Structural, Morphological, and Optical Properties of CuO Thin Films Synthesized by Dip-coating Technique for Gas Sensing Applications

A. M. M. Musa[a*], M. A. Gafur[b], S. U. F. Farhad[c], A. T. M. K. Jamil[a]

[a]Department of Physics, Dhaka University of Engineering & Technology, Gazipur-1707, Bangladesh
[b]Pilot Plant and Process Development Centre, Bangladesh Council of Scientific and Industrial Research, Dhaka-1205, Bangladesh
[c]Central Analytical and Research Facilities (CARF), Bangladesh Council of Scientific and Industrial Research, Dhaka-1205, Bangladesh
*Corresponding author, *E-mail address:* musamonsur80@gmail.com (A. M. M. Musa) Mobile: +8801679-789109

Abstract

Copper oxide (CuO) thin films have been deposited onto clean glass substrates by sol-gel dip-coating technique with different withdrawal speeds at molar concentration, 0.35 M. The thickness of the film, *t* decreases with the increase of dip-coating withdrawal speed which is influenced the structural, morphological, and optical properties of CuO films. The XRD spectra reveal that the CuO thin films are polycrystalline in nature having a monoclinic crystal structure which confirmed by Raman analysis. The surface morphology of the films is observed to be uniform, continuous, and defectless with uniformly distributed nanosized grain. The direct and indirect band gap decrease with increasing *t*. The lower withdrawal speed show the maximum gas sensing response of carbon dioxide (CO_2) vapor in the air indicating the good quality thin film.

Motivation

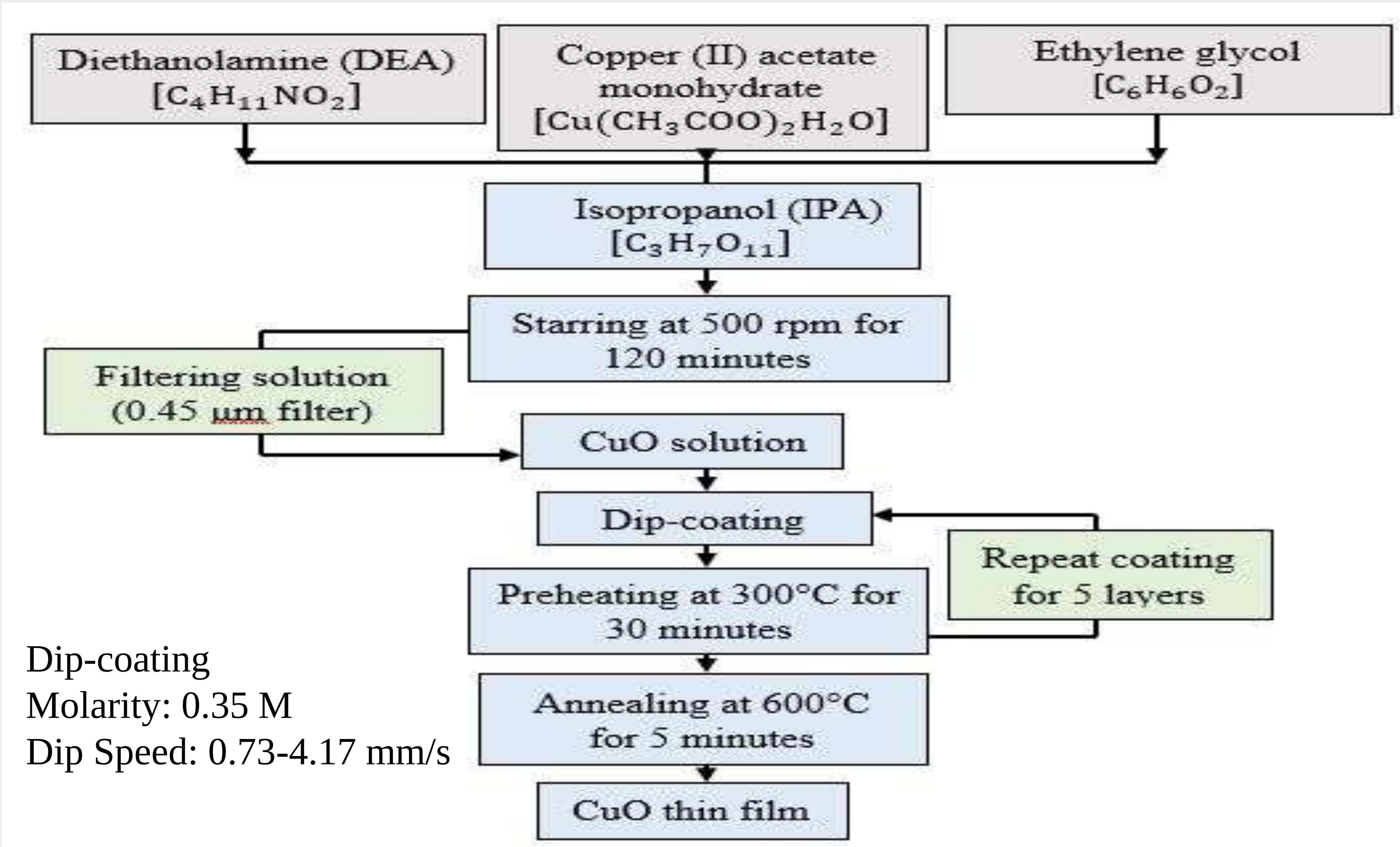
Limitation of previous study:

