Characterization of CuO/Si Thin Films grown by the Magnetron Sputtering Technique

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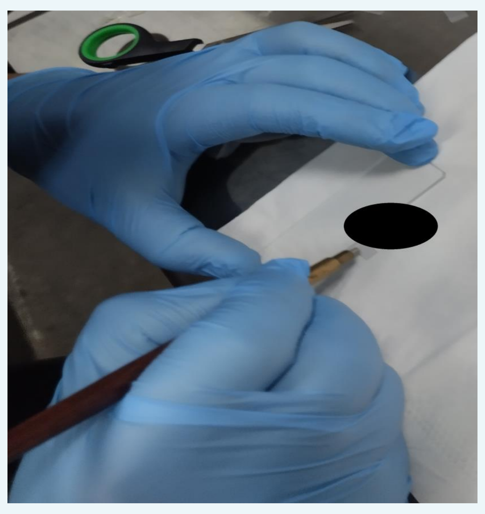
Introduction

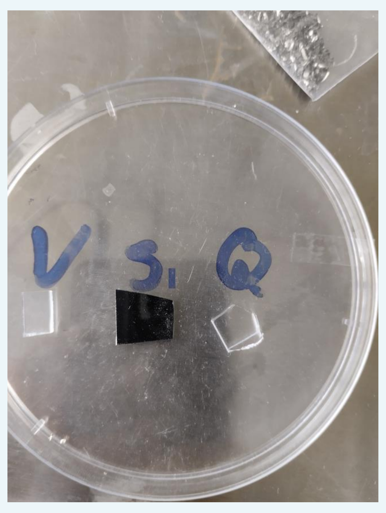
Two thin layers of copper oxide (CuO) were deposited on silicon substrates using DC magnetron sputtering, a technique that provides precise control over film thickness and composition. The films were structurally, morphologically, and optically characterized using X-ray reflectometry (XRR), X-ray diffraction (XRD), atomic force microscopy (AFM), and UV–Vis spectroscopy. XRR measurements show an approximate thickness of 54-60 nm. AFM analysis primarily determined the layer thickness, yielding values between 53.4 and 60.2 nm. Also, a surface roughness values between 0.8 and 2.1 nm was found, revealing homogeneous surfaces and uniform topography suitable for optoelectronic applications. Finally, UV–Vis spectroscopy exhibited high absorbance in the visible range, characteristic of CuO and enabled determination of the optical bandgap using Tauc plots, yielding direct bandgap values ranging from 2.85 to 5 eV and indirect bandgap values from 1.31 to 2.51 eV. These results highlight the high potential of the CuO thin films for photovoltaic devices and sensors, and demonstrate the effectiveness of DC magnetron sputtering combined with advanced characterization techniques.

