Effect of Thermal Annealing on Cadmium Distribution in $\{ZnO/CdO\}_m$ Superlattices

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Introduction

Zinc oxide (ZnO) is a II – VI n-type composite semiconductor with a wide band gap and a high exciton binding energy, which is used in many optoelectronic devices. Successful modulation of the band gap in a wide range due to ZnO alloying is attractive for practical application[1].

The alloying of ZnO with CdO reduces band gap, which led to a detailed study of the structure of $Zn_{1-x}Cd_xO$[2]. Synthesis of $Zn_{1-x}Cd_xO$ alloys is possible by various methods, but regardless of the growing method, there are a number of restrictions affecting the production of high-quality $Zn_{1-x}Cd_xO$ heterostructures[3,4]. The multiphase or polycrystalline nature of the material significantly complicates the production of good quality thin films and also QWs, heterojunctions as well as superlattices (SLs).

Method

The set of $\{CdO/ZnO\}_m$ short-period superlattices (SLs) were grown on m-plane sapphires (Al_2O_3) substrates by plasma assisted molecular beam epitaxy (MBE).

SLs structures in the A and B series differ in the first deposited layer (CdO or ZnO), thickness of the sublayers and / or the number of pairs of SLs.

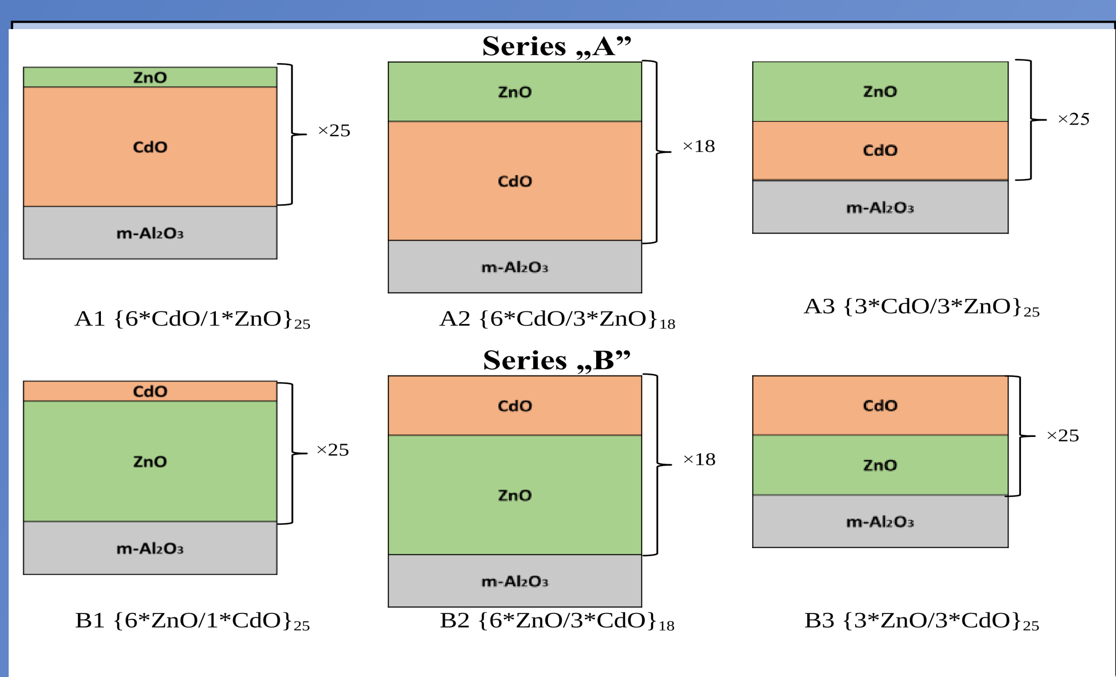

Fig. 1. The schematic diagrams of *as grown* $\{CdO/ZnO\}_m$ SLs structures.

To study the thermal stability of the SLs structures the samples were annealed for 5 minutes in an O_2 environment at a temperature of 900 °C

Cathodoluminescence spectra (CL) for the annealing SLs were obtained at low temperatures (~ 5 K) by a beam with kinetic energy in the range of 2-15 kV corresponding to the depth of penetration into the samples ~ 20, 70, 200, 400 nm.

Results: *as grown* SLs

The SIMS depth profile of *as grown* $\{CdO/ZnO\}_m$ SLs shows that the individual layers of CdO and ZnO are clearly traced and their order corresponds to the planned structures.

The Cd concentration, estimated from EDX measurements, depending on the structure design. Comparison of the Cd/Zn ratio in the samples calculated using the data obtained by the SIMS method and the EDX correlate well.