- Stable p-type semiconductor [1]
- Assure good quality [2]
- Higher band gap [3]
- Most of the films are still not reliable
- Bipolarity problem of CuO [2]

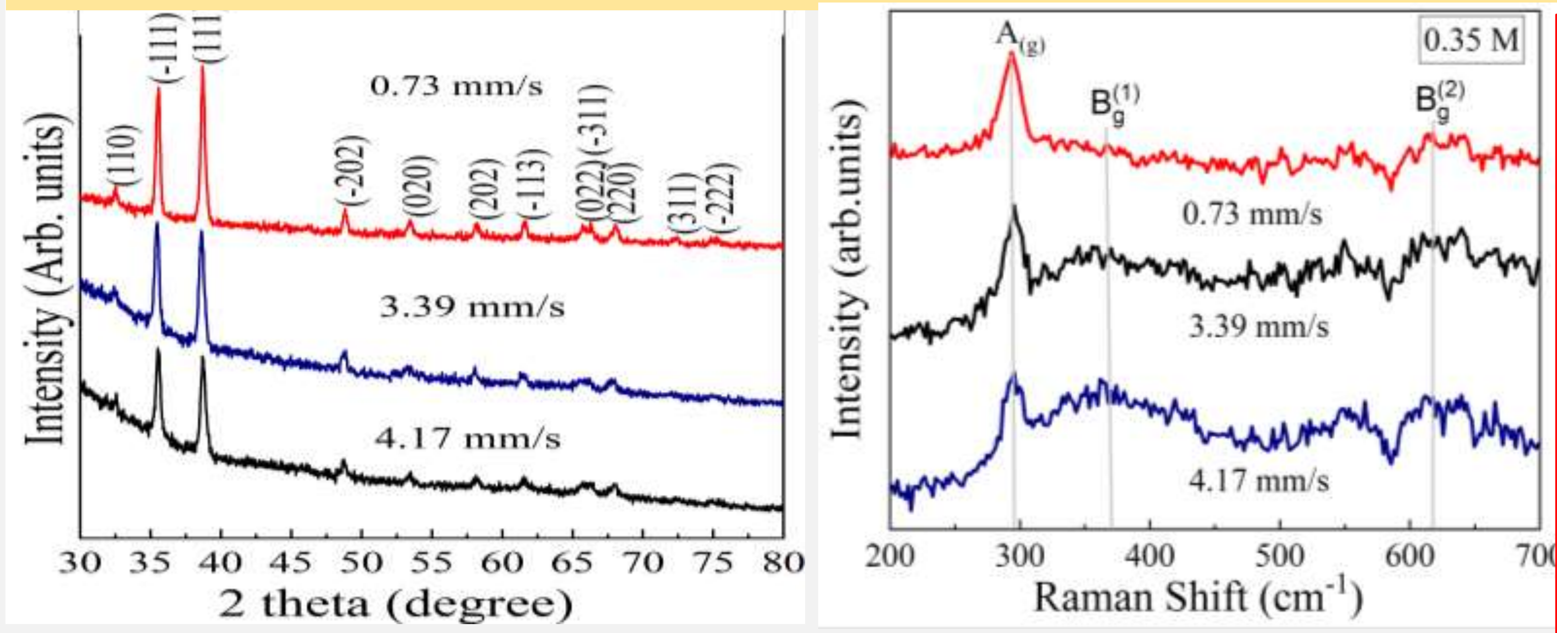
Objectives

- To prepare CuO thin films on glass substrates using sol-gel dip coating method.
- To characterize the structural, morphological and optical properties of films.
- To investigate the gas sensing response of these thin films.

Methodology for Sample Preparation



Results and Discussion



- XRD revealed two prominent peaks at 32.52° (-111) and 35.58° (111) for CuO films.
