Material, optical and electrical characterization of DC sputtered CuO by tuning oxygen concentration

Xi Zeng[1, *], Maria Zhukova[1], Sébastien Faniel[1], Joris Proost[2], Denis Flandre[1]
[1]Institute of Information and Communication Technologies, Electronics and Applied Mathematics
[2]Institute of Mechanics, Materials and Civil Engineering
Université Catholique de Louvain, Louvain-la-Neuve 1348, Belgium
*Corresponding author: xi.zeng@uclouvain.be

Abstract

To fabricate large-area photodetection material with high sensitivity, low cost and easy processing for biomedical imaging and environmental applications, P-type CuO layers with proper bandgap, high optical absorption and good electrical performance have been fabricated by DC reactive magnetron sputtering. Considering that Copper oxide has three different phases (CuO, Cu_4O_3 and Cu_2O), it features the advantage of multiple bandgaps by tuning the oxygen concentration. By XRD, Raman and SEM measurements, the phases of sputtered layers can be determined. For the calculation of Bandgap and Urbach energy, UV-VIS-IR spectrophotometer has been used to measure the reflectance and transmittance of thin films. Hall measurements have also been carried out to measure the carrier type, mobility, concentration and sheet resistance.

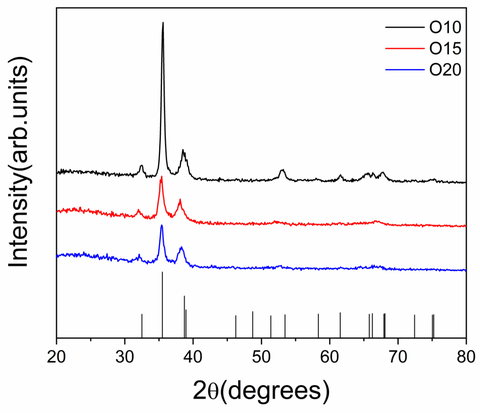
Sputtering Parameters

Sample	Target	O_2 (SCCM)	Ar (SCCM)	Power (W)	I(mA)	V(V)	Deposition Time	Temperature(˚C)	Base pressure (Torr)	Sputtering pressure (mTorr)	Thickness (nm)
O10	Cu	10	20	50	95	515	30min	Room	1.40E-07	5	160
O15	Cu	15	15	50	105	470	30min	Room	2.00E-07	5	65
O20	Cu	20	10	50	115	427	45min	Room	2.00E-07	5	66

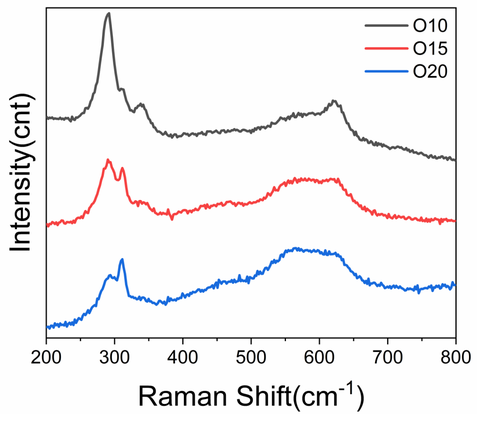
Material Characterization [1]

- Fig(a): XRD patterns exhibit tenorite CuO (JCPDS-45-0937)
- Fig(b): Raman peaks at 291, 343 and 623cm^{-1}
- Fig(c) and Fig (d): SEM of O10 Sample shows a triangular grain structure and a grain size around 20nm

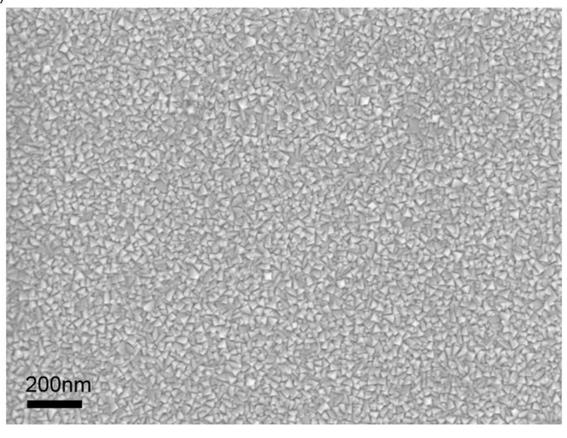
(a)



