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UV 酸化による p-NiO/n-Si ヘテロ接合ダイオードの作製

A Heterojunction Diode p-NiO/n-Si Formed by UV Oxidation of Ni on n-Si

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1. Introduction

Although nickel monoxide (NiO) is usually an insulator with the NaCl-type structure and pale green color, oxygen-rich NiO_x often shows p-type conductivity as a semiconductor. Recently its resistive switching behavior also attracts much attention to place NiO as a candidate material for resistive switching memory. We paid a great attention to the p-type conductivity of NiO and have been motivated to form a pn heterojunction of p-NiO with another n-type semiconductor. In this study, a p-NiO/n-Si heterojunction diode was formed by UV oxidation of nickel on n-Si substrate. Its electrical properties will be discussed.

2. Experimental

Metallic nickel (99.95% purity) was deposited on n-Si and p-Si substrates with 4 - 6 Ω·cm and 15 - 21 Ω·cm resistivity respectively by electron-beam (e-beam) vacuum evaporation technique. The n-Si and p-Si substrates were ultrasonically cleaned in acetone, ethanol and deionized water each for 5 minutes subsequently. The pressure of e-beam evaporation chamber was 5 - 7×10^{-7} torr during evaporation, and the Ni film thickness was 50 nm controlled by crystal thickness monitor. Then the Ni samples were transferred to UV oxidation furnace for oxidation. The metal-halide UV lamp was used as the UV irradiation source, and the power was about 600 mW/cm^2. Pure oxygen was used as oxidation ambient, therefore “dry UV” is usually used as the abbreviation for UV oxidation with oxygen.

The Pt/Au metal scheme was selected to form ohmic contact with p-NiO. 100 nm Pt and 300 nm Au was patterned (shadow mask or Circular Transmission Line Model (CTLM) pattern) and deposited on NiO by e-beam vacuum evaporation technique. Back side of Si substrate was intentionally scratched to form ohmic contact with Au. Both metal-semiconductor contact were confirmed to be ohmic.

3. Results and Discussion

Fig.1 (a) is about the I-V characteristic of p-NiO/n-Si. The inset shows the front (NiO/Pt) and back (Au/Si) semiconductor-metal ohmic contact (the front contact is fairly linear). Clear rectifying characteristic can be seen from the plot. It is about two orders different between forward and reverse current. The reverse leaking current density was 2×10^{-5} A/cm2 at 2V. It is one order higher than early report for the p-NiO/n-Si diode formed by thermal evaporation of NiO powder on n-Si [1], but much lower than that of the diode formed by sputtering of NiO on n-Si [2].

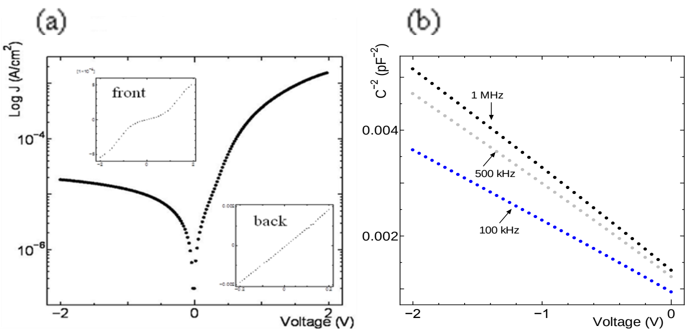

Fig. 1. (a) The I-V characteristic of p-NiO/n-Si heterojunction diode. Inset shows I-V characteristics of front (Pt/NiO) and back (Au/n-Si) metal-semiconductor contacts. (b) C^{-2} vs. V plots obtained from the C-V characteristics of NiO/n-Si heterojunction measured for various frequencies.

Fig. 1 (b) shows the C-V characteristic of the p-NiO/n-Si heterojunction diode. The frequencies were varied from 100 kHz to 1 MHz. The C^{-2}-V plot shows good linearity. Such linearity was never reported for p-NiO/n-Si diode by either thermal evaporation [1] or by sputtering [2] or PLD deposition of NiO [3]. The doping concentration calculated from the slope for 1MHz with the assumption that the depletion region only extends to n-Si because of high doping concentration in p-NiO agrees with the doping concentration evaluation obtained from the resistivity of n-Si. The p-NiO/n-Si heterojunction diode formed by UV oxidation seems to have an abrupt p^+n junction. However the value of capacitance changes with frequency which suggests the presence of deep-level traps.

4. Conclusions

UV oxidation technique was developed to form p-NiO by oxidizing metallic nickel. A p^+-NiO/n-Si heterojunction diode was fabricated. It shows good rectifying behavior and linear C^{-2}-V characteristic. Nickel diffusion into Si makes deep-levels in Si and may lead to large and bias-dependent leaking current.

References

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