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Influence of Lithiation on Nanomechanical Properties of Silicon Nanowires Probed with Atomic Force Microscopy

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The nanomechanical properties of fully lithiated and unlithiated silicon nanowire deposited on silicon substrate have been studied with atomic force microscopy. Silicon nanowires were synthesized using the vapor-liquid-solid process on stainless steel substrates using Au catalyst. Fully lithiated silicon nanowires were obtained by using the electrochemical method, followed by drop-casting on the silicon substrate. The roughness, derived from a line profile of the surface measured in contact mode atomic force microscopy, has a smaller value for lithiated silicon nanowire and a higher value for unlithiated silicon nanowire. Force spectroscopy was utilitzed to study the influence of lithiation on the tip-surface adhesion force. Lithiated silicon nanowire revealed a smaller value than that of the Si nanowire substrate by a factor of two, while the adhesion force of the silicon nanowire is similar to that of the silicon substrate. The Young's modulus obtained from the force-distance curve, also shows that the unlithiated silicon nanowire has a relatively higher value than lithiated silicon nanowire due to the elastically soft amorphous structures. The frictional forces acting on the tip sliding on the surface of lithiated and unlithiated silicon nanowire were obtained within the range of 0.5-4.0 Hz and 0.01-200 nN for velocity and load dependency, respectively. We explain the trend of adhesion and modulus in light of the materials properties of silicon and lithiated silicon. The results suggest a useful method for chemical identification of the lithiated region during the charging and discharging process.

Keywords: nanomechanical properties, fully lithiated silicon nanowire, atomic force microscopy, roughness, adhesion, Young's modulus, friction, chemical identification