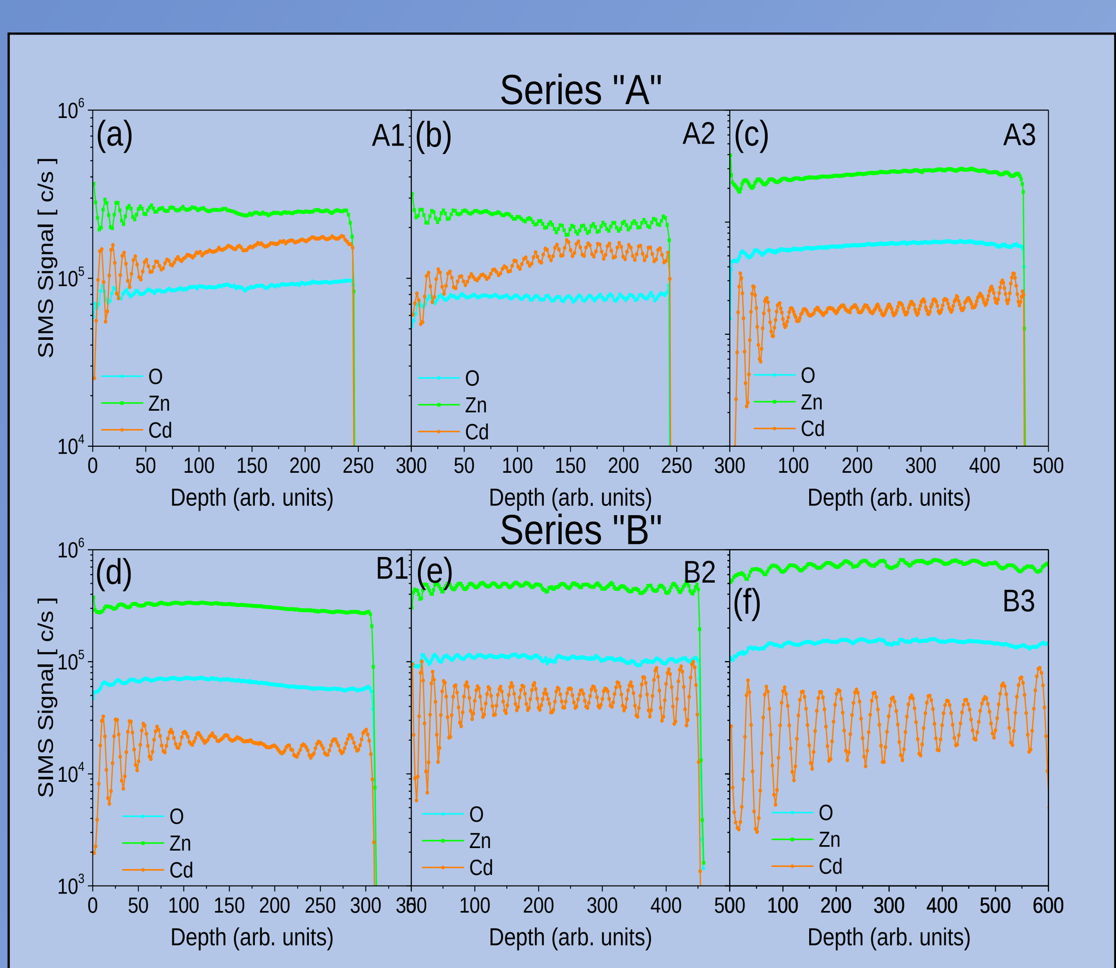

Fig. 2. SIMS depth profiles of *as grown*
(a) $\{6*CdO/1*ZnO\}_{25}$;
(b) $\{6*CdO/3*ZnO\}_{18}$;
(c) $\{3*CdO/3*ZnO\}_{25}$;
(d) $\{6*ZnO/1*CdO\}_{25}$;
(e) $\{6*ZnO/3*CdO\}_{18}$;
(f) $\{3*ZnO/3*CdO\}_{25}$.

Table: Summary data for *as grown* and annealing $\{CdO/ZnO\}_m$ SLs.