Methodology

Sample Preparation

Substrate Cutting

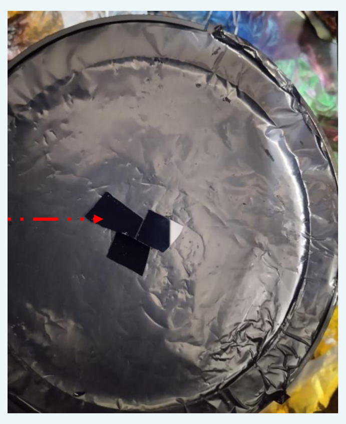


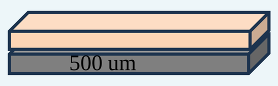


Deposition of CuO/Si using DC Magnetron Sputtering

Magnetron sputtering equipment in operation

Plasma Generated

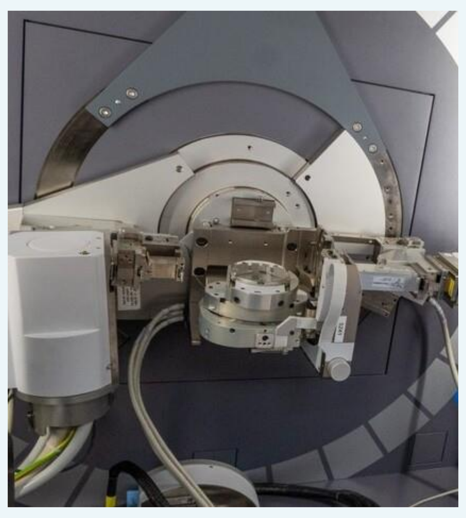


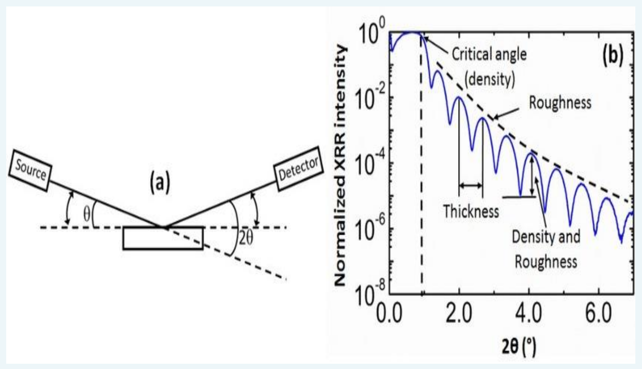


Film of CuO/Si.

Sample Analysis

X-Ray reflectometry (XRR)

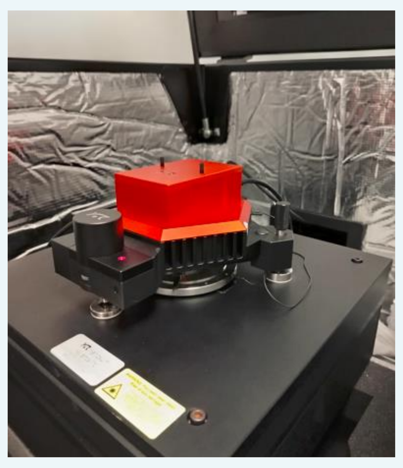


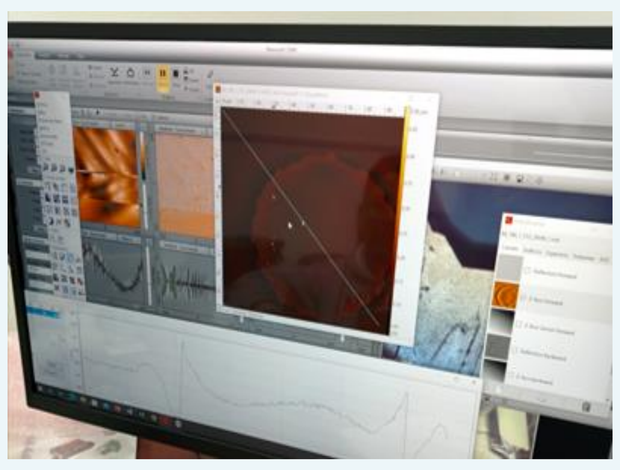


XRR principle

Panalytic system DRX and XRR system

Atomic Force Microscopy (AFM)





