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Fabrication of nanoscaled-schottky diodes based on metal silicide/silicon nanowire with scanning probe lithography and Wet etching and its electrical characterization

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1. Introduction

In recently years, Schottky barrier junctions are used in a variety of devices and circuit applications, such as the gate electrode of the field-effect transistor, the drain and source contacts in SBMOSFET [1]. However, as the size of the schottky diode is shrunk into the nanometer-sized region, the ratio of the diode perimeter to the diode area becomes much larger as compared with the case of macroscopic schottky junction, and current transport properties show several deviations from conventional diode behavior [2]. In this paper, we have fabricated a nanoscaled-schottky diode, utilizing a single nickel monosilicide (NiSi) / silicon nanowire (SiNW) schottky diode, and characterized by electrical transport measurements. A rectifying behavior consistent with a 0.22eV schottky barrier was found, which is found very useful for many future applications of nanoelectronics.

2. Experimental

The fabrication sequence of nanoscaled-Schottky barrier junction by forming a NiSi/Si heterojunction in silicon nanowire is summarized in Fig. 1. Samples with SiNWs, details of SiNWs fabrication with scanning probe lithography and tetramethylammonium hydroxide solution has been reported previously [3], were deposited one-half of a SiNW with Ni films. The NiSi/Si nanowire schottky diodes were produced by rapid thermal annealing the Ni coated SiNWs. The unreacted Ni was completely removed by a selective etching solution [4]. Figure 2 shows the SEM image of NiSi/Si nanowire schottky diode, one-half of the wire is Si and the other half is NiSi. The feature sizes of SiNW and NiSi nanowire follow the relationship of $W_{Si}=0.82\times W_{NiSi}$.This results are expected for conversion of Si to NiSi on the basis of different unit-cell volumes [4]. Electrical contacts were made on individual nanowires and electrical transport measurements were then performed.

3. Results and Discussion

As shown in Fig. 3, the I_{ds}-V_{ds} characteristics of SiNW, NiSi nanowire and NiSi/Si nanowire schottky junction diode by two-terminal measurement. Current rectification with a turn-on voltage of ca. 0.2V in forward bias has been observed clearly in NiSi/Si nanowire schottky diode. The typical forward-biased I-V characteristics of schottky barrier diode follow the relationship:

$$I = A^{*}AT^{2}\exp\left(-\frac{e\varphi_b}{kT}\right)\left[\exp\left(\frac{eV}{nkT}\right)-1\right] \qquad (1)$$

where A is the diode area, A* is effective Richardson constant, φ_b is the schottky barrier height, n is the ideality factor, T is the absolute temperature and V is the applied voltage. The parameter φ_b can be derived from the experimental I-V data using current-temperature methods from eq. (2) [5]:

$$\varphi_b = \frac{V}{n} - \frac{k}{q}\left(\frac{d\left(I/T^2\right)}{d\left(1/T\right)}\right) \qquad (2)$$

From the data of temperature-dependent I-V, the Schottky barrier height of φ_b =0.22eV was obtained. The experimental results also show that nanoscaled-Schottky diodes have an on-off current ratio of nearly 10^3 at 0.2/-4V bias. In inset of Fig. 4 (b), it is clear that I-V curve shows a reverse bias breakdown up to -5V. The built-in potential is given by V_{bi}=φm-φs, φs depends on the doping level of semiconductor, i.e. not a constant. Since more negative V_g induces higher the φs such that the smaller built-in potential barrier is obtained. Figure 4 (b) shows the diode can be modulated by the back gate voltage V_g. So, the ability to tune the built-in potential by the gate modulation may enhance the performance the diodes for different applications.

4. Conclusions

We have demonstrated that coating one-half of single SiNW with Ni film and annealing the coated SiNW yields gate-modulated nanoscaled-schottky diode. The electrical transport properties of nanowire devices is studied. The measured data exhibited a clear rectifying behavior and no reverse-bias breakdown was observed up to -5 volts. It is believed that a single NiSi/Si nanowire schottky diode can served as basic components for nanoelectronic applications.

Acknowledgements

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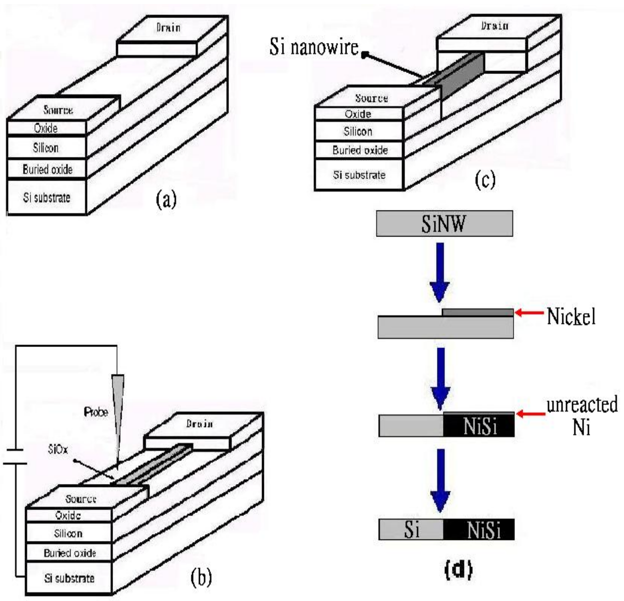


Fig. 1. Schematic of major steps for NiSi/Si nanowire schottky diode.

