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Jian-Wei Liu

Well-Organized Inorganic Nanowire Films

Assemblies and Functionalities

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Well-Organized Inorganic Nanowire Films

Assemblies and Functionalities

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Supervisor's Foreword

In the past two decades, accompanied by the development of nanoscience and nanotechnology, the research field of nanowire films has flourished with research activity both fundamental and applied. Ordered nanowire films of a diverse range of compositions and architectures were assembled after synthesis showing tailored physical and chemical properties. Macroscopic-scale integrating nanowires from disordered nanowire solution into ordered or controlled assembled structures will provide an advanced understanding of self-assembly and a new way for tailoring the properties of nanowires for application potential.

In this thesis, in the introduction section nanowire assembly strategies are summarized and many related literatures are also highlighted. However, we still meet serious issues and encounter severe challenges in fabrication of macroscopic nanowire assemblies.

Using simple solution-based strategies, such as microwave-assisted method and solvothermal process, uniform and high-quality one-dimensional nanowires were synthesized with sufficient characterization. The rational design and precise shape and size control of one-dimensional nanostructures through solution-based approaches plays an important role in fabricating functional nanodevices. Macroscopic well-defined periodic Tellurium and $W_{18}O_{49}$ nanowire mesostructures can be produced by the Langmuir–Blodgett (LB) technique without any extra hydrophobic pretreatment or functionalities. Based on the reactivity of the Te nanowire arrays, Te-telluride heteronanowire films were obtained with component and structure controllable. Using LB technique, Ag nanowires and Te nanowires were selected to construct co-assemblies. Besides LB technique, liquid–liquid interface, electron beam, and flowing shear interaction can provide driving forces for nanowire assembly. The ability to manipulate the assembly of nanowires, together with an understanding of the structure-dependent properties will offer a great opportunity to rationally design new nanodevices with substantially enhanced performance.

This thesis provides fresh insight into the nanowire assemblies and their functionalities. Based on these insights, versatile interface-induced nanowire assembly strategies are innovatively developed to optimize the applications. These findings also open opportunities for designing new nanodevices with ordered nanowire films.

December 2016

Prof. Shu-Hong Yu
Hefei, China

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Liu, J. W.; Chen, F.; Zhang, M.; Qi, H.; Zhang, C. L.; Yu, S. H., Rapid Microwave-Assisted Synthesis of Uniform Ultra long Te Nanowires, Optical Property, and Chemical Stability. *Langmuir* **2010**, *26* (13), 11372–11377.

Liu, J. W.; Zhu, J. H.; Zhang, C. L.; Liang, H. W.; Yu, S. H., Mesostructured Assemblies of Ultrathin Superlong Tellurium Nanowires and Their Photoconductivity. *J. Am. Chem. Soc.* **2010**, *132* (26), 8945–8952.

Liu, J. W.; Zhang, S. Y.; Qi, H.; Wen, W. C.; Yu, S. H., A general strategy for self-assembly of nanosized building blocks on liquid/liquid interfaces. *Small* **2012**, *8* (15), 2412–20.

Liu, J.-W.; Liang, H.-W.; Yu, S.-H., Macroscopic-Scale Assembled Nanowire Thin Films and Their Functionalities. *Chem. Rev.* **2012**, *112* (8), 4770–4799.

Liu, J.-W.; Wang, J.-L.; Huang, W.-R.; Yu, L.; Ren, X.-F.; Wen, W.-C.; Yu, S.-H., Ordering Ag nanowire arrays by a glass capillary: A portable, reusable and durable SERS substrate. *Sci. Rep.* **2012**, *2*, 987.

Liu, J.-W.; Xu, J.; Liang, H.-W.; Wang, K.; Yu, S.-H., Macroscale Ordered Ultrathin Telluride Nanowire Films, and Tellurium/Telluride Hetero-Nanowire Films. *Angew. Chem. Int. Ed.* **2012**, *51* (30), 7420–7425.

Liu, J.-W.; Xu, J.; Ni, Y.; Fan, F.-J.; Zhang, C.-L.; Yu, S.-H., A Family of Carbon-Based Nanocomposite Tubular Structures Created by in Situ Electron Beam Irradiation. *ACS Nano* **2012**, *6* (5), 4500–4507.

Liu, J. W.; Zheng, J.; Wang, J. L.; Xu, J.; Li, H. H.; Yu, S. H., Ultrathin W18O49 Nanowire Assemblies for Electrochromic Devices. *Nano Lett.* **2013**, *13* (8), 3589–93.

Liu, J.-W.; Huang, W.-R.; Gong, M.; Zhang, M.; Wang, J.-L.; Zheng, J.; Yu, S.-H., Flexible Electronics: Ultrathin Hetero-Nanowire-Based Flexible Electronics with Tunable Conductivity. *Adv. Mater.* **2013**, *25* (41), 5909–5909.

Liu, J. W.; Wang, J. L.; Wang, Z. H.; Huang, W. R.; Yu, S. H., Manipulating Nanowire Assembly for Flexible Transparent Electrodes. *Angew. Chem. Int. Ed.* **2014**, *53* (49), 13477–13482.

Liu, J.-W.; Xu, J.; Hu, W.; Yang, J.-L.; Yu, S.-H., First Systematic Synthesis of Tellurium Nanostructures and Their Optical Property: From Nanoparticles, to Nanorods, Nanowires, and Nanotubes. *Chem Nano Mat* **2016**, 392–393.

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