Temperature-dependent bandgap study of Eu doped CdO thin film prepared by PA-MBE

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Motivation:

- CdO is one of the oldest known semiconductor oxides that have been studied widely because of its high transparency, high electron mobility, low resistivity, high electron concentration, and high exciton binding energy.
- From a transparent conducting oxide point of view, CdO is sufficiently effective for Eu doping as it stresses the CdO crystalline structure and changes the optical and electrical properties [1,2].
- Furthermore, understanding the bandgap behavior of Eu doped CdO layer is important for developing various optoelectronic devices such as solar cells.
- Here we have studied a thin layer of CdO and Eu doped CdO grown on quartz substrate using plasma-assisted molecular beam epitaxy (PA-MBE) technique.

Methodology:

- CdO and Eu doped CdO thin films were grown using plasma-assisted MBE technique (PA-MBE) on Si and quartz substrates
- Eu content was varied by increasing the Eu effusion cell temperature
- The following characterization were performed
  - Morphological study→ AFM
  - Optical Study→ UV-Vis spectroscopy

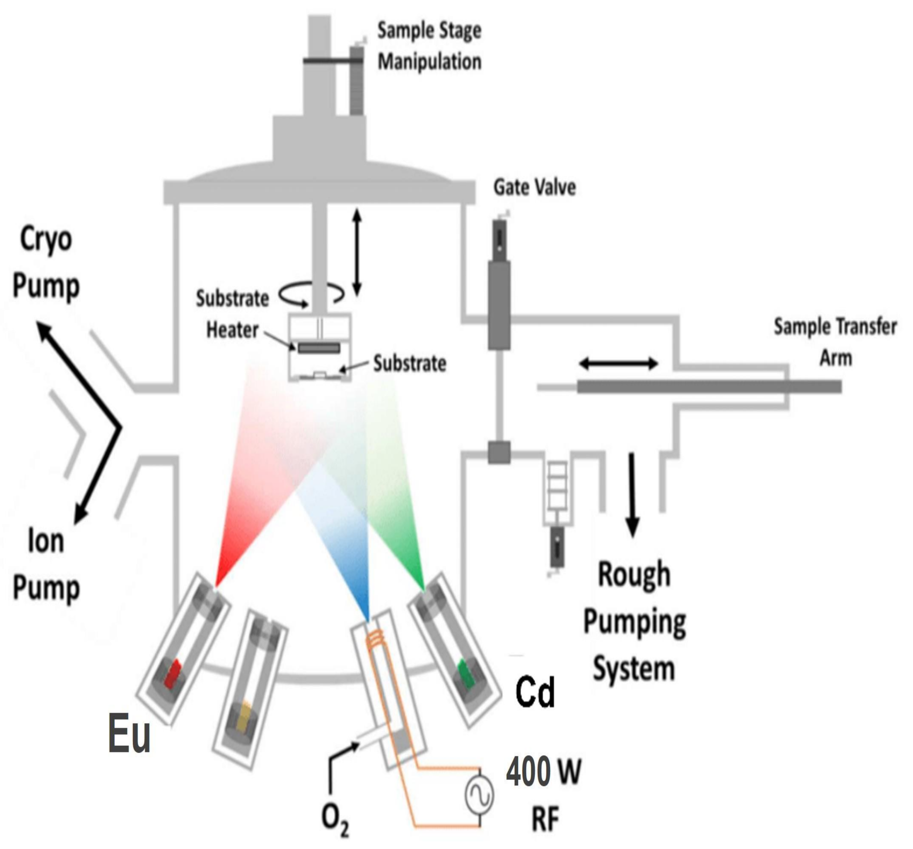

Figure 1. Schematic diagram for Eu doped CdO film grown using PA-MBE technique

Surface morphology Study:

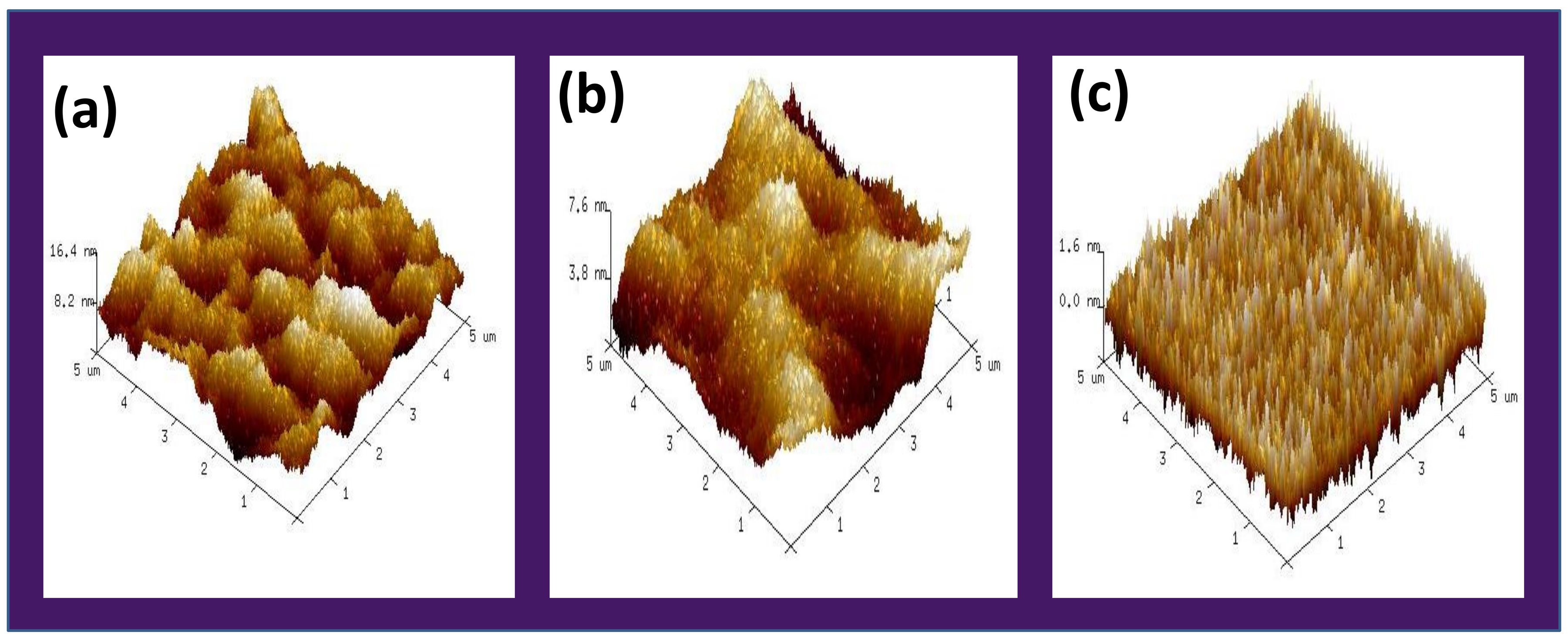

Figure 2. AFM image of (a) CdO, (b) CdO: Eu320 and (c) CdO: Eu380 on quartz

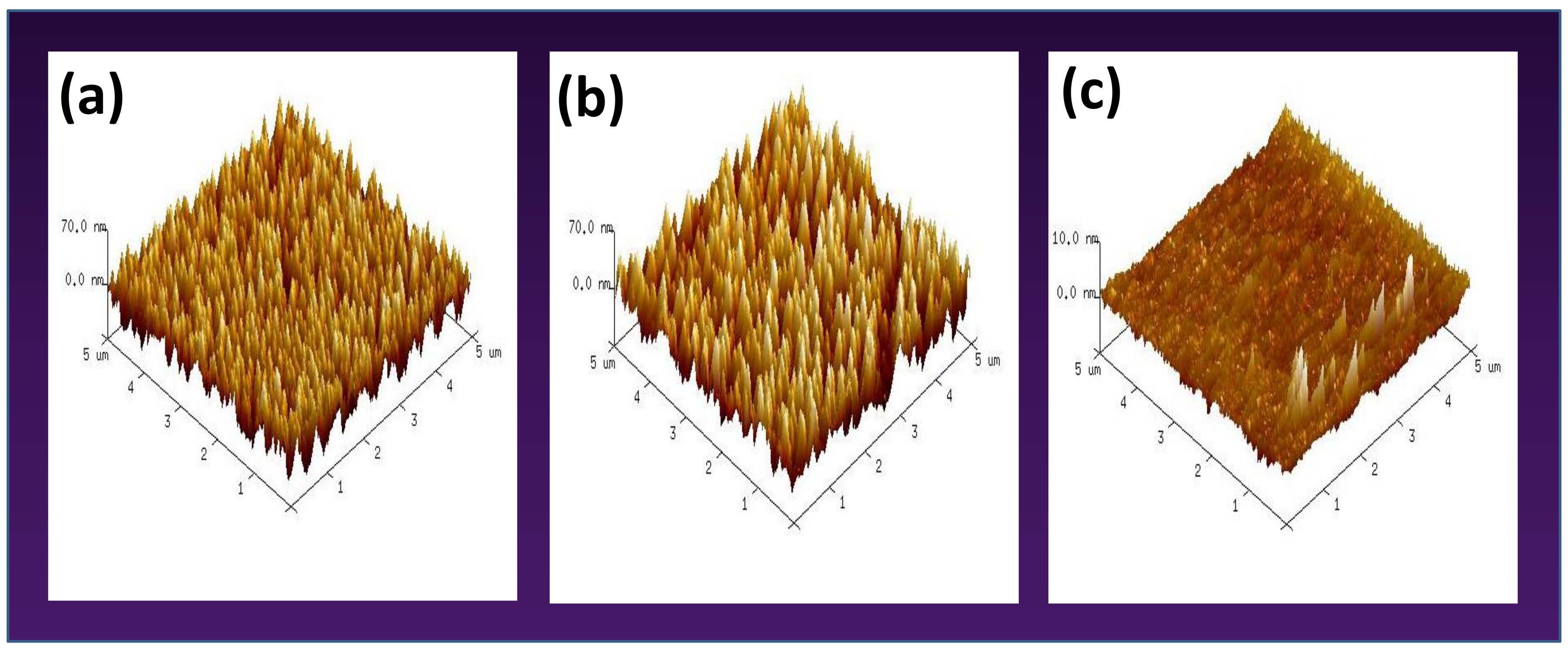

Figure 3. AFM image of (a) CdO, (b) CdO: Eu320 and (c) CdO: Eu380 on Si

- Eu influences the surface morphology of the grown layer
- The average roughness parameter (Ra) of grown layers on Si substrate is higher compared to the grown layer on the quartz substrate.
- Ra value decreases with an increase in Eu doping content in CdO

Sample	On quartz Ra(nm)	On Si Ra(nm)
CdO	2.08	15.3
CdO: Eu320	0.96	17.6
CdO:Eu380	0.36	0.89

UV-Vis Spectroscopy:

Transmittance, $T = \frac{I}{I_0}$

Absorption coefficient, $\alpha = -\frac{1}{d} ln(T)$

Tauc relation, $\alpha h\nu = A\,(h\nu - E_{g,o})^n$

Urbach energy, $\alpha = \alpha_0 \exp(\frac{h\nu}{E_U})$

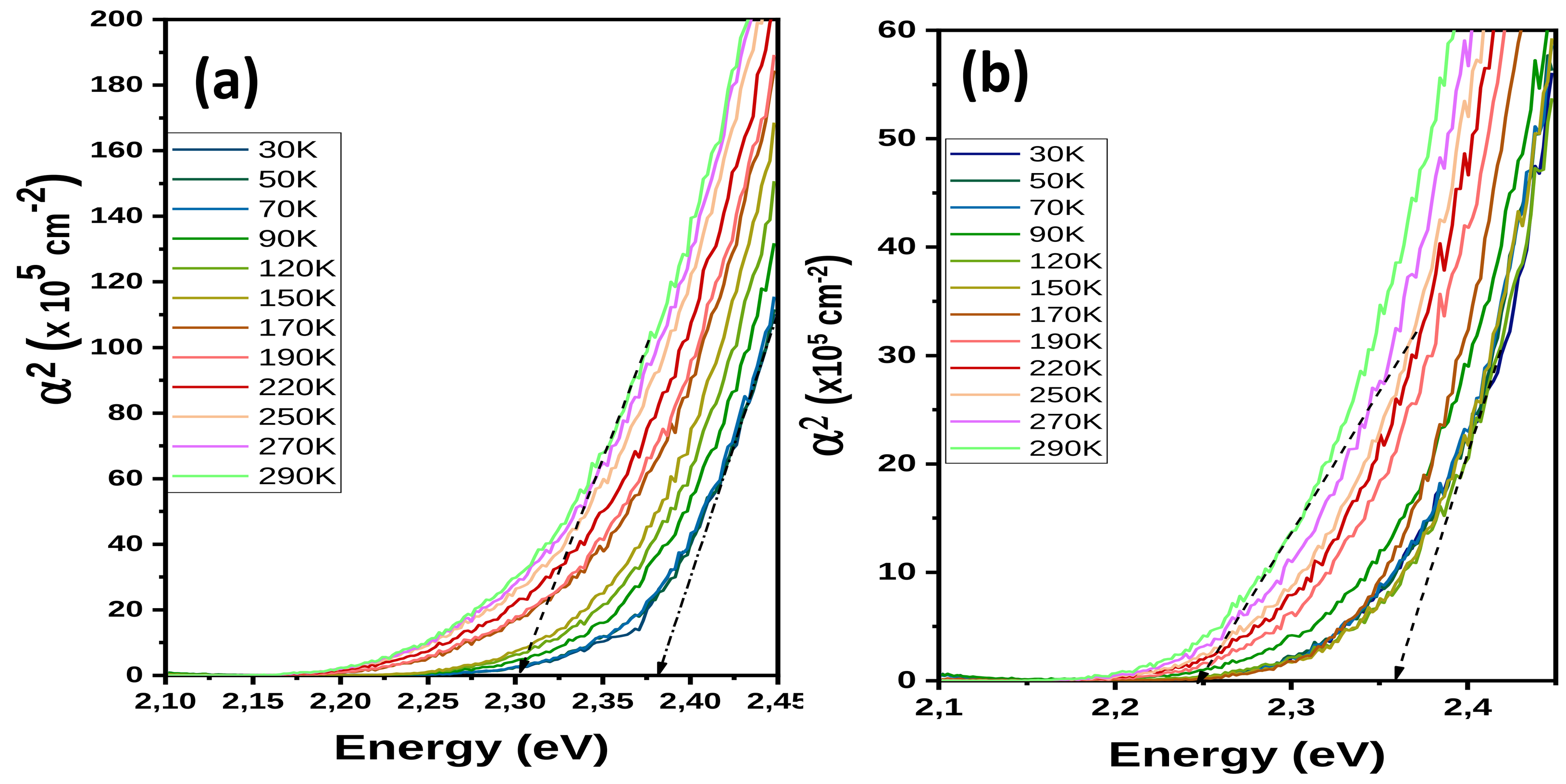

Figure 4. α² plot as a function of photon energy (hν) for (a) CdO, and (b) Eu doped CdO on quartz

Varshni's Model[3] $$Eg(T) = Eg(0) - \frac{\alpha T^2}{\beta + T}$$

Bose-Einstein Model[4] $$Eg(T) = Eg(0) - \frac{k}{\exp\left(\frac{\theta}{T}\right) - 1}$$

