論文の内容の要旨

論文題目　　Ultraviolet light detection with bridged semiconductor nanowires

（半導体ナノワイヤ架橋を用いた紫外光検知）

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Ultraviolet (UV) photodetectors have wide range of applications including flame detection, chemical and biological analyses, optical communications, UV source monitoring, and UV astronomy. UV photodetectors fall into two categories, namely, photoemissive detectors and semiconductor detectors. The photoemissive detectors are based on the photoemission effect, which requires high operating voltage that limits the applications of these detectors. The semiconductor detectors have many advantages over the photoemissive detectors including high quantum efficiency, high dynamic range of operation, and low operating voltage. However, semiconductor detectors are currently fabricated with single-crystalline thin films by epitaxial growth techniques which require lattice-matched substrates and sophisticated processes. On the other hand, single-crystalline semiconductor nanowires can be synthesized without resorting to epitaxial growth techniques. Further, nanowires exhibit superior photoconductive properties over the thin films due to their good crystal quality, small dimensions, and large surface-to-volume ratio. Therefore, the nanowire photodetectors can yield higher light sensitivity than their thin-film counterparts. Nanowire photodetectors are usually assembled using a top-down approach. Typically, the nanowires are transferred randomly to an insulating substrate and connected to metal electrodes using a lift-off process. However, this approach is not amenable to production because it is time consuming and not scalable. A new and efficient approach for the assembly of nanowires into photodetectors is therefore needed.

In this study, a single-step bridging method is proposed for the fabrication of bridged nanowire photodetectors. The bridged nanowire photodetector consists of thick nanowire layers serving as electrodes and nanowires bridging the gap between the thick layers serving as sensing elements. The nanowire layer electrodes and the bridged nanowires are synthesized simultaneously in a single-step chemical vapor deposition process. In order to achieve selective growth of the thick nanowire layers, very thin (~2 nm) gold layers having the shape of the electrodes are patterned on a quartz substrate. Bridged nanowires are formed across the gap between the nanowire layer electrodes. The bridged nanowire photodetector has several advantages over the conventional nanowire photodetectors: 1) the fabrication process is efficient and cost-effective; 2) the nanowire surfaces are free of contamination because no post treatment is needed after nanowire growth; 3) the nanowire properties are not affected by the substrate because the bridged nanowires are not in contact with the substrate.

The outer region of a semiconducting nanowire is depleted of mobile carriers due to surface-state charges. This effect is called surface depletion. The extent to which this depleted region penetrates the nanowire varies with nanowire diameter, dopant concentration, surface charges, and dielectric properties. By studying the effect of surface depletion on the photoresponse of semiconductor nanowires, two types of bridged nanowire photodetectors have been devised and realized using the bridging method. One consists of nanowires directly bridging the electrodes with almost no barrier. The other consists of bascule nanobridges formed by nanowires between the electrodes with double-Schottky barriers. Depending on the strength of the surface depletion of the nanowires, one of the two structures should be used to fabricate photodetectors with both high sensitivity and fast response. For nanowires with strong surface depletion effect, such as ZnO nanowires, the bascule nanobridge structure with double-Schottky barrier was used. The demonstrated ZnO bascule nanobridge photodetector shows high sensitivity (photocurrent to dark current ratio > 10^4), fast response (decay time $\tau \ll 20$ ms), and visible-blind spectral selectivity (cutoff wavelength ~ 380 nm). The decay time is much faster than that of the directly bridged ZnO nanowire photodetector ($\tau \sim 1$ s) and the ZnO nanowire photoconductor fabricated by top-down approach ($\tau \sim$ tens of seconds). For nanowires with weak surface depletion effect, such as β-Ga_2O_3 nanowires, the bridged nanowire structure with no barrier was used. The bridged β-Ga_2O_3 nanowire photodetector exhibits high sensitivity (photocurrent to dark current ratio > 10^4), fast response (decay time << 20 ms), and solar-blind spectral selectivity (cutoff wavelength ~ 275 nm).