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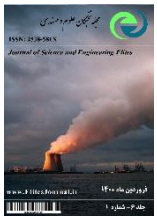

Effect Adding Silver on Electrical and Magnetic Properties of Copper Oxide Thin Film

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Abstract

In this study, CuO-Ag thin film are deposited on the glass substrate using a plasma focus device and sputter system. The obtained results based on the electrical and magnetic properties are discussed. The diagram I-V shows that the current changes in voltage follow the Ohm's law almost. By 4probe method, deposition of silver nanoparticles on copper oxide film results in decrease sheet resistance. According to the analysis VSM, the penetration of silver nanoparticles on the surface copper oxide leads to a linear increase in the magnetization of sample.

Key Words: CuO-Ag, Plasma Focus, Sputtering, I-V, VSM.

1- Introduction

Nano-structured transition metal oxides (TMO) have gained a great interest from scientific community due to different properties compared with corresponding bulk counterparts, which in turns provides promising applications in the various fields of technology such as photonic devices, transparent conductive oxide materials, photovoltaic cells, catalysts, and gas sensors [1-5]. Among them, copper oxides are nontoxic and the abundant availability of copper makes these oxides a cheap material available for many applications. CuO is a p-type semiconductor with an indirect band gap of 1.2–2.1 eV [6] Various techniques such as magnetron sputtering [6-8], microwave annealing [9,10], sol-gel [11], chemical vapour deposition[12], spray pyrolysis [13], pulsed laser deposition [14] and chemical bath deposition[15] have been used for CuO thin film deposition.
Silver nanoparticles are increasingly used in various fields, including medical, food, health care, consumer, and industrial purposes, due to their unique physical and chemical properties [16]. It is known that silver has very high electrical conductivity Silver have better electrical conductivities than CuO; with the addition of silver nanoparticles, electrical conductivity properties of the CuO is expected to rise [17]. A.A.Menazea et al, showed that Ag doped CuO thin film enhanced

degradation efficiency compared to CuO thin film alone [18]. Sayantan Das and T. L. Alford, Ag doped CuO thin film were deposited on the substrate using spattering method and then by microwave oxidation of metal film [19]. M Sh Abdel-wahab et al, have reported sunlight-activated photo-catalysis response of direct current radio frequency (DC/RF)-sputtered CuO–Ag nanoparticles thin films. This research study could provide a platform to understand and develop metal oxide thin films with an efficient photo-catalytic response in sunlight [6].
In most of these methods the structural and optical properties of CuO-Ag have been investigated and the electrical and magnetic properties have been less studied. These properties of the thin film is critical parameter in evaluating the performance of photovoltaic cells and electrochromic devices; the parameter have been reported to depend on the growth conditions, such as the method of fabrication, growth and annealing temperatures [20-22].
In this study, the first layer of CuO was deposited on the glass substrate using a plasma focus device and then the silver nanoparticles were formed CuO-Ag multilayer by reactive dc magnetron sputtering system. The dense plasma focus (DPF) is a simple, cost-effective, and pulsed coaxial plasma accelerator utilizing self-generated magnetic field to compress the plasma to high densities (10^{25}–10^{26} m^{-3}) as well as high temperatures (~ 1–2 keV) for a short period of time (~ 10^{-7} s) [23] The DPF is a promising source of hard/soft X-rays, neutrons, relativistic electrons, and high energy ion beams over a wide energy spectrum [24]. While being primarily designed for fusion research applications, the DPF device has been recently considered for many purposes including ion implantation [25], surface modification [26], thermal surface treatments [27], and thin film deposition [28].

2- Experimental method

The used DPF device was Mather type having a 39μF capacitor bank with the ability to be further charged up to 10 Kv. the device consisted of a copper anode electrode with 1.8cm of diameter and 5.3cm of length, surrounded by 6 brass cathode electrodes, each with 5.3cm of length. A Pyrex insulator has separated the electrodes (Fig 1).