	Samples	Thickness of layers, nm	as grown Cd % (EDX)	as grown Cd/Zn (SIMS)	as grown Cd/Zn (EDX)	RTP 900 °C Cd % (EDX)	RTP 900 °C Cd/Zn (EDX)
Series „A”	A1	12/1.5	38.22	0.571	0.62	18.51	0.23
	A2	9.3/4.5	46.11	0.584	0.86	17.04	0.21
	A3	5/5	8.79	0.064	0.10	4.18	0.04
Series „B”	B1	8/1	8.82	0.060	0.10	3.19	0.03
	B2	9/5	13.79	0.106	0.16	4.65	0.05
	B3	5/5	7.27	0.044	0.08	3.35	0.03

Results: annealing SLs

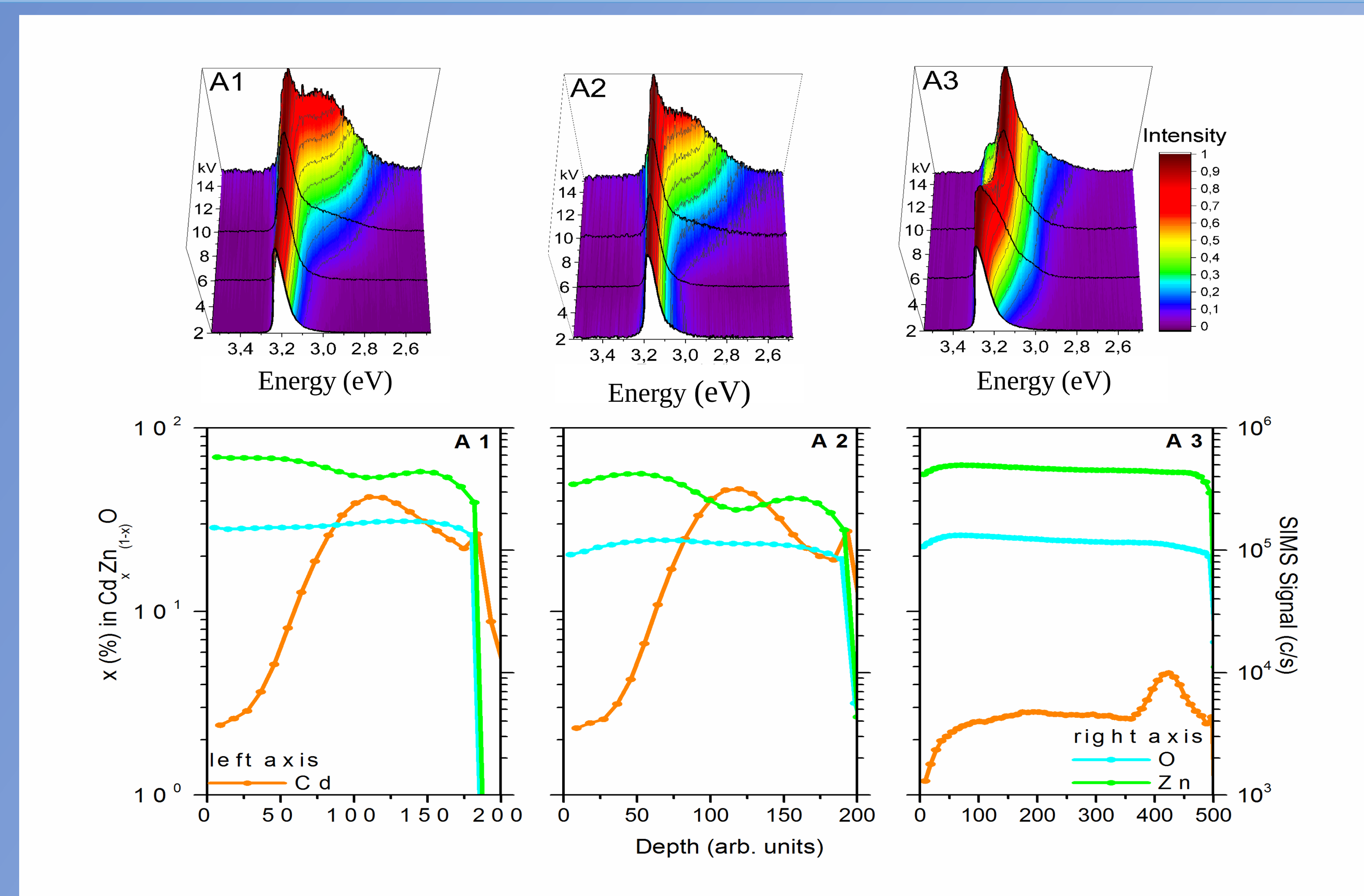

Fig. 3. The SIMS depth profiles and 3D CL spectra of annealing $\{CdO/ZnO\}_m$ heterostructures at different electron beam kinetic energies: 2 kV, 6 kV, 10 kV and 15 kV for series A.

After annealing in O_2, measurements by the EDX method showed that the Cd concentration decreases almost linearly compared to its Cd content in as grown SLs.

SIMS measurements showed that there is a structural deformation of the annealing SLs. The SIMS plots revealed an inhomogeneous depth distribution of cadmium.

LT-CL shows a redshift of about 4-60 meV with depth and strongly depends on the structure, namely on the Cd content. The Cd concentration at the interface is always less than in the depth of the sample.

