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Probing charge transport through individual molecules on silicon surfaces

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The ultra-high vacuum (UHV) scanning tunneling microscope (STM) allows individual molecules to be imaged, addressed, and manipulated on semiconducting surfaces with atomic resolution. In particular, this paper considers three different molecules on the Si(100) surface: styrene, cyclopentene, and 2,2,6,6-tetramethyl-1-piperidinyloxy (TEMPO). In all cases, room temperature STM current-voltage characteristics on individual molecules mounted on degenerately n-type Si(100) show multiple negative differential resistance (NDR) events at negative sample bias. On the other hand, at positive sample bias, the current-voltage characteristics do not show NDR, although a discontinuity in the differential conductance is observed. When the Si(100) substrate is changed to degenerate p-type doping, multiple NDR events are observed at positive sample bias while the discontinuity in the differential conductance occurs at negative sample bias. These empirical observations can be qualitatively explained by considering the energy band diagram for a semiconductor-molecule-metal junction [1]. More sophisticated nonequilibrium Green's function theoretical treatments also confirm the experimental data [2]. This paper will also describe recent efforts to characterize the temperature dependence of charge transport through molecule-semiconductor junctions using cryogenic UHV STM at temperatures between 10 K and 300 K [3]. In addition, using multi-step feedback controlled lithography [4], heteromolecular nanostructures consisting of both styrene and TEMPO molecules have been fabricated on hydrogen passivated Si(100). Atomic-scale characterization of these structures will be discussed in the context of silicon-based molecular electronics. [1] N. P. Guisinger, M. E. Greene, R. Basu, A. S. Baluch, and M. C. Hersam, *Nano Letters*, **4**, 55 (2004). [2] T. Rakshit, G.-C. Liang, A. W. Ghosh, and S. Datta, *Nano Letters*, **4**, 1803 (2004). [3] E. T. Foley, N. L. Yoder, N. P. Guisinger, and M. C. Hersam, *Rev. Sci. Instrum.*, **75**, 5280 (2004). [4] R. Basu, N. P. Guisinger, M. E. Greene, and M. C. Hersam, *Appl. Phys. Lett.*, **85**, 2619 (2004).