Advanced control of nanowire growth

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Low-temperature solution chemistry, combined with the right conditions, can create high-quality straight, bent, and branched nanowires.

Because the optical and electrical properties of low-dimensional materials depend on their size and shape, researchers have invested great effort in synthesizing high quality nanostructures. Some of the best systems to date are colloidal quantum dots (QDs) and nanorods made of CdSe, CdTe and PbSe.

Recent efforts have yielded branched, zero-dimensional (0D) nanostructures such as CdSe/CdTe ‘tetrapods’ with dimensions on the order of 50nm. These and other successes have given researchers glimpses into the size- and shape-dependent properties of nanomaterials.

Rapid progress has also been made in the realm of one-dimensional (1D) systems, such as creating semiconductor nanowires (NWs) using vapor-liquid-solid (VLS) growth. These efforts have been motivated in part by the strong polarization anisotropy of NWs in both absorption and emission, which has uses in polarization-sensitive photodetectors and photovoltaics.

For branched 1D structures, progress has been made by Ruda and Samuelson using epitaxial techniques. The resulting materials have potential uses in high-speed electronics. For example, the y-branch switch is a quantum-effect device capable of room-temperature terahertz switching. However, despite these initial successes, further developments are needed to controllably create high-quality branched 1D nanostructures.

In the mid 1990s, Buhro showed that 1D growth could be seeded at lower temperatures (< 400°C). Termed solution-liquid-solid (SLS) growth, this seminal discovery is still significant because it lets researchers couple such 1D-growth strategies with developments in the solution-phase synthesis of QDs and branched 0D nanostructures. The result has been high quality NWs made of common II-VI, III-V and group IV materials.

Recently, we have found that high-quality branched II-VI and IV-VI NWs can be made by varying NW growth conditions, such as the reaction-mixture temperature, the choice of coordinating ligands and the initial metal/chalcogen precursor ratio.

![Figure 1](image_url)

**Figure 1.** (a) Low-resolution transmission electron micrographs show branching of CdTe nanowires. High-resolution images of such II-VI, branched nanowires reveal tripod [(b) and (c)], v-shaped [(d) and (e)] and y-shaped [(f) and (g)] junctions.

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Characteristic shapes include tripods, v-shapes, and y-shapes (see Figure 1) as well as t-shapes and right angles for branched II-VI and IV-VI NWs respectively. These successes stem to a great extent from the preferred nucleation of specific crystal phases, aided by the choice of metal binding ligands and overall growth conditions. This illustrates the above-mentioned synergy between low-temperature NW growth and colloidal nanocrystal syntheses. Future developments exploiting parallel advances in the 0D realm may eventually lead to general shape control of branched NWs.

Advances in the low-temperature solution chemistry of high quality branched NWs supplement concurrent developments in the area of branched 0D nanostructures. They also open the door to further developments in the general shape control of mesoscopic materials. This may ultimately enable a deeper understanding of the size and shape-dependent properties of these materials.

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Masaru Kuno received his BA from Washington University in St. Louis. He then worked under Mouni Bawendi at Massachusetts Institute of Technology, receiving his PhD in 1998. Following a National Research Council postdoctoral stint at JILA (a National Institute of Standards and Technology laboratory) with David Nesbitt, he did work at the Naval Research Laboratory and is now at the University of Notre Dame.

References