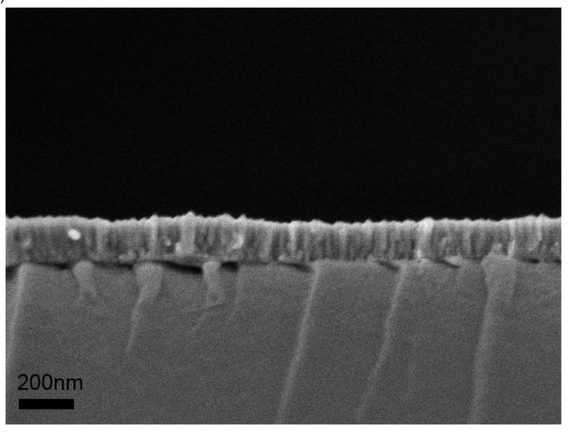
(b)



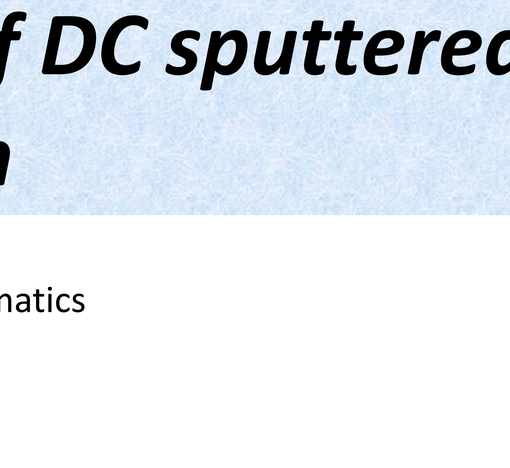
(c)



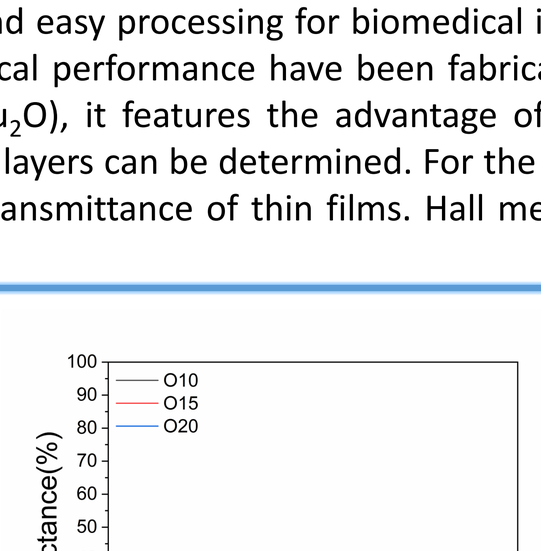
(d)