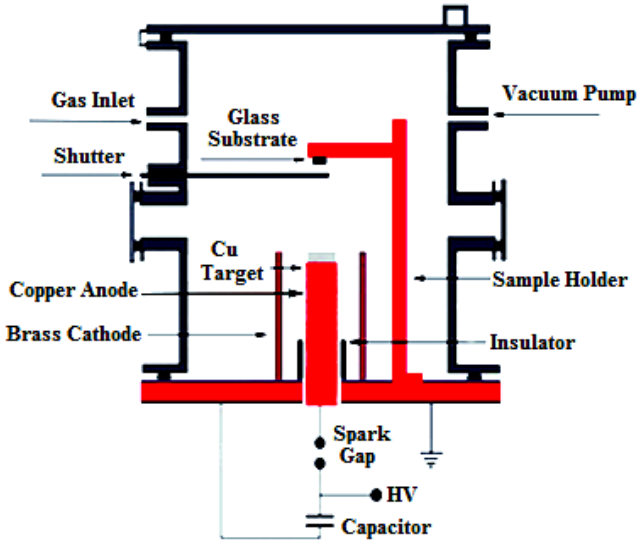

Fig. 1- Schematic of Mather Plasma Focus Device

In this experiment, the anode was made of metal Cu (99.9% purity). There was a shutter between the anode electrode and the sample holder for the initial shots to achieve an excellent pinch. The entire set of the electrodes were inside a vacuum container that was pressure-dropped by a rotary

compressor to 0.2torr. Then, a mix of O2 and Ar gases was injected inside the vacuum container as the working gas. The optimum pressure for the excellent pinch in the experiment was 0.2torr at 8.7kV of voltage. The voltage wave form versus current at pinch time, which was received from Rogowsky coil, was recorded by an oscilloscope (Fig 2).

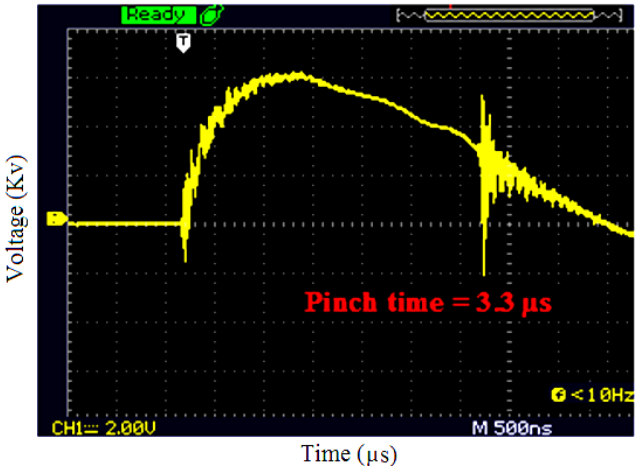

Fig. 2- Rogowsky Coil Current Derivative Signal at Pinch Time

For the operation of the plasma focus device, a high voltage was applied between two anode and cathode electrodes by one 39µF capacitors charged by a high voltage. Then, an electrical discharge took place on the insulator surface in 100ns, creating a current layer on the insulator surface. A self-consistent magnetic field is created, producing Lorentz force and accelerating the current layer to the open end of the anode. As a result, the J×B force compressed the current layer on the anode, which created warm dense plasma. At this time, the plasma column created by the sausage instability (m=0) was eliminated by the production of high-energy electron, ion, and X-ray particles. Since a strong magnetic field was created when the plasma column was eliminated, this magnetic field accelerated the ions and electrons in opposite directions such that the high-energy electrons collided with the anode (Cu) and resulted in their melt. Cu atoms were mixed with the ionized O2 gas and deposited on the sub-layer at the pinch time by the produced plasma jet. Before the formation of the thin films, glass sample were cleaned with alcohol, acetone, and distilled water, each for 20 minutes in an ultrasonic device with the help of ultrasonic waves. The sample were placed 9cm above the anode. CuO films were prepared at a zero-degree angle to the anode with 25 shots.

