Quantum-Dot Molecules on the InAs(110) Cleavage Surface Created by Atom Manipulation

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Cryogenic scanning tunneling microscopy (STM) was employed in combination with density-functional theory calculations to explore quantum dots made of In adatoms on the InAs(110) surface. Each adatom adsorbs at a surface site coordinated by one cation and two anions, and transfers one electron to the substrate, creating an attractive quantum well for electrons at the surface. We used the scanning-probe tip to assemble the positively charged adatoms into precisely defined quantum dots exhibiting a bound state roughly 0.1 eV below the Fermi level at an intrinsic line width of ~4 meV, as revealed by scanning tunneling spectroscopy. For quantum-dot dimers (Fig. 1), we observed the emergence of a bonding and an antibonding state with even and odd wave-function character, respectively, demonstrating the capability to engineer quasi-molecular electronic states [1]. The method described in this work can be used to create quantum-dot molecules of even higher complexity. InAs(110) constitutes a promising platform in this respect because highly perfect surfaces can be readily prepared by cleavage and charged adatoms can be generated *in situ* by the scanning-probe tip. Moreover, working in (110) surface orientation offers the prospect of exploring cleaved III-V semiconductor heterostructures in cross-sectional geometry to ultimately be able to create electrical gating of the STM-generated nanostructures.

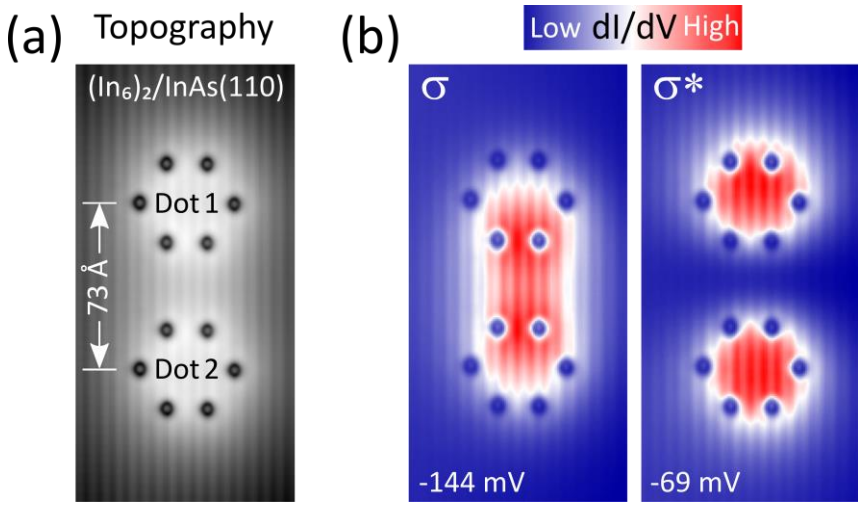

Fig. 1. (a) STM topography image (0.1 nA, 0.1 V) of two In_6 dots at a center-to-center spacing of $17a_0/\sqrt{2}$=72.85 Å with a_0=6.06 Å the InAs lattice constant; each dot consists of six In adatoms on InAs(110) assembled into a hexagon $7a_0$ wide and $8a_0/\sqrt{2}$ tall. (b) Spatial conductance maps recorded at constant tip height and the sample biases where the bonding (σ) and antibonding states (σ∗) of the quantum-dot dimer are observed in *dI*/*dV* spectra (not shown), confirming the symmetric (σ) and antisymmetric (σ∗) wave-function character, respectively.

References

[1] V. D. Pham *et al*., Phys. Rev. Res. **6**, 013269 (2024).