- CuO is also confirm from Raman spectra.

Fig. 1. XRD and Raman analysis of CuO thin films for different speeds.

Table: Microstructural parameters from XRD

Withdrawal speed (mm/s)	2θ (degree)	Dislocation density, δ (line/nm^2)	Micro strain, ε × 10^{-3}	X- ray density, ρ (g/cm^3)	Crystallite size, D (nm)
0.73	35.61	2.09	0.098	5.954	21.83
3.39	35.51	2.43	0.102	5.241	20.11
4.17	35.58	3.12	0.191	5.159	15.41

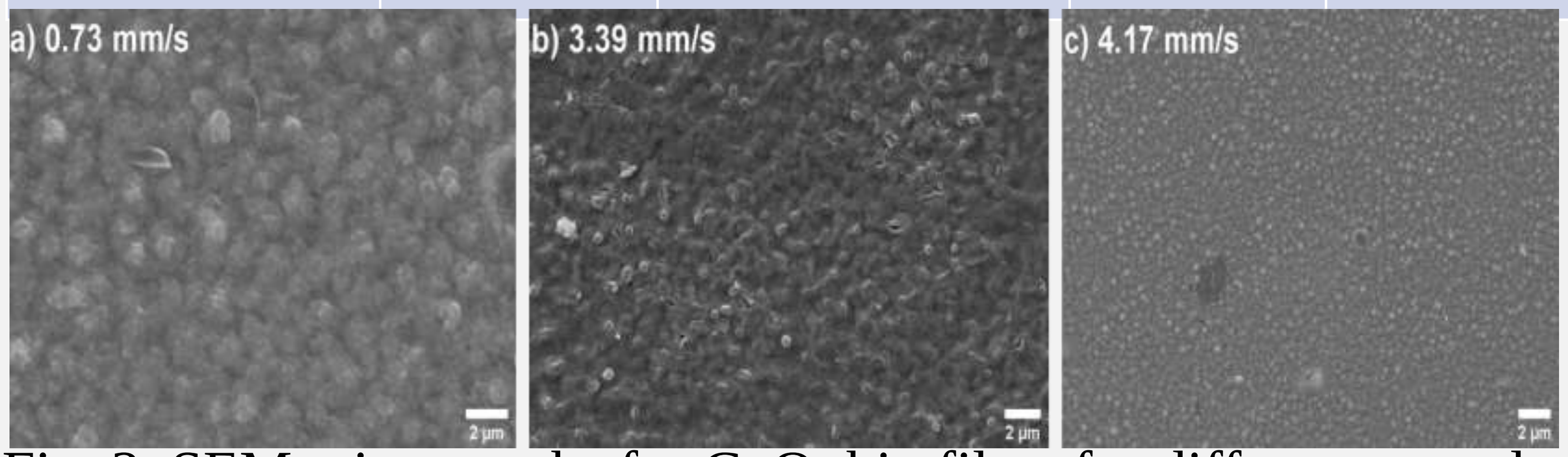


Fig. 2. SEM micrographs for CuO thin films for different speeds.

Grain size increases with the increase of *t*, higher grain size is found 204±65 nm for 0.73 mm/s.