Table 1- The deposition conditions of the prepared CuO films

Ar/O_2 pressure ratio	**1**
substrate	**glass**
target	**copper**
diameter target(cm)	**1.8**
length target(cm)	**5.3**
optimal pressure(torr)	**0.2**
optimal voltage(kv)	**8.7**
number of shots	**25**
distance(cm)	**9**
substrate temperature	**RT**

In the next step, Ag thin films with a rate deposition of 4.7 A^0/ Sec were synthesized using a single-cathode desk sputtering on a CuO layer. Fig. 3 shows schematic diagram of DC-magnetron sputtering system. The vacuum system was a glass cylindrical chamber having two electrodes with different areas. A flat circular disk with the 0.1 mm thickness and 5 cm diameter made of Ag sheet was installed on the smaller electrode as a deposition target and was connected to DC source. During the deposition process, the distance between the target and the substrates were kept 7 cm, approximately. The chamber was vacuumed up to the base pressure of 30 mtorr by rotary and turbo pumps. As the Ar gas enters, the pressure of the chamber increased to 70 mtorr working pressure. The current and power of the system were set to form uniform, continuous and dense layers. The only variable parameter in the deposition process was deposition time, changing from 5 to 10 min. Deposition process was carried out at room temperature, constant pressure (70 mtorr), and constant power equals to 70 W. Thickness of the layers was measured by quartz thickness gauge.

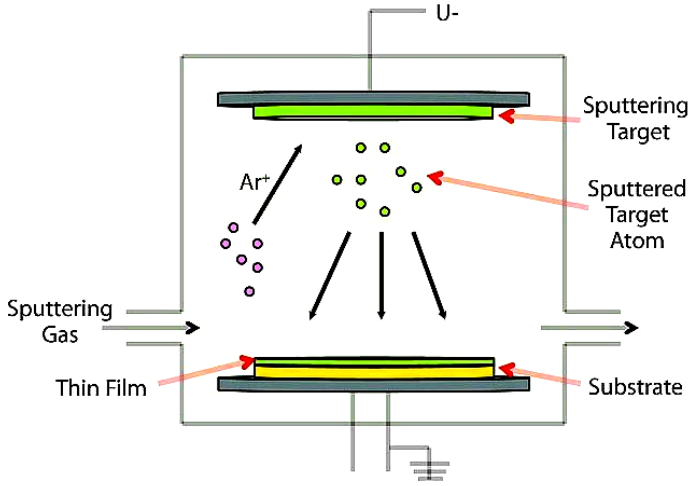

Fig. 3- Schematic diagram of DC-magnetron sputtering system

Table 2- Ag nanoparticle sputtering process parameters

gas enters	Ar
deposition rate(A^0/sec)	4.7
target	silver
sputtering power(W)	70
working pressure(mtorr)	70
diameter target(cm)	5
thickness target(mm)	0.1
distance(cm)	7
substrate temperature	RT

I–V measurements of CuO-Ag thin film prepared for 2Molar KOH solution and applied voltages from -0.5 to 1.5V and 10mv/s rate. The magnetic properties of CuO-Ag were also investigated by the VSM device LBKFB Kashan Kavir Magnetic Company.

3- Electrical Properties

I–V measurements of CuO and CuO-Ag thin film prepared for 2Molar KOH solution. The current values were measured for different applied voltages from -0.5 to 1.5V and 20mv/s rate. I-V diagram shows that as the applied voltage increases, the current intensity increases exponentially and almost follows the Ohm's law (Fig 4). Also the CuO-Ag sample was less stable than the sample CuO.

