Ultra fast asymmetric MIM diode structure employing vertical MWCNT

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Abstract

The ultra fast driving diode structure can be a key technology as basic electrical unit for those various applications [1]. *p-n* junction diode structure has been used generally to convert alternating current (AC) signal to direct current (DC) signal. The structure is also a core technology of Si based transistor, which is employed widely to various electrical components. However, the working mechanism is not suitable for high-speed driving since the speed limit is induced by the mobility of hole and electron in semiconductor. [2] Schottky barrier effect can make a much faster rectifying speed than that of *p-n* junction due to one side depletion formed by just hole or electron movement. [3,4] But, the estimated driving frequency limit is still less than ~ THz. Additionally, the thermionic injection mechanism leads to a poor power efficiency regarded as important in mobile devices. [5] On the issues, all metallic structure and tunneling mechanism can be a key solution factors. However, if we make tunneling diode using all metallic electrodes or even using semiconductor materials, the high reverse current level is an inevitable consequence, which results in a low conversion efficiency and much heat production causing driving speed retardation. [6,7] Here we report a tunneling diode structure using metallic materials as electrode structures with high contrast between the reverse and the forward current. The structural asymmetric effect [8,9] makes a large difference of the tunneling probability, the barrier height and width for the forward and the reverse bias state, respectively. Applying the structural asymmetric effect to MIM diodes, better electrical asymmetric characteristic was achieved in the lateral MIM and the MIC structure. Especially in the MIC diode, high contrast ratio between on- and off-current is as high as about forth-order at room temperature. Its temperature dependence is quite good up to 423K, compared to the other results. The structural sharpness of nanometer level from the fabrication process or the originality of material induces the low threshold voltage (~0.2V) and the high forward current value (16.97MA/cm^2) as well as simple fabrication process. The estimated frequency limit is about 4.74 THz.

References

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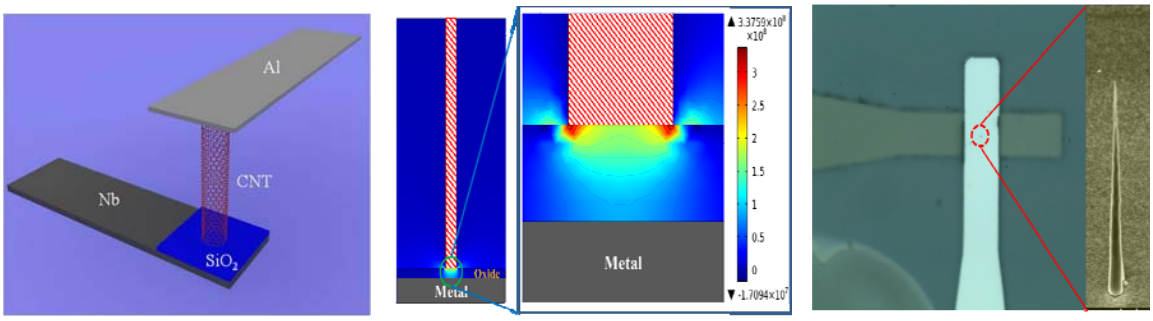
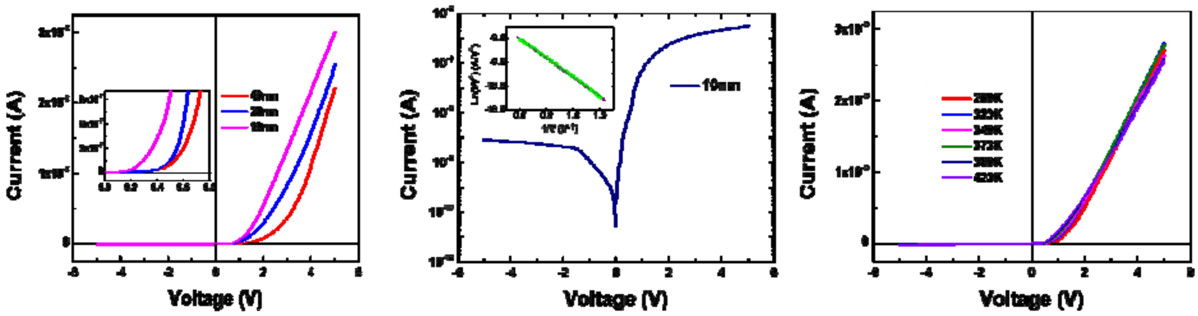
Figures



(a) (b) (c)

Figure 1. Vertical MIC diode structure a) shematic diagram of the MIC diode composed of Nb-SiO_2-Carbon nanotube on the SiO_2 substrate. b) The simulation of electrical field distribution of the MIC structure. c) The optical photo image of MIC structure. The point inside the red circle is the vertical MWCNT. The inset: 45° tilted view of SEM image for a multi-walled carbon nanotube grown on SiO_2/Nb layers.



(a) (b) (c)

Figure 2. The electrical characteristics of vertical MIC diode structure. a) Currernt-Voltage plots of MIC diodes. The inset of the plots: threshold plots with 10, 20, 40 nm (thickness of SiO_2) MIC diodes with magnified voltage-axis from 0 to 0.8 V. b) Log scale plot for of MIC diode of 10 nm SiO_2 layer and the inset that shows the plot based on Fowler-Nordheim tunneling model. c) The I-V plot of temperature-dependence of MIC diode from 298K to 423K.