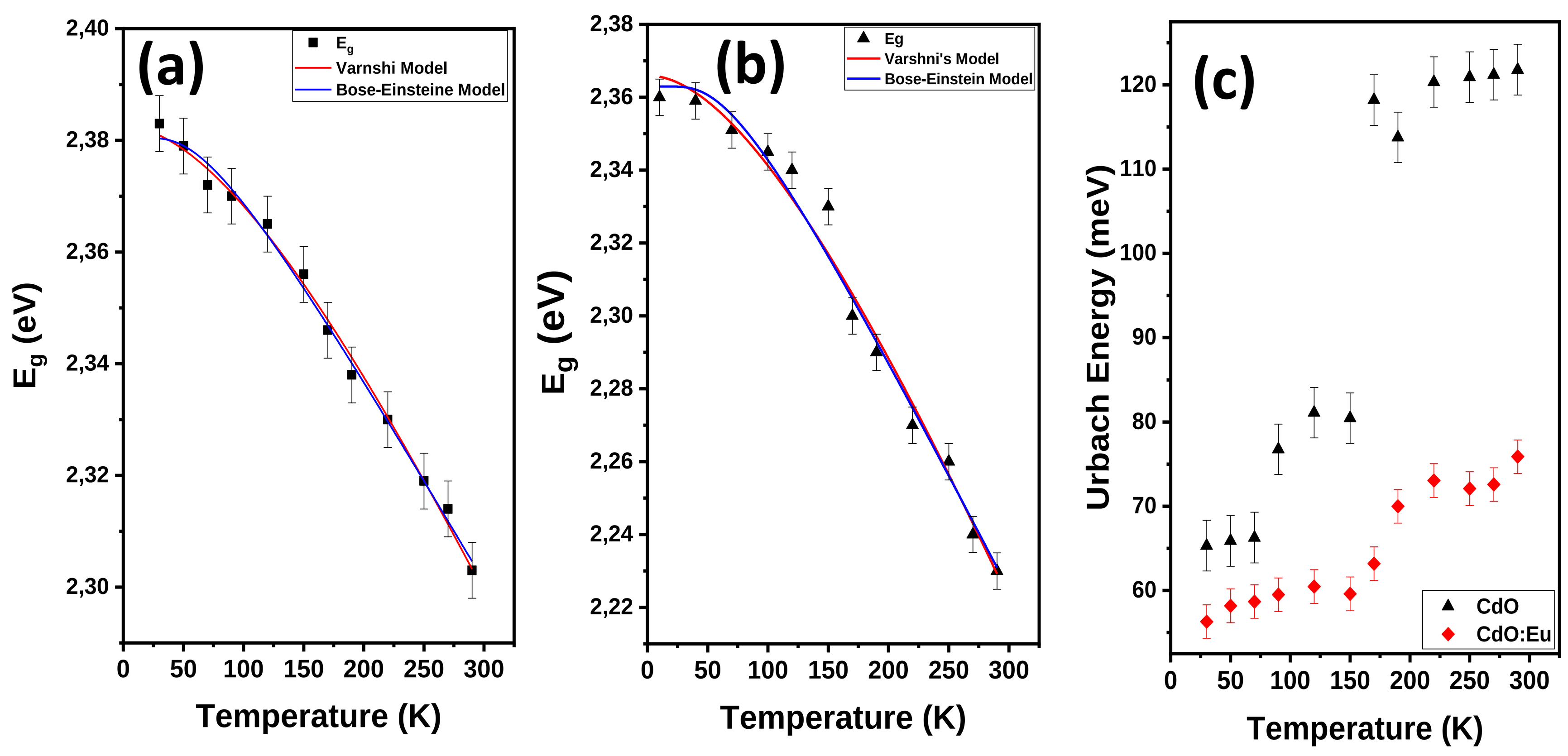

Figure 5. Variation of optical bandgap with temperature for (a) CdO, and (b) Eu doped CdO on quartz, (c) variation of Urbach energy with temperature

Sample	Varshni's Model			Bose-Einstein Model		
	$Eg(0)$	α(meV/K)	β(K)	$Eg(0)$	k	θ(K)
CdO	2.382	0.53	272	2.380	0.07	200
CdO:Eu	2.365	0.9	263	2.362	0.13	203

Relation between Debye temp and average phonon temperature

$$\beta = \frac{4}{3}\theta$$

Conclusions:

- CdO layer and Eu doped CdO layers were grown on Si and quartz substrate using PA-MBE technique. Eu influences the surface morphology of layers. The fundamental direct bandgap at ambient condition and 0K (Eg(0)) was determined from temperature-dependent UV-Vis spectroscopy.
- From fitting the bandgap value using Varshni's model, the temperature coefficient is found to be 0.5 and 0.9 meV/K for CdO and Eu doped CdO samples. The Debye temperatures were also determined.
- Using the Bose-Einstein model, the average phonon temperature of CdO and Eu doped CdO samples were found to be 200 and 203 K respectively.
- The relation between Debye temperature and Average phonon temperature is well approximated.
- Urbach energy decreases with Eu doping in CdO suggests a lower lattice disorder state is formed for Eu doped CdO layers.

References

[1] G. Turgut, G. Aksoy, D. İskenderoğlu, U. Turgut, and S. Duman (2018) Ceramics International 44, 3921
[2] A.A. Dakhel, (2011) Curr. Appl. Phys., 11,11
[3] Y. P. Varshni (1967) Physica, 34, 149–154.
[4] S. Logothetidis, L. Via, and M. Cardona (1985) Phys. Rev. B, 31, 947

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