Electrical Properties of V-I Curve of p-ZnO:Al/n-ZnO:Al Junction Fabricate by RF Magnetron Sputtering

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Abstract: Al-doped p-type ZnO films were fabricated on n-Si (100) and homo-buffer layers in pure oxygen at 450^{0}C by RF magnetron sputtering. Target was ZnO ceramic mixed with 2wt% Al_2O_3. XRD spectra show that the Al-doped ZnO thin films have ZnO crystal structure and homo-buffer layers arebeneficial to Al-doped ZnO films to grow along c-axis. Hall Effect experiments with Van der Pauw configuration show that p-type carrier concentrations are ranged from 1.66x10^{16} to 4.04x10^{18}cm^{-3}, mobilities from 0.194 to 2.3cm^{2}V^{-1}s^{-1}and resistivities from 7.97 to 18.4Ωcm. P-type sample has density of 5.40cm^{-3} which is smaller than theoretically calculated value of 5.67cm^{-3}. XPS spectra show that O1s has O-O and Zn-O structures and Al2p has only Al-O structure. P-ZnO:Al/n-ZnO:Al junctions were fabricated by magnetron sputtering. V-I curves show that the p-n junctions have rectifying characteristics.

Key words: p-ZnO:Al/n-ZnO:Al junction, p-type ZnO:Al, V-I curve, rectifying characteristic.

1. Introduction

ZnO has be intensively investigated for its potential application of highly efficient light emitting since it has large direct energy bandgap of 3.37eV at and large exciton binding energy of 60meV. Some large radius elements, such as As and Sb, show effects of p-type dopants in ZnO [1], which is theoretically explained as a complex acceptor model of X_{Zn}-2V_{Zn}(X=As, Sb) [2]. If Al-doped ZnO is grown under O_2-rich condition, many Zn vacancies (V_{Zn}) should occur for the strong bonding of Al-O. In the present study we have grown highly Al-doped ZnO thin films under the condition of O_2-rich ambient and obtained Al-doped p-type ZnO films. We have fabricated p-ZnO:Al/n-ZnO:Al junctions which show rectifying characteristic.

2. Experimental process

Al-doped ZnO films were prepared in O_2 on homo-buffer layers and n-(100) Si by an RF magnetron sputtering. The buffer layers were fabricated on Si in the mixture of O_2 and Ar with ratio of 1:4 at 100^{0}C and 15mTorr with ZnO ceramic as target and then were annealed in-situ at 800^{0}C and 15mTorr of O_2 for 20min. Al-doped ZnO films were grown in oxygen at 450^{0}C and annealed in oxygen at 10Torr and 600^{0}C and 800^{0}C respectively. ZnO ceramic mixed with 2wt% Al_2O_3 is as target. Samples are denoted as Wx. W=B or S means that the substrate is a buffer layer template or a silicon wafer and x=0, 1 or 2 means that the Al-doped ZnO film is as-grown, 600^{0}C- or 800^{0}C-annealed one. Homo p-n junctions were fabricated and their V-I curves were done.

3. Results and discussion

Fig. 1 shows that except S0 the XRD spectra of the buffer layer and the ZnO:Al films exhibit (002) peak of 2θ angle at 34.44^0 which is the value of corresponding peak of bulk ZnO. All (100) and (101) peaks are consist with the positions at which the corresponding peaks of bulk ZnO are. This implies that all films haven't stress. As annealing temperature

Table 1 Electric properties

sam.	type	con. 10^{18}cm^{-3}	mob. cm^{2}V^{-1}s^{-1}	resist. Ωcm
S0	p	0.0166	2.03	18.4
S1	n	8.99	0.161	4.32
S2	n	2.45	1.98	1.29
B0	-	-	-	-
B1	p	4.04	0.194	7.97
B2	n	4.0	1.15	1.35

