Nanometer-scale structures by means of aerosol clusters

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Nanometer-sized particles are promising candidates for a number of applications for quantum devices. All these applications can be realized only when at least one of the following requirements is fulfilled: (i) all nanometer particles have the same size, (ii) this size can be precisely controlled, (iii) the particles have a certain structure, and (iv) the particles are located at certain places. Here, aerosol technology exhibits a great advantage since it is naturally suited to fabricate well-defined nanometer particles with good size control and in amounts sufficient for mass production.

In this talk, we will describe some approaches to fabricate quantum devices using aerosol technology. Metal nanometer particles with well-defined insulating layers, like oxides, nitrides and carbides, as produced using an arc evaporation source [1] could be employed for single electron tunneling devices. Combining extreme electron beam lithography to define contact gap geometries with dimensions of 10-50 nm with aerosol technique for the fabrication of metallic nanocrystals with diameters in the range 5-50 nm, and atomic-force microscopy based manipulation technique, in connection with on-line electrical measurements of the device characteristics, for positioning the particles with Ångström-level accuracy allowed the demonstration of four types of devices: an ohmic ultra-narrow wire, a nano-mechanical switch, a quantized conductance device, and a single-electron tunneling device [2,3]. Metallic particles embedded into a GaAs crystal have recently been used to control the current level in resonant tunneling devices [4]. In this case, the electrostatic repulsion from the carriers in the particles restricted the current transport to the areas without particles. The position-controlled deposition of particles directly from the aerosol phase is, however, difficult but under development [5,6].

Semiconductor nanometer particles have been produced with aerosol technologies. Using the reaction of ultrafine metal droplets, e.g. gallium, with gaseous precursors, e.g. arsine, GaAs and InP nanocrystals were fabricated [7]. Here, a future application towards quantum dot laser devices can be foreseen. Electroluminescence devices have been fabricated using silicon nano-particles produced by pulsed laser ablation at reduced pressure [8]. As a first step towards more efficient solar cells, PbS nanocrystals have been produced via the evaporation/conden-sation method [9]. Another example is the fabrication of needle-like structures with incorporated quantum dots with metal aerosol particles acting as etch masks [10] or as catalytic seeds [11].

These few applications of aerosol methods for future electronic devices demonstrate the need for a more concentrated effort to employ the potentials of this technology.

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