Crystal phase control of MBE growth InAs nanowires and its application for infrared photodetectors

P.P.Chen[1], S.X.Shi[1], Z.Zhang[2],Z.Y.Lu[1], J.S.Miao[1], W.D.Hu[1], J.Zou[2,3] and W. Lu[1]

[1]National Laboratory for Infrared Physics, Shanghai Institute of Technical Physics, Chinese Academy of Sciences, 500 Yu Tian Road, Shanghai 200083, China

[2]Materials Engineering and [3] Center for Microscopy and Microanalysis, The University of Queensland, St. Lucia, QLD 4072, Australia

***Abstract*—In this paper, we review our recent research on crystal phase control of InAs nanowires by molecular beam epitaxy, and its application for infrared photodetectors. We find the crystal phase of InAs nanowires can be controlled not only by Au-In catalyst phase, and also by additive bismuth atoms. High quality near-infrared single InAs nanowire photodetectors is also reported at last.**

I. INTRODUCTION

III-V semiconductor nanowires have attracted intense interest due to their potential applications in photonics and electronics [1]. Molecular beam epitaxy (MBE) has been increasingly employed to grow III-V semiconductor nanowires using the metal-assisted vapor–liquid–solid (VLS) mechanism. Recently, InAs nanowires have attracted special research interest due to their relatively high electron mobility, narrow band gap and small electron effective mass, which have made them a promising candidate for applications in infrared photo-detectors,transistors, and quantum computation[2]. For nanowires to be practically useful, it is critical to control their crystal phase and structure quality. However, it is a challenging task to control the InAs nanowire structure grown by MBE. In this paper, we review our recent research [3-6] on crystal phase control of InAs nanowires by MBE, and the application of InAs nanowire in the area for infrared photodetectors

II. RESULTS

InAs nanowire were grown in a Riber 32 MBE system on (111)B-oriented GaAs substrates. The effect of the growth temperature and V/III flux ratio on the morphology and microstructure of grown InAs nanowires by Au-assisted MBE was investigated. We find that a lower growth temperature is more beneficial to the synthesis of uniform defect-free wurtzite (WZ) InAs nanowires (as shown in Fig. 1). While the zinc blende (ZB) and defect-free ⟨00$\bar{1}$⟩ InAs nanowires with {00$\bar{1}$} catalyst/nanowire interface can be grown on the GaAs $\{111\}_B$ substrates at higher temperature (as shown in Fig. 1).Our detailed investigations indicate that the growth of ⟨00$\bar{1}$⟩ nanowires is governed by the small in-plane lattice mismatch between catalysts and nanowires. This study provides a new approach to control the growth of defect-free zinc-blende InAs nanowires by controlling the Au-In catalyst phase.

Recently, we also found that the crystal structure of InAs nanowires can be tailored by bismuth [5]. Detailed TEM characterizations reveal that, with the introduction of Bi into the InAs growth process, a sharp transition from WZ to ZB phase happens. With increasing the Bi flux to a certain value, a stable, defect-free ZB region of InAs NWs can be obtained. The tuning mechanism of the crystal of InAs nanowires can be attributed to the surfactant effect Bi ambient. This study provides an insight into the manipulation of crystal structure of InAs semiconductor nanowires through additive bismuth atoms.

At last, we report InAs nanowire near-infrared photodetectors with wavelength up to 1.5 µm. Fig.3. is the photocurrent spectrums of a single InAs NW (with WZ structure) near-infrared photodetectors. The single InAs NW photo -detectors displayed minimum hysteresis with a high I_{on}/I_{off} ratio of 10^5. These devices are attractive for applications in infrared photodetectors

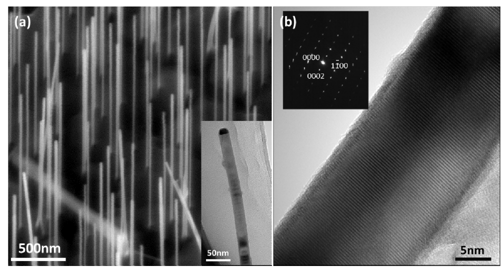

Fig. 1. (a) SEM image of high-quality InAs nanowires grown at 330C, (b) High-resolution TEM image of an InAs NW segment, the inset is its SAED pattern, demonstrating the formation of a pure wurtzite structure.

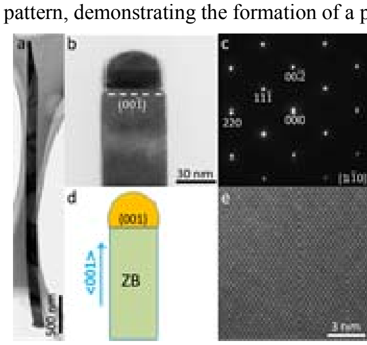

Fig. 2 (a) TEM image of a typical <00$\bar{1}$> InAs nanowire. (b) TEM image of the NW top region. (c) SAED pattern of the NW. (d) Schematic illustration of the <00$\bar{1}$>NW. (e) High-resolution TEM image showing defect-free ZB structure.

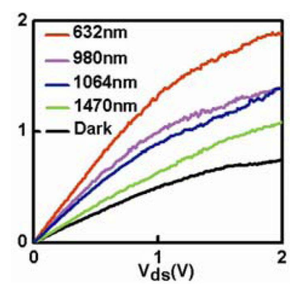

Fig.3. Photocurrent spectrums of single InAs NW near-infrared photo- detectors changing from red to near-infrared light.

REFERENCES

[1]W.Lu, C.Lieber, “Nanoelectronics from the bottom up,” *Nat. Mater*. 6, 841 (2007).

[2] S. Nadj-Perge, S. M. Frolov, et.al “Spin-orbit qubit in a semiconductor nanowire, ’’ *Nature*, 468, 1084 (2010).

[3]Z.Zhang, K.Zheng,Z.Y.Lu,P.P.Chen,W.Lu, J.Zou, “Catalyst Orientation-Induced Growth of Defect-Free Zinc-Blende,Structured ⟨00$\bar{1}$⟩ InAs Nanowires” *Nano Lett*., 15, 876 (2015).

[4]S.X .Shi, Z.Y .Lu, Z.Zhang, C.Zhou, P.P.Chen, J. Zou. “ Morphology and microstructure of InAs nanowires on GaAs substrate grown by molecular beam epitaxy,” *Chinese Physics Letters* 31 , 098101(2014).

[5] S.X.Shi, Z.Zhang, Z.Y.Lu, , P.P.Chen et.al “Crystal structure control of InAs nanowires by bismuth in molecular beam epitaxy,” (unpublished)

[6] J.S.Miao, W.D. Hu, N.Guo, et.al, “Single InAs Nanowire Room-Temperature Near-Infrared Photodetectors,” *Acs Nano*,8, 3628 (2014).