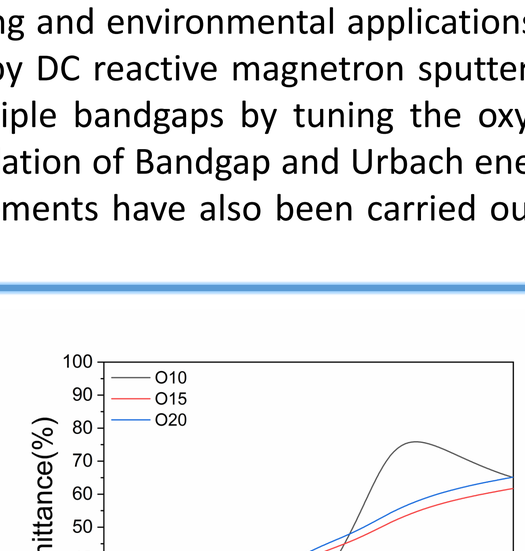
Reflectance spectra of CuO thin films



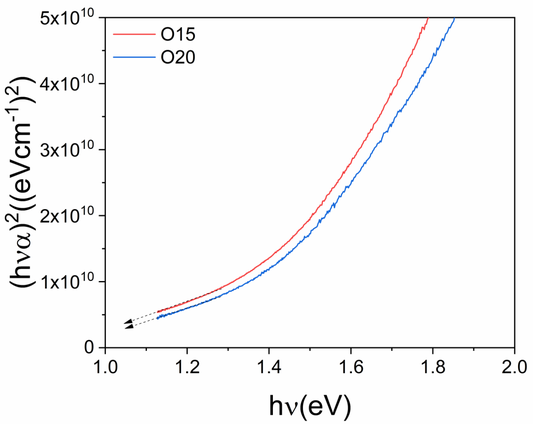
Transmittance spectra of CuO thin films



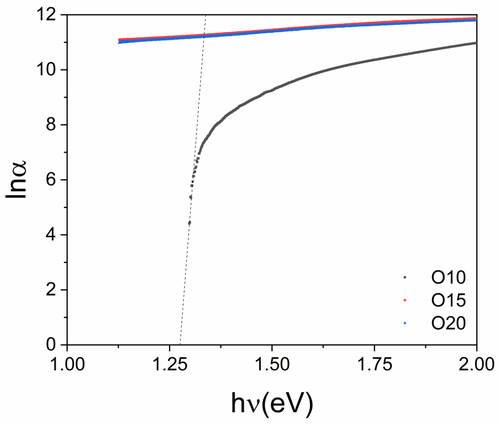
Absorption Coefficient spectra of CuO thin films



Tauc plots of O10 sample



Tauc plots of O15, O20 samples



Urbach tails plots of CuO thin films

Optical Characterization

- Higher Absorption Coefficient for samples sputtered at higher O_2
- Bandgap decreases with increasing O_2
- Unpredictable Urbach energy for O15 and O20 Samples
- Key parameters for O10 Sample:
  - R<25%
  - Average T=44.2% (λ=400-1100 nm)
  - $\alpha>1\times10^5$ cm^{-1} (λ<540 nm)
  - Bandgap=1.39 eV
  - Urbach Energy=4.1 meV

Electrical Characterization

Sample	Carrier Concentration (cm^{-3})	Hole Mobility (cm^{2}V^{-1}s^{-1})	Sheet resistance(Ω·sq^{-1})
O10	1.75×10^{15}	11.1	1.90×10^7
O15	3.30×10^{17}	2.43	1.10×10^6
O20	2.10×10^{18}	0.444	1.13×10^6
[2]	10^{16}	20	/

Conclusions

By varying the oxygen to argon ratio during sputtering, p-type CuO with high absorption coefficient of over 10^5 cm^{-1} in UV and near visible spectral range shows a decreasing bandgap from 1.39 to around 1 eV with the increase of oxygen ratio from 33.3% to 66.7%. The best performing O10 sample (O_2/Ar=10/20 SCCM) exhibits a low Urbach energy of 4.1 meV, a good carrier concentration of 1.75×10^{15} cm^{-3}, an excellent hole mobility of 11.1 cm^{2}V^{-1}s^{-1}, and a sheet resistance of 1.90×10^7 Ω·sq^{-1}. This p-type CuO thin film shows good optical and electrical performances, which can be used as large-area photodetection material in the UV and near visible spectral range for future photodetector applications. In the future work, post-annealing can be considered to further improve the performances of CuO thin films.

References

[1] Zeng, Xi, et al. "Structural and Opto-electronic characterization of CuO thin films prepared by DC reactive magnetron sputtering." *Journal of Materials Science: Materials in Electronics* (2020): 1-11.
[2] Kim, Hong-Sik, et al. "Optical and electrical properties of Cu-based all oxide semi-transparent photodetector." *Applied Physics Letters* 109.10 (2016): 101902.

Acknowledgements

This work is financially supported by China Scholarship Council and Université Catholique de Louvain Co-Funding Fellowship (No. CSC201806130158) and H2020 "ARCIGS-M" project (No.720887).