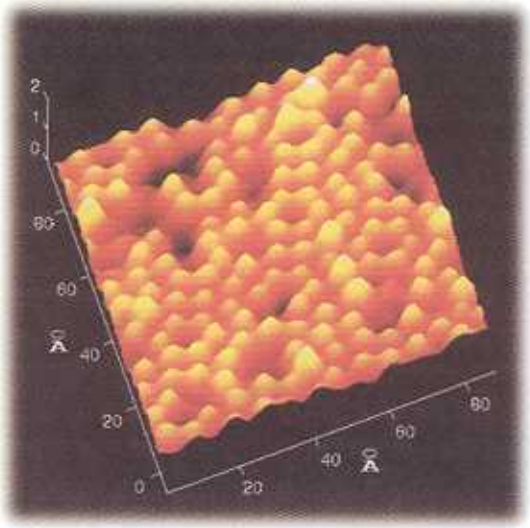
RESEARCH NOTES: Scanning the Semiconductor Surface

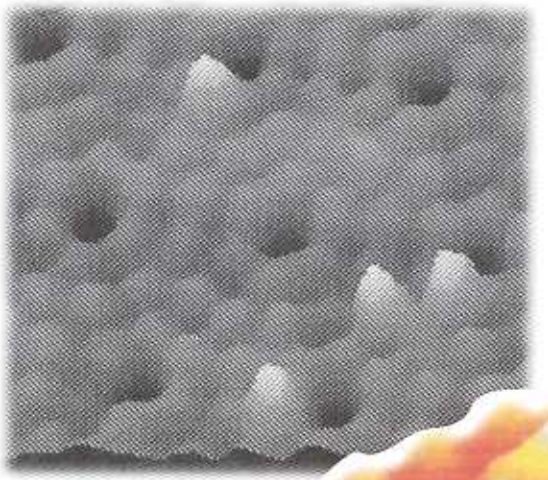
Semiconductors have two types of charge carriers: familiar negatively charged electrons, and collective entities that behave like mobile positive charges ("holes"). Incoming light can generate electron-hole pairs at the semiconductor surface, changing local electronic conditions and promoting local chemical interactions, e.g., between active atoms and molecules adsorbed to the semiconductor's surface. Such reactions have major implications for solar energy conversion and electronic material processing.

Previous studies have used tools that usually measure only the bulk (volume) or spatially averaged parameters of semiconductors. In contrast, Israel Science Foundation grantee Dr. Gad Haase has been using scanning tunneling microscopy (STM) to directly image the location and photo-induced interactions of individual atoms and molecules on the well-characterized surfaces of silicon, under ultra-high vacuum (10^{-10} Torr). The investigator's system is now capable of greater than 0.1 nm (10^{-10} m) lateral resolution and 0.01 nm resolution perpendicular to the semiconductor surface. It readily resolves single atoms (see STM photomicrographs on right).

For example, the middle photomicrograph shows a surface of p-doped silicon exposed to oxygen in the dark. The few adsorbed oxygen atoms (bright protrusions) show a two-to-one preference for corner, rather than center, positions in the silicon crystal structure in agreement with other studies. When illuminated by intense light from a 670 nm diode laser, with a photon energy above the band gap of silicon, the picture changes dramatically (top photomicrograph). Far more oxygen is adsorbed, and there is no preference for corner over center sites. In contrast, in similar experiments with ammonia, illumination changed neither the amount of adsorbed ammonia nor ammonia's preference for center sites. Despite the technical difficulties involved, the investigators have also taken sharp, stable images of the same surface coated with individual potassium atoms. Higher concentrations lead to white "islands", conglomerates of three or more potassium atoms covalently attached to the surface.



Pioneering ISF-sponsored studies are opening an important new window on photocatalysis at the atomic level.



To help elucidate photodissociation reactions, the investigators have been studying the photodecomposition of $Mo(CO)_6$, an important model reaction, on silicon surfaces. This reaction occurs only when potassium atoms are preadsorbed to the silicon substrate. In preliminary images, molybdenum (Mo) features seem to appear between neighboring potassium atoms. This is probably because positively charged potassium atoms at the surface facilitate the transfer of photoelectrons into the $Mo(CO)_6$ anti-bonding orbitals.

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