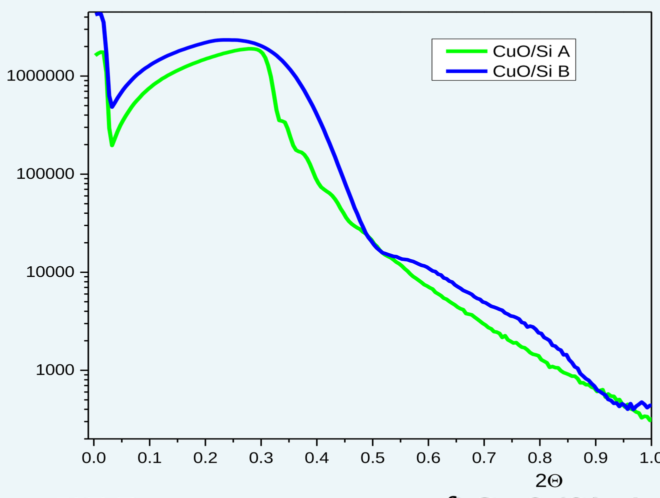
AFM Nanosurf, Dynamic Mode

UV- VIS Spectroscopy measurements

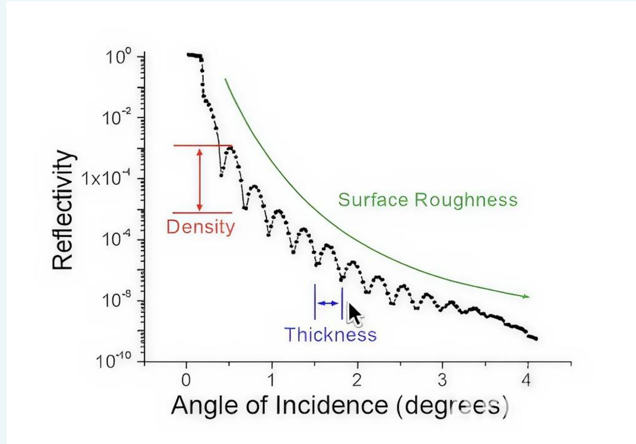
UV-VIS Perkin Elmer Modelo Lambda 25

Results and discussion

XRR Results



XRR measurements of CuO/Si A-B



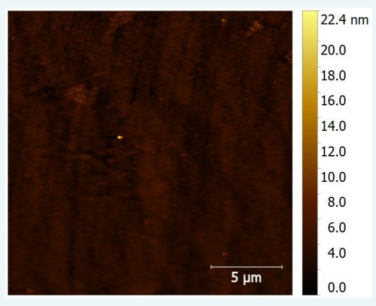
Experimental diagram of XRR

Thickness of CuO/Si A ≈ 57−60 *nm* ±2-4 nm

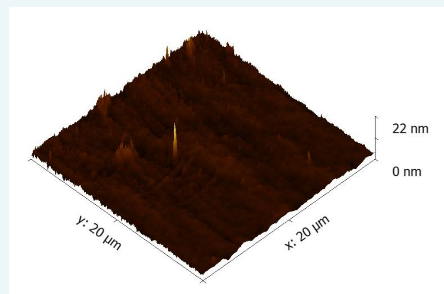
Thickness of CuO/ S B ≈ 54−57*nm* ±2-4 nm