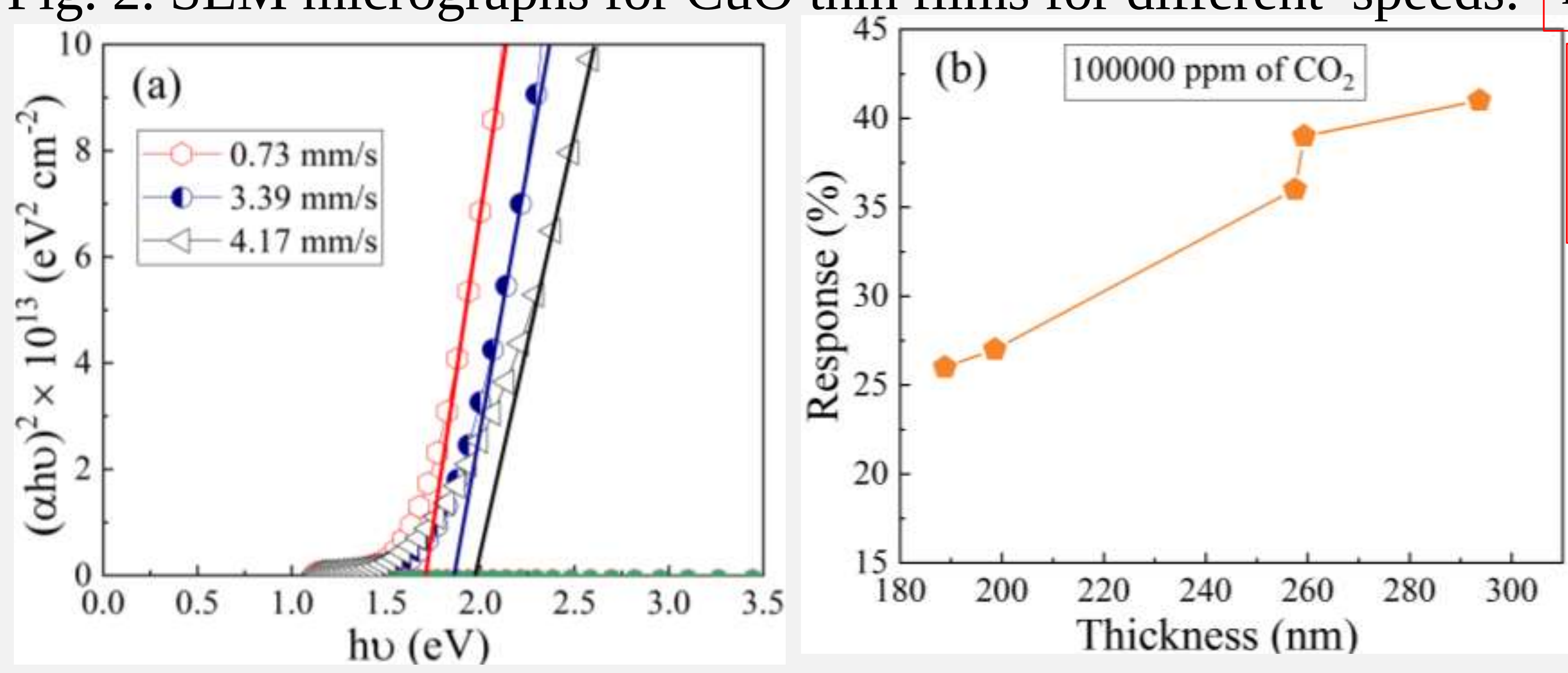


Fig. 3. (a) Direct band gap and (b) response with thickness for CuO films.

$$\text{Response (\%)} = \frac{R_a - R_g}{R_a} \times 100\%$$

Gas sensing response increase with *t* and maximum response is found 34%.

Conclusion

CuO thin films were successfully synthesized by the sol-gel dip-coating method.

- The direct and indirect band gap are found to decrease from 2.15 to 1.74 eV and 1.42 to 1.21 eV respectively with increasing *t* due to the improvement of crystalline size as well as grain size.
- The film deposited at 0.73 mm/s show the maximum response (~34%) at 10000 ppm of CO_2 vapor in the air.

References

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