ULTRAVIOLET PHOTODETECTORS MADE BY BRIDGING WIDE BANDGAP SEMICONDUCTOR NANOWIRES

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Introduction

The fabrication of UV photodetectors with wide bandgap semiconductor nanowires is a trending topic in the UV photodetection research field. Wide bandgap semiconductors have many advantages over the commonly used narrow bandgap Si, such as better radiation stability and better spectral selectivity allowing for visible-blind or solar-blind photodetection [1, 2]. The 1D structure of nanowire provides confinement to the carriers along the radius while allows effective carrier transport along the length of nanowire. Furthermore, in nanowire one type of carrier is trapped by surface states while the other circulates under the influence of an electric field, which could result in photoconductive gain. The large surface-to-volume ratio of nanowires enhances the photoconductive gain, which makes nanowires great sensing elements for photodetectors [3]. In spite of all the merits, the application of wide bandgap semiconductor nanowires in photodetectors is hindered by the lack of effective integration method because of the difficulty in manipulating the nanowires. In this report, a single-step bridging method is proposed to integrate wide bandgap semiconductor nanowires into UV photodetectors. The wide applicability of our bridging method is demonstrated by the high performance of UV photodetectors made of nanowires with very different surface depletion properties. Direct nanobridges and bascule nanobridges are fabricated for nanowires with weak and strong surface depletion, respectively. The two types of the bridged nanowire UV photodetectors both show high sensitivity and fast response to UV light.

Method

Fig. 1 represents a general route for the fabrication of nanowire UV photodetectors by our single-step bridging method. A thin catalyst (usually Au) layer is pre-patterned on a quartz substrate by sputtering. The catalyst layer is only a few nanometers in thickness, which does not form a conductive layer. The bridged nanowire structure is then grown directly on the pre-patterned substrate in a chemical vapor deposition process. Details of the single-step bridging method have been reported elsewhere [4-6].

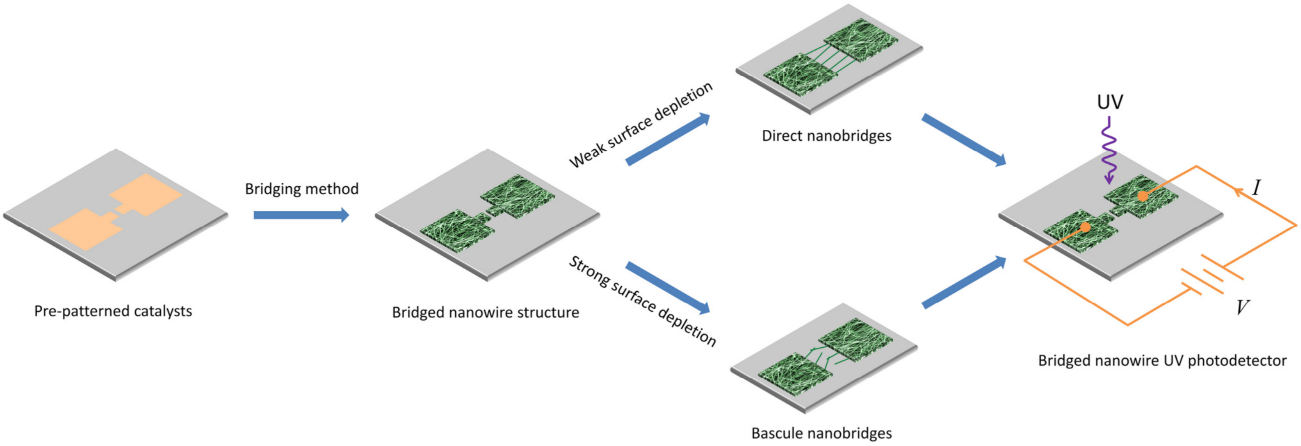

Fig. 1 A general route for the fabrication of nanowire UV photodetectors by bridging method.

Thick nanowire layer serving as native electrode is formed on top of the catalyst patterned area, while the nanowires bridging the gap between the nanowire electrodes serve as the sensing elements of the photodetector. The possibility to control the length of the bridged nanowires allows us to realize two types of bridged structures for nanowires with different surface depletion properties in an effort to maximizing the performance. For nanowires with weak surface depletion, such as β-Ga_2O_3 nanowires, a direct nanobridge structure is employed [5]. For nanowires with strong surface depletion, such as ZnO nanowires, a bascule nanobridge structure is employed [6]. Finally, UV photodetectors are constructed with the fabricated bridged nanowire structures by forming Ohmic contacts to the native nanowire electrodes.

Results and Discussion

Fig. 2 shows representative photoresponse results of the bridged nanowire photodetectors. The photoresponse properties of the nanowires are strongly influenced by the surface depletion. For β-Ga_2O_3 nanowires with weak surface depletion, the direct nanobridge structure, which is basically a photoconductor, is suitable for achieving high photodetection performance. As shown in Fig. 2a, the device shows a low dark current (~0.2 pA), a high and stable photocurrent ($I_{UV}/I_{dark} > 10^4$), and a fast time response. Because of the wide bandgap of β-Ga_2O_3 (~4.5 eV), the device also shows solar-blind spectral photoresponse [5]. For ZnO nanowires, because of the strong surface depletion the creation of a double Schottky barrier at the nanowire junction of the bascule nanobridge is found to improve the photodetection performance [6]. As shown in Fig. 2b, the ZnO bascule nanobridge photodetector also shows a low dark current (~20 pA), a high and stable photocurrent ($I_{UV}/I_{dark} > 10^4$), and a fast time response. Since ZnO has a bandgap of ~3.3 eV, the device is visible blind.

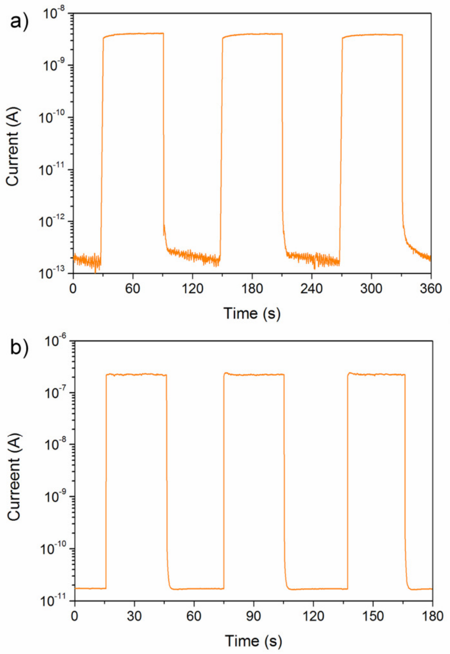

Fig. 2 a) Photoresponse of β-Ga_2O_3 direct nanobridges to UVC light (254 nm, 2 mW cm^2) at 30 V. b) Photoresponse of ZnO bascule nanobridges to UVA light (365 nm, 0.8 mW cm^2) at 1 V.

Conclusion

Wide bandgap semiconductor nanowires were integrated into high-performance bridged nanowire UV photodetectors by an efficient bridging method. Two types of bridged nanowire structures, direct nanobridges and bascule nanobridges, were realized for nanowires with weak and strong surface depletion, respectively.

References

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