SPM-AFM Results

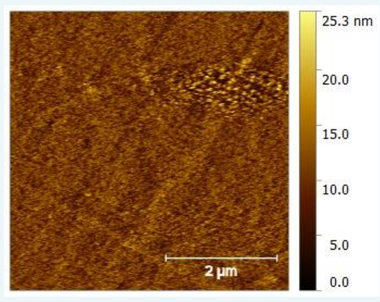
Sample CuO/ Si- A



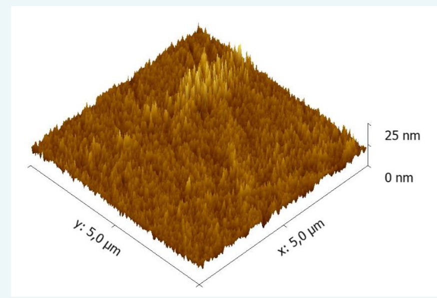
Topographic 20x20 μm



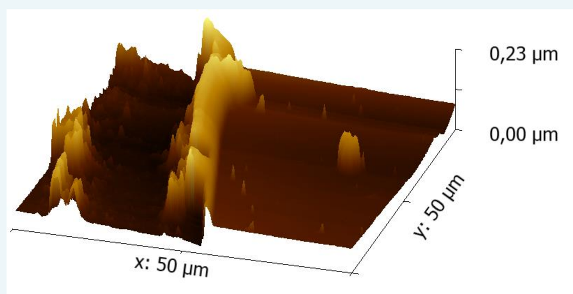
Rms (Sq): 0,8161 nm

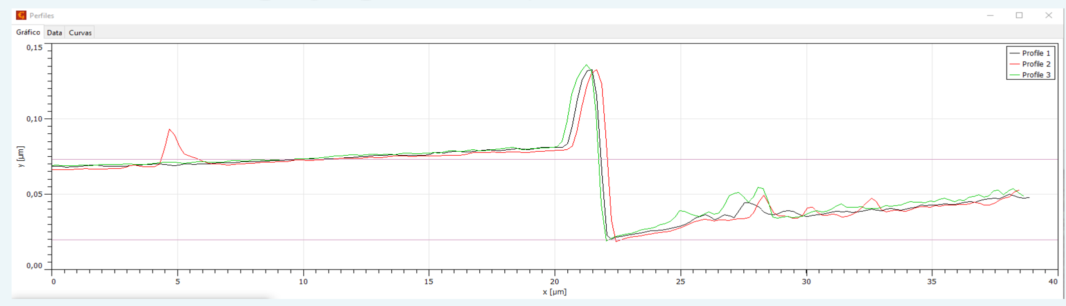


Topographic 5x5 μm



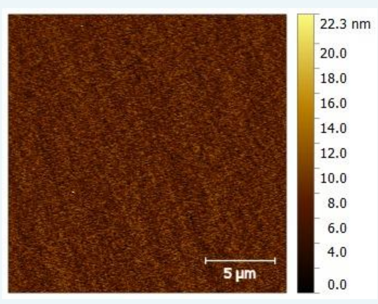
Rms (Sq) : 2,182 nm



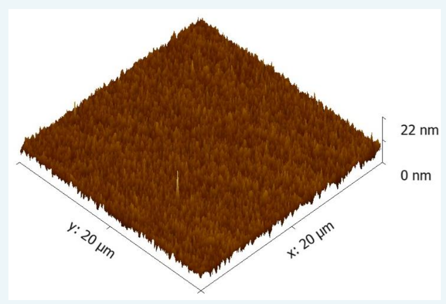


Thickness of CuO ≈ 53.4 nm

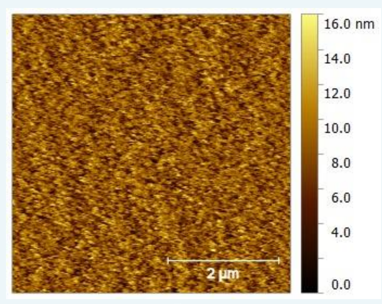
Sample CuO/ Si- B



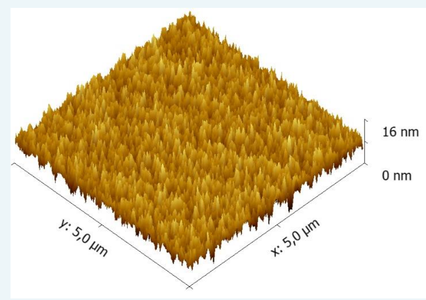
Topographic 20x20 μm



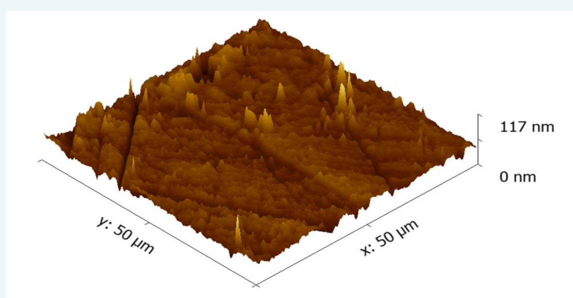
Rms (Sq): 1,726 nm

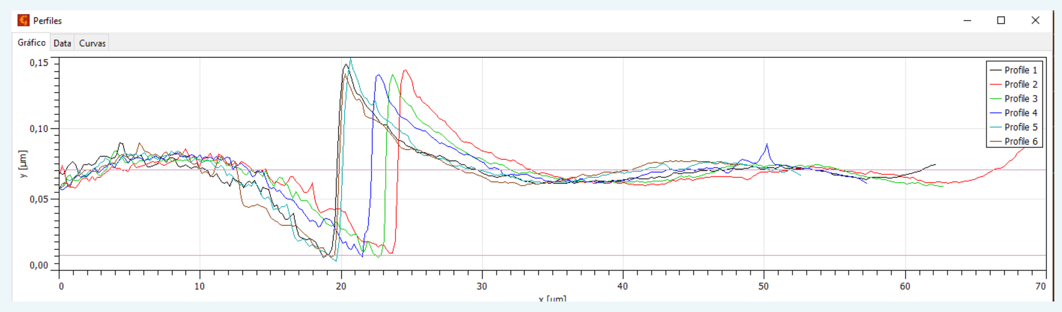


Topographic 5x5 μm



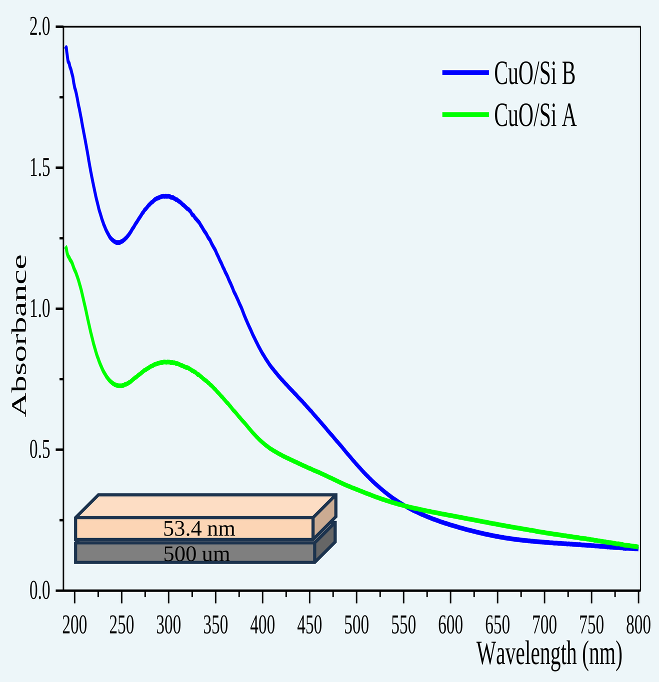
Rms (Sq): 2,073 nm



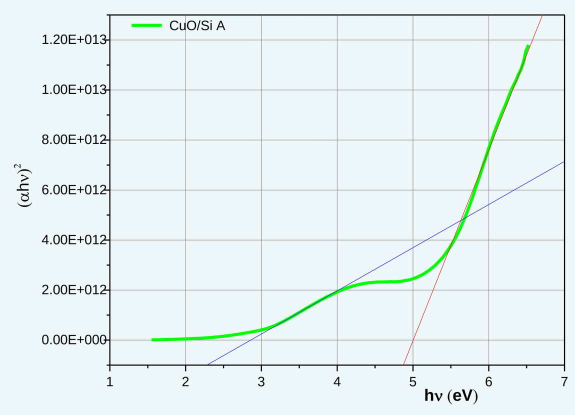


Thickness of CuO ≈ 60.2 nm

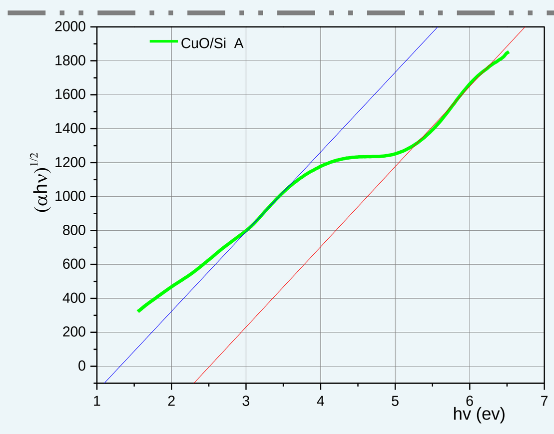
UV-VIS Results



CuO/ Si- A

