How do guided nanowires grow on surfaces?

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Resumen

The large-scale assembly of NWs with controlled orientation on surfaces remains one challenge toward their integration into practical devices. During the last decade, we have reported the growth of perfectly aligned, millimeter-long, horizontal NWs of many different semiconductor materials (GaN, ZnO, ZnSe, ZnTe, CdSe, CdS, CdTe, CsPbBr 3 and more), with controlled crystallographic orientations on different planes of sapphire, SiC, quartz, and spinel [1,2]. The growth directions and crystallographic orientation of the NWs are controlled by their epitaxial relationship with the substrate, as well as by a graphoepitaxial effect that guides their growth along surface steps and grooves. We demonstrated the massively parallel “self-integration” of NWs into circuits via guided growth [3] and the production of optoelectronic nanosystems, including photodetectors, photodiodes and photovoltaic cells [4]. Systematic studies were performed to map the crystallographic rientations and polarity of epitaxially guided nanowires based on their nonlinear optical response under external electric fields, revealing interesting details about their formation [5]. More systematic studies were aimed at understanding the mechanism of guided nanowire growth based on both in situ and ex situ kinetic studies. Ex situ studies reveal the role of dimensionality in guided growth being controlled by the surface-diffusion of adatoms over the substrate [6]. In situ SEM studies yield beautiful movies of guided nanowires growing in real time, and reveal intricate qualitative and quantitative details of the guided growth mechanism [7]. The guided growth approach is now being extended from nanotubes and nanowires to other 1D, 2D and mixed-dimensional nanostructures like nanoribbons, nanofins and nanoplatelets by van der Waals epitaxy, enabling the controlled production of defect-free nanostructures and heterostructures with unique optoelectronic properties and potential applications ([1] Science 2011, 333, 1003 ; [2] Nature Commun., 2020, 11, 489 ; [3] PNAS 2013, 110, 15195 ; [4] ACS Nano, 2017, 11, 6155 ; [5] Nature Commun., 2021, 12, 3286 ; [6] PNAS 2020, 117, 152 ; [7] ACS Nano 2022, 16, 18757).