# Fabrication and Properties of Silicon Carbide Nanowires

by

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## ABSTRACT

Silicon carbide (SiC), with excellent electrical, thermal, and mechanical properties, is a promising material candidate for future devices such as high-temperature electronics and super-strong lightweight structures. Combined with superior intrinsic properties, the nanomaterials of SiC show further advantages thanks to nanoscale effects. This thesis reports the growth mechanism, the self-integration, and the friction of SiC nanowires. The study involves nanowires fabrication using thermal evaporation, structure characterization using electron microscopy, friction measurement, and theoretical modeling.

The study on nanowire growth mechanism requires understanding of the surfaces and interfaces of nanowire crystal. The catalyzed growth of SiC nanowires involves interfaces between source vapor, catalytic liquid, and nanowire solid. Our experimental observation includes the periodical twinning in a faceted SiC nanowire and three stage structure transitions during the growth. The proposed theoretical model shows that such phenomenon is the result of surface energy minimization process during the catalytic growth.

Surface interactions also exist between nanowires, leading to their self-integration. Our parametric growth study reveals novel self-integration of SiC-$SiO_2$ core-shell nanowires as a result of $SiO_2$ joining. Attraction between nanowires through van der Waals force and enhanced $SiO_2$ diffusion at high temperature transform individual nanowires to the integrated nanojunctions, nanocables, and finally nanowebs. We also show that such joining process becomes effective either during growth or by annealing.

The solid friction is a result of the interaction between two solid surfaces, and it depends on the adhesion and the deformation of two contacting solids among other factors. Having strong adhesion as shown from gecko foot-hairs, nanostructured materials should also have strong friction; this study is the first to investigate friction of nanostructures under (compressive) normal loads. Here, we show that the friction forces of SiC

nanowires films is 5-12 that of macroscopic solids. For nanowires films, the maximum static frictional force varies linearly with, but is not proportional to, normal load; it increases linearly with interface area; and it is independent of loading speed

To summarize, the combined experimental and theoretical studies in this thesis demonstrated unique structures and surface properties of SiC nanowires, including: **(1) Periodical twinning, surface faceting, and structure transition,** [Shim & Huang, *Appl. Phy. Lett.* 90, 083106] **(2) Twinning growth mechanism,** [Shim, Zhang & Huang, *J. Appl. Phys.*, submitted; Zhang, Shim, & Huang, *Appl. Phys. Lett.* 92, 261908] **(3) Self-integration (nanowebs formation) during growth,** [Shim & Huang, *Nanotechnology* 18, 335607] **(4) Thermal stability and self-integration by annealing,** [Shim, Kuppers & Huang, *J. Nanosci. Nanotech.* 8, 3999] and **(5) Strong friction of nanowires film**. [Shim, Kuppers & Huang, *NATURE Nanotech.*, submitted] The collection of these results enhances the understanding of SiC nanowires growth, the better control of their microstructure and integration, and the application of ceramic nanowires as friction material at high temperature.