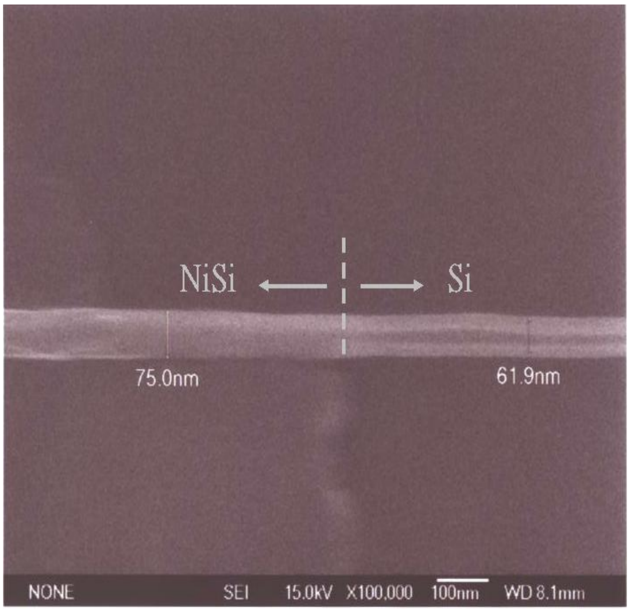


Fig. 2. SEM images of NiSi/Si nanowire schottky diode.

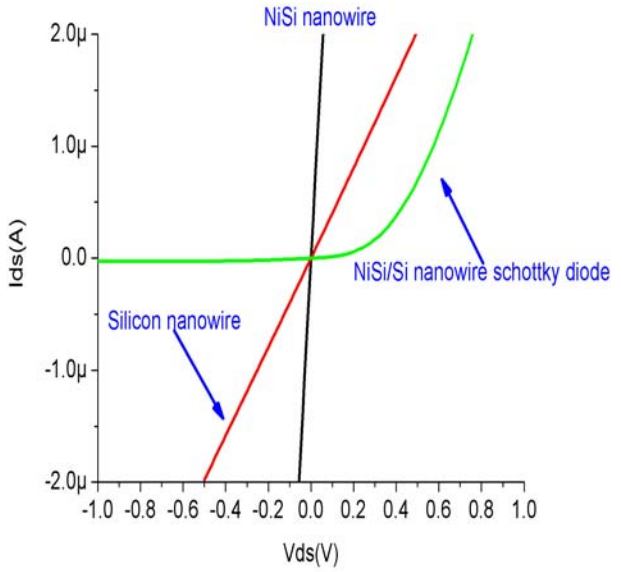
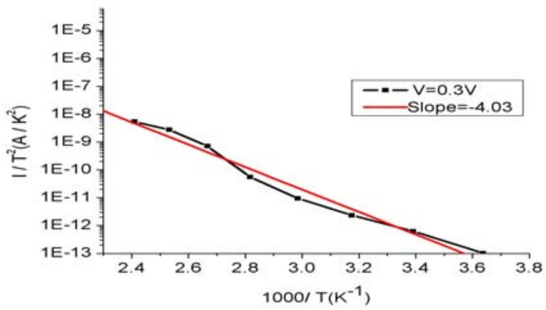
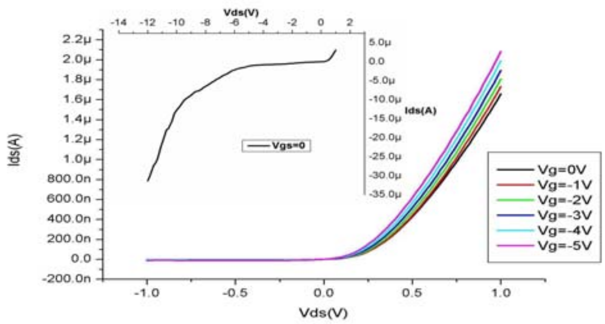


Fig. 3. I-V characteristics of silicon nanowire,NiSi nanowire and NiSi/Si nanowire schottky diode.



(a)



(b)

Fig. 4. (a) Richardson plot of NiSi/Si nanowire schottky diode.(b) Output characteristics of the diode at different gate voltages.