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Generating and probing quantum dots with single-atom precision

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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 talk, it will be shown that quantum dots with identical, deterministic sizes can be created in a scanning tunneling microscope one atom at a time [1]. 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 electrostatic confinement of intrinsic surface-state electrons [2]. The described approach allows one to construct reconfigurable quantum-dot assemblies (“artificial molecules”) whose quantum coupling has no intrinsic variation but can nonetheless be tuned over a wide range [2,3]. Quantum dots with precisely defined wave functions and energy levels - as realized here - also represent an ideal model case for studying the behavior of electrons in reduced dimensions, avoiding the disturbing effect of stochastic variations in size and shape. At the same time, they can serve as the building blocks of coherently coupled dot arrays in two dimensions - an important step towards the realization of artificial quantum materials with broadly variable and precisely controlled properties.

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