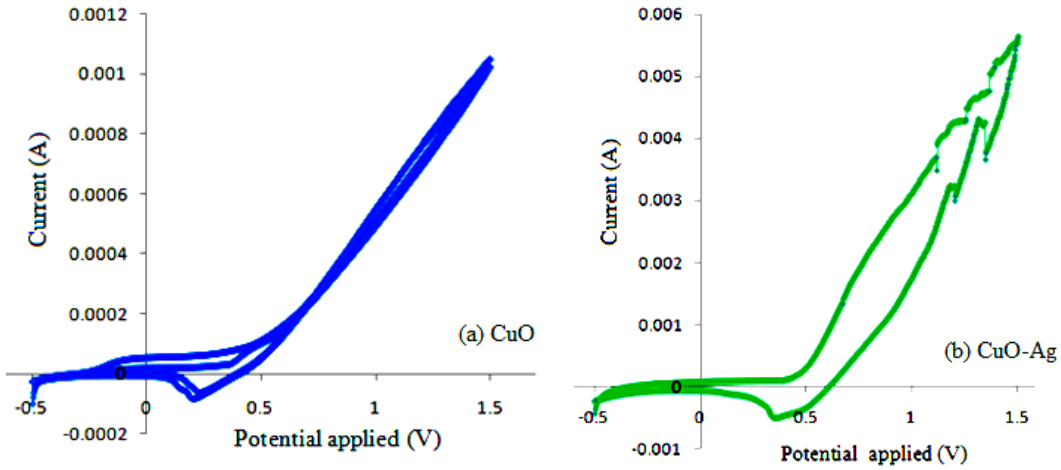

Fig. 4- I-V Chart of a) CuO and b) CuO-Ag

The electrical resistance of metallic thin films is measured by a four-probe method. The sheet resistance was determined by measuring the ratio of the voltage drop (**V**) from the two inner probes to the applied current (**I**) measured from the outer probes. The result was multiplied by a geometric correction factor that depands on the probe geometry, given by the relationship (4) [8],

$$R_s = K\left(\frac{V}{I}\right) \quad (1)$$

Where $\mathbf{R_s}$ is the sheet resistance and **K** is the geometric factor, which is 4.53 for a semi-infinite thin sheet. Four probes are placed on the sample at distances of 2 mm from each other and then the device is applied from 0.01 to 0.15 V and the sample pass current is read in the range of 0 to 0.001A. The electrical resistance of CuO and CuO-Ag thin film 0.68 KΩ and 0.3 KΩ Approximately. Thus deposition of Ag nanoparticles on CuO results in an increase in current and thus a decrease in resistance.

4. Magnetic Properties

To measure the magnetic properties of the samples, analysis Vibrating Sample Magnetometer (VSM) is used. In VSM, a sample is vibrated physically sinusoidally and magnetic momenta are measured as a function of magnetic field and temperature. Due to vibrations, the magnetic field of the sample changes and according to Faraday's law, concurrently generates electric field in the coil. Figure 5 displays room temperature magnetization-field (M–B) curves of CuO and CuO-Ag thin film. The current values were measured for different applied magnetic field from -1.5 to 1.5 T. M-B diagram shows that as the applied magnetic field increases, the magnetization of CuO increases linearly. In the CuO-Ag sample, magnetism is placed at the top of the diagram related to CuO. As a result, it can be seen that the addition of Ag nanoparticles leads to an increase in magnetism of CuO.

