is low, even lower compared to the open circuit potential case. These changes in friction, by a factor of approximately 35, as a function of the applied potential are found to be reversible over multiple cycles. We attribute the origin of the high friction at positive potentials to the formation of a highly confined, ordered icelike water layer at the Au/electrolyte interface that results in effective hydrogen bonding with the AFM probe. At negative potentials, the icelike water layer is disrupted, resulting in the water molecules acting as boundary lubricants and providing low friction. Such friction experiments can provide valuable insight into the structure and properties of water at charged surfaces under various conditions and can potentially impact a variety of technologies relying on molecular-level friction.