The Puzzling Electrical Conduction of Single-Layer Surface Channels Fabricated by Electron Beam Chemical Patterning of Monomolecular Films on Silicon

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Ionic surface paths with planned dimensions and shapes embedded in an inert, insulating surface background (single-layer surface channels) are fabricated using a novel electron beam patterning methodology that enables nondestructive local chemical modification of the top surfaces of highly ordered organosilane monolayers self-assembled on silicon substrates. Such atomically-thin surface channels with precisely defined micrometer-to-centimeter lengths and widths down to less than 20 nanometers exhibit unusual electrical conduction, critically dependent on their chemical composition, dimensions, the nature of the metal electrodes contacting the channel, the type and conductivity of the silicon substrate, the proximity of the channel to the silicon surface, the nature of the insulating spacer layer between the channel and the silicon surface, and the presence and nature of a top covering layer. The interplay between these different parameters allows modulating the conductivity of a given channel between that of a practical insulator to some abnormally high values.

Empirical correlations have been established between channel structure and chemical composition and its electrical conductivity using a comprehensive characterization methodology that combines electrical measurements with multi-mode AFM imaging, quantitative FTIR and micro-FTIR measurements, and post-patterning as well as post-current-passage surface chemical modifications. The accumulated experimental evidence points to a complex conduction mechanism that involves coupling of electronic with ionic transport, mediated and enhanced by interfacial electrical interactions with the underlying silicon substrate.

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