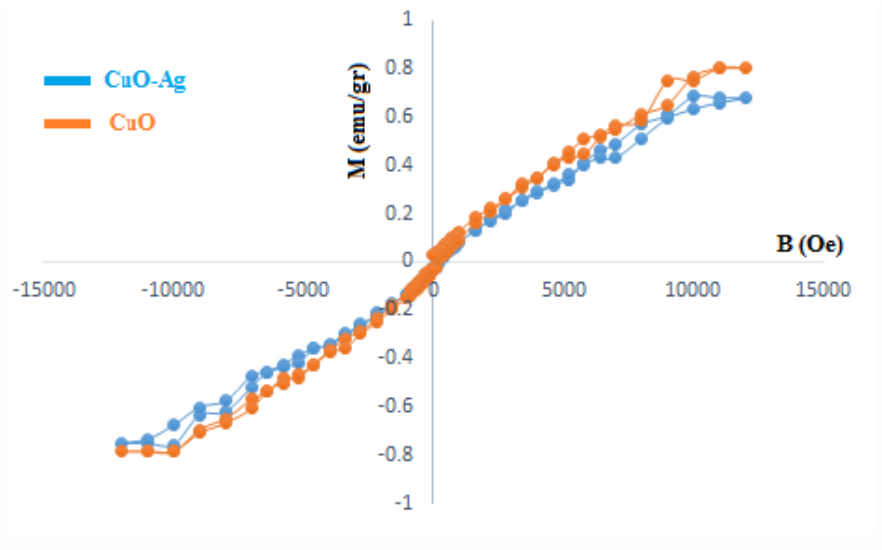

Fig. 5- M-B Chart of CuO and CuO-Ag

5- Conclusion

In this experiment, CuO film synthesized using a low energy plasma focus device was Mather type having a 39μF capacitor bank with the ability to be further charged up to 10 Kv. Then, Ag nanoparticles with a rate deposition of 4.7 A^0/ Sec were synthesized using a single-cathode desk sputtering with 70W power on a CuO layer. The diagram I-V shows that the current changes in voltage follow the Ohm's law almost. According to the diagram M-B, the penetration of silver nanoparticles on the surface of copper oxide leads to increase in the magnetization of sample.

6- Acknowledge

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7- References

1. B. Purusottam Reddy, K. Sivajee Ganesh, O.M. Hussain, Growth, microstructure and supercapacitive performance of copper oxide thin films preparedby RF magnetron sputtering, Appl. Phys. A 122 (128) (2016) 1–10
2. J. Lv, C. Liu, W. Gong, Z. Zi, X. Chen, K. Huang, F. Liu, T. Wang, G. He, X. Song, and Z. Sun, Electron. Mater. Lett. 8, 477 (2012)
3. X. Xiao, L. Miao, G. Xu, L. Lu, Z. Su, N. Wang, and S. Tanemura, Appl. Surf. Sci. 257, 10729 (2011)
4. D. Barreca, E. Comini, A. Gasparotto, C. Maccato, C. Sada, G. Sberveglieri, and E. Tondello, Sensor. Actuat. B 141, 270 (2009)
5. E. J. Lee, T. Noh, M. S. Jeon, Y. Jeong, and H. Lee, Korean J. Met. Mater. 51, 145 (2013)
6. Waleed M A El Rouby, Attieh A Al-Ghamdi, M Sh Abdel-wahab & Asim Jilani .Sunlight-enhanced catalytic degradation over Ag–CuO nanoparticles thin films prepared by DC/RF sputtering technique, Bull. Mater. Sci. (2018) 41:58
7. B. Purusottam Reddy, K. Sivajee Ganesh, O.M. Hussain, Growth, microstructure and supercapacitive performance of copper oxide thin films preparedby RF magnetron sputtering, Appl. Phys. A 122 (128) (2016) 1–10
8. A.A. Ogwu, T.H. Darma b, E. Bouquerel, Electrical resistivity of copper oxide thin films prepared by reactive magnetron sputtering, Journal of Achievements in Materials and Manufacturing Engineering, Volume 24, Issue 1, September 2007

9. Sayantan Das and T. L. Alford, Structural and optical properties of Ag-doped copper oxide thin films on polyethylene napthalate substrate prepared by low temperature microwave annealing, Journal of Applied Physics 113, 244905
10.Rejith G.S, and Krishnan C., Material letters, (2013),106, 87-89 (2013)
11.Etefagh R.; Azhir E. and Shahtahmasebi N.; Scientia Iranica, 2013, 20(3), 1055-1058
12.Maruyama T.; Jpn. J. Appl. Phys, 1998, 37, 4099

13. Shabu R.; Moses Ezhil Raj A.; Sanjeeviraja C. and Ravidhas C.; Material Research Bulletin; 2015, 68, 1-8

14. Chen A.; Long H.; Li X.; Li Y.; Yang G. and Lu P., Vacuum, 2009, 83,927

15. Ramya V.; Neyvasagam K.; Chandramohan R.; Valanarasu S.; Milton Franklin Benial A., J Mater Sci: Mater Electron, 2015, 26, 8489

16. Markus Diantoro, Thathit Suprayogi, Ulwiyatus Sa'adah, Nandang Mufti, Abdulloh Fuad, Arif Hidayat and Hadi Nur, Modification of Electrical