Work function engineering on transparent conducting ZnO thin films

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Abstract

A possibility of work function engineering on ZnO thin film is studied by in-situ and ex-situ doping process. The work function of ZnO thin film decreases with increasing boron and phosphorus doping quantity. But, the work function of Al-doped ZnO (AZO) thin film increases as the boron doping quantity incresess. The range of work function change on ZnO thin films is 3.5 eV to 5.5 eV. This result shows that the work function of ZnO thin film is indeed engineerable by changing materials of dopants and their compositional distribution of surface. We also discuss the possible mechanism of work function engineering on ZnO thin films.

1. Objectives

The work function of semiconductor thin films is a critical factor to influence the performance of optoelectronic devices like Organic Light-Emitting Diodes (OLEDs), Inorganic LEDs, and solar cell, and also semiconductor devices like ZnO-TFT. We try to engineer the work function of the fabricated ZnO and AZO thin films by doping boron and phosphorus using RF magnetron sputtering and ion implantation methods.

2. Results

Figure 1 shows the changes of work function as a function of ion doses and ion energy for boron doped ZnO (BZO), phosphorus doped ZnO (PZO), and boron doped AZO (BAZO) thin films. When boron and phosphorus doping was conducted on ZnO thin films by ion implantation, the initial work functions relatively decreased compared to undoped ZnO thin film.

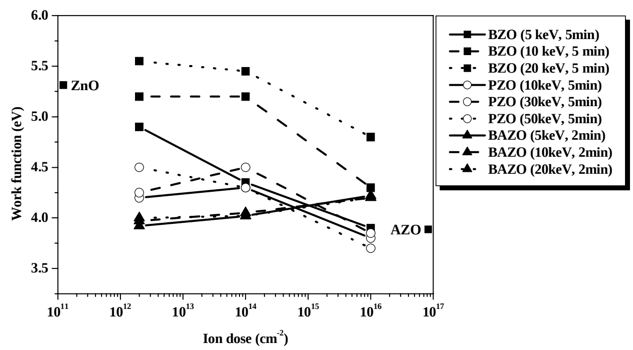

Figure 1. Work function characteristics of impurity doped ZnO thin film as a function of ion dose and ion energy.

It was also observed that the work function of BZO and PZO decreased with increasing ion doses, whereas that of BAZO increased with increasing ion doses. For the BZO thin film, its work function has been reduced by 1.5 eV, which was larger compared to that of PZO and BAZO thin film.

Based on the analysis of lattice constant and bandgap energy and so on, those work function changes are combined results with various effects of defect chemistry and energy band structure concerned with oxygen vacancy (V_O), zinc interstitial (Zn_I), zinc vacancy (V_{zn}), oxygen interstitial (O_I), substitional aluminium donor (Al_{zn}), substitional boron donor (B_{zn}), substitional phosphorus donor (P_{zn}), boron interstitial (B_I), and phosphorus interstitials (P_I) and so on. We'll suggest the possible mechanism of work function engineering on ZnO thin films.

In addition, since the carrier concentration of ZnO thin film with V_o and Zn_I for a native donor could not reaches $10^{17}cm^{-3}$ by theoretical studies, the effect of hydrogen donor that always exists below 600℃ on ZnO has recently been studied. We compared the electrical and optical properties of doped ZnO thin film before and after annealing process with the temperature of 600℃ to confirm the hydrogen effect as a native donor. It was difficult to confirm any result as the hydrogen effect, and also some result like decreasing carrier concentration was preferably opposite to the reported hydrogen effect. The effect of hydrogen donor was relatively lower than that of dominant shallow boron donor.

5. References

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