Sensing properties of Cu_xO thin films grown by reactive PLD

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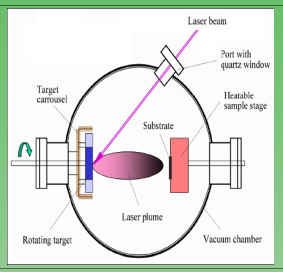
Abstract

- **Undoped copper oxide (Cu_xO) thin films were grown by reactive pulsed laser deposition (R-PLD) on SiO_2 substrates.**
- **In order to improve the gas sensing characteristics of the Cu_xO thin films, Au nanoparticles were deposited on the surface of the Cu_xO/SiO_2 thin film.**
- **All structures were investigated by contact mode atomic force microscopy (AFM), by transmission electron microscopy (TEM) and by energy dispersive X-Ray spectroscopy (EDX).**
- **The Cu_xO-based thin films were investigated as potential carbon monoxide (CO) and methane (CH_4) sensing layers.**

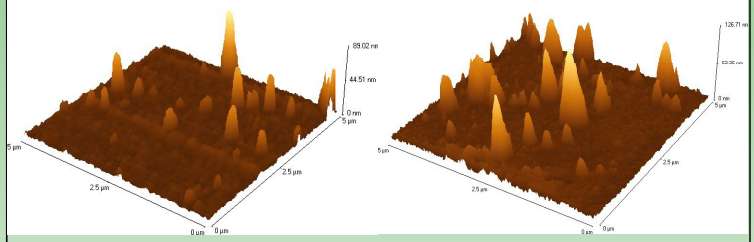
Films Preparation

- Undoped p-type Cu_xO thin films have been developed on SiO_2 substrates by reactive pulsed laser deposition technique (R-PLD).
- A KrF laser (λ = 248 nm, τ_{FWHM} ~10 ns) source at 10Hz repetition rate was focused on a metallic Cu target. The laser fluence incident on the target surface was set at ~2 J/cm^2.
- The Cu_xO films were grown under a constant oxygen partial pressure of 40 Pa for 90 min and at a substrate temperature of 200 ^oC.
- After the film growth, the chamber was evacuated down to its nominal pressure and the Au target (99,998% purity) was ablated by the focused beam of the KrF laser for about 2 min.



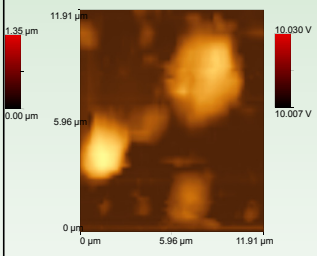
Films Characterization

Without Au nanoparticles **With Au nanoparticles**

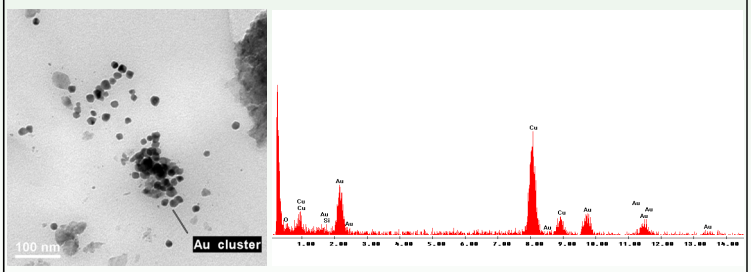


Sample	Area Ra (nm)	Area RMS (nm)	Avg. Height (nm)	Max. Range (nm)
Without Au nanoparticles	2.91	6.68	4.52	89.02
With Au nanoparticles	5.34	10.85	8.02	126.71

The addition of Au nanoparticles had an effect on the surface morphology of the films; the one without Au was smoother than the other with Au nanoparticles.



Conductive AFM image of the Au/Cu_xO/SiO_2 structure.



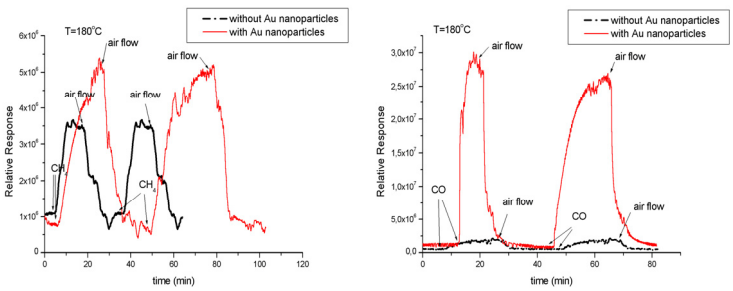
The EDX spectrum provided evidence for the presence of Au nanoparticles on the surface of the Cu_xO/SiO_2 thin film.

Gas Sensing Tests

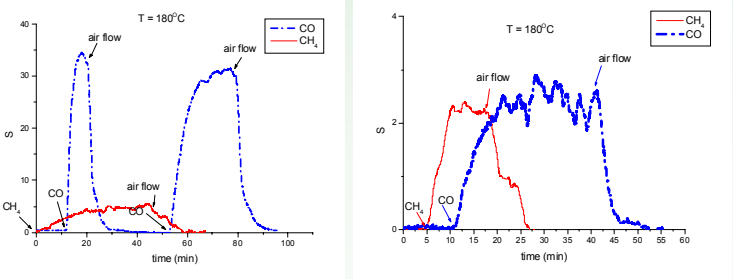
For a p-type semiconductor, the resistivity increases in the presence of a reducing gas. This is due to the redox reaction of the gas with the adsorbed oxygen on the film surface: delocalized electrons reduce the number of holes (charge carriers) in the valence band leading to the resistivity increase.

Dynamic resistivity response measurements were performed in presence of two different gases (CO and CH_4) in air ambience.

$$S = \frac{R_g - R_0}{R_0}$$



The modified Cu_xO film with Au nanoparticles on its surface exhibited higher relative response on both gases (methane and carbon monoxide).



The surface modification of the Cu_xO films with Au nanoparticles enhance the selectivity over CO with almost complete discrimination against CH_4.

Conclusions

- **Undoped copper oxide (Cu_xO) thin films were grown by reactive pulsed laser deposition on SiO_2 substrates.**
- **The gas sensing characteristics of these films are strongly influenced by surface modification.**
- **The modified Cu_xO film with Au nanoparticles on its surface increased the sensor response with respect to the unmodified one by more than 2 times.**
- **Selectivity of Cu_xO thin films over CO gas was enhanced with surface modification.**