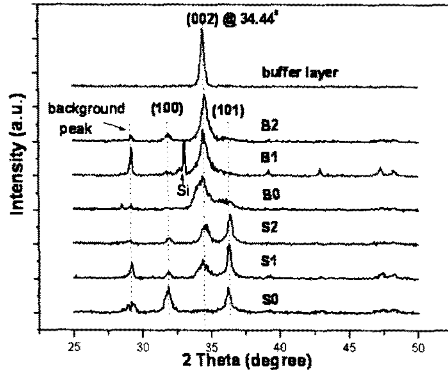

Fig. 1 XRD spectra of ZnO:Al and buffer layer

goes up to 600 and 800^{0}C (002) peak appears and gets higher, implying that annealing temperature makes the films recrystallize along c-axis. The films grown on buffer layers and high annealing temperatures are beneficial to ZnO:Al film growth along c-axis. P-type sample has density of 5.40cm^{-3} which is smaller than theoretically calculated value of 5.67cm^{-3}.

Table 1 shows that as-grown film on Si shows p-type with carrier concentration of 1.66x10^{16}cm^{-3}. While annealing process is set at 600^{0}C and 800^{0}C, the type converts to n-type. The film annealed at 600^{0}C shows p-type and high carrier concentration of 4.04x10^{18}cm^{-3}.

Fig. 2 shows XPS spectra of O1s and Al2p. It can seen by Gaussian fitting that two peaks appear at about 530.7 and 532.3eV respectively. 530.7eV is attributed to O^{2-} ion in ZnO. 532.3eV is attributed to loosely bound oxygen O^{2-} ions [3], indicating presence of Zn vacancies. Binding energy peaks of Al2p are both at 74.4eV that is the value of Al-O bonding in Al_2O_3 [4]. In metal Al the peak of Al2p appears at

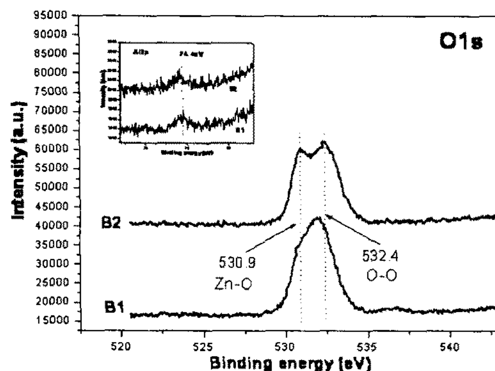

Fig. 2 XPS spectra of O1s with Al2p in inlet.

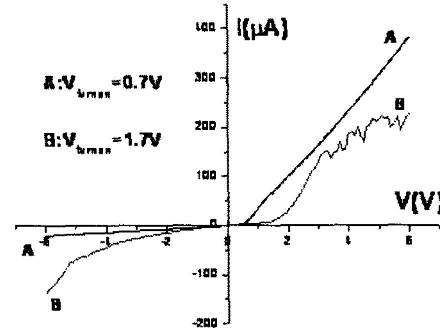

Fig.3 I-V curves of p-ZnO:Al/n-ZnO:Al/Si

72.2eV, implying that all Al is at Al-O bonding state.

Fig.3 shows that Al-doped ZnO p-n homo-junctions have rectifying characteristics, which imply that Al-doped ZnO can be with p-type conduction. Sample A and B are with p-type thicknesses of about 200 and 400nm respectively. N-type films with high electron density make deep depletion layers into p-type films. 200nm hardly caver it, making p-n junction have little turnon voltage. Because of high resistivity in p-type films, slopes of linear parts of I-V curves are not ideal.

4. Conclusion

In summary, Al-doped p-type ZnO films could be obtained in oxygen by RF magnetron sputtering and high hole concentrations of 4.04x10^{18}cm^{-2} is obtained. P-type ZnO:Al films have density of 5.40gcm^{-3} with structure of O-O and Al-O. V-I curves of Al-doped p-n junctions have rectifying characteristic.

5. Acknowledgement

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6. References

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