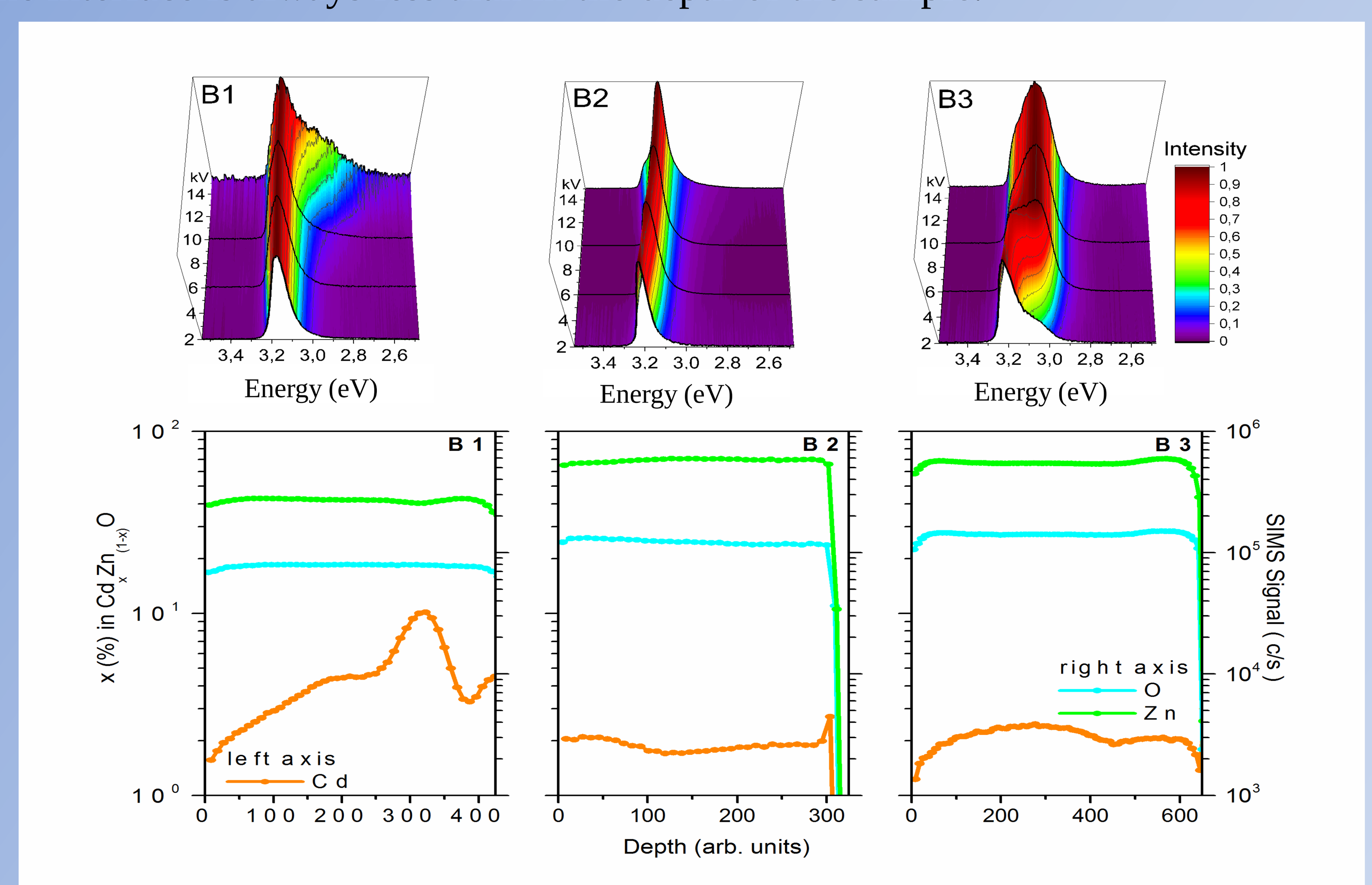

Fig. 4. The SIMS depth profiles and 3D CL spectra of annealing $\{CdO/ZnO\}_m$ heterostructures measured at different electron beam kinetic energies: 2 kV, 6 kV, 10 kV and 15 kV for series B.

Conclusion

The Cd concentration on as grown SLs depending on the structure design, and decreases significantly after annealing.

The CL spectra reflect the Cd profiles for annealing SLs measured using SIMS.

Based on the analysis of SIMS and CL data, it was found that the lower the Cd content in as grown $\{ZnO/CdO\}_m$ SLs, the more evenly the distribution of Cd along the depth profile after annealing.

References

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This work was supported in part by the Polish National Science Center, Grants No. 2019/35/B/ST8/01937, and 2021/41/B/ST5/00216.