Kolloquium

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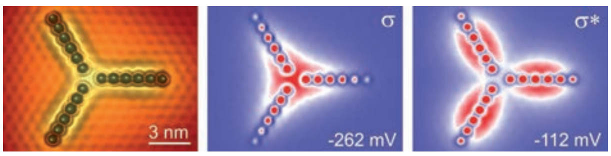
Generating and probing quantum dots with single-atom precision

physikalisches

Mo. 19.1.15
16:00 Uhr
Ort: H34

Quantum dots are often called 'artificial atoms' because, like real atoms, they confine electrons to quantized states with discrete energies. This makes them promising candidates for technological applications in photonics, optoelectronics, and quantum information processing. The main obstacle in the fabrication of semiconductor quantum dots is to control their size, shape, and arrangement because usually they consist of hundreds or thousands of atoms, resulting in inevitable variations in their energy level structure. In this presentation, it will be shown that quantum dots with identical, deterministic sizes can be created in a scanning tunneling microscope one atom at a time. By using the lattice of a reconstructed indium arsenide surface to define the allowed atomic positions, the shape and location of the dots can be controlled with effectively zero error. The dots are assembled from positively charged indium atoms, leading to the confinement of intrinsic surface state electrons. The described approach enables to construct quantum dot assemblies (quantum dot 'molecules') whose quantum coupling has no intrinsic variation but can nonetheless be tuned over a wide range. Quantum dots with precisely defined wave functions and energy levels – as realized here – are also excellent candidates for studying the behavior of electrons in reduced dimensions, avoiding the disturbing effect of stochastic variations in size and shape.



Left: 3D-rendered STM image showing the topography of a quantum dot 'molecule' consisting of three 6-atom indium chains. The dots are in a trigonal planar arrangement yielding a level structure similar to that of a real NH_3 *molecule.*

Center, right: Density-of-states maps revealing the bonding (σ) ground state and the doubly degenerate antibonding (σ) excited state of the quantum structure; red (blue) in the color-coded maps corresponds to a high (low) density of electronic states.*

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