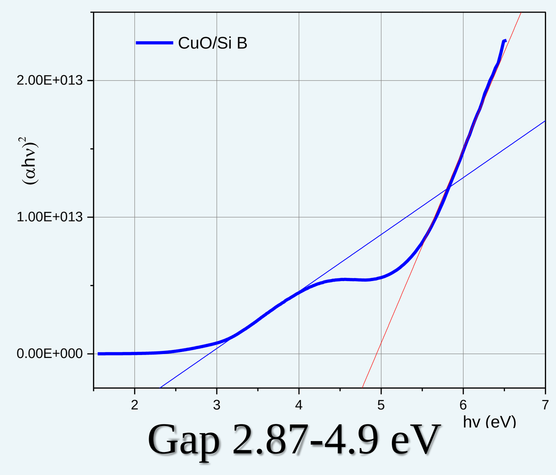


Gap 2.85-5.00 eV

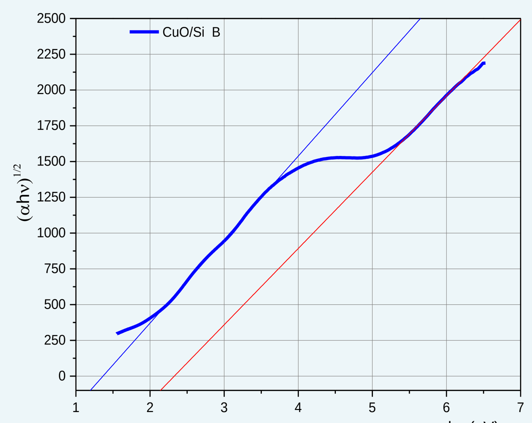


Gap 1.31-2.51 eV

CuO/ Si- B



Gap 2.87-4.9 eV



Gap 1.36-2.32 eV

Conclusions

DC magnetron sputtering was shown to be an effective method for depositing high-quality CuO thin films on silicon substrates with controlled thickness and composition. The films has exhibited smooth and homogeneous surfaces, with thicknesses of 53.4–60.2 nm and low surface roughness (0.8–2.1 nm), which are important for reliable device integration. Optical characterization revealed strong absorption in the visible region, with direct band gap values of 2.85–5 eV and indirect band gap values of 1.31–2.51 eV. Overall, these properties demonstrate the suitability of CuO thin films for photovoltaic, optoelectronic, and sensor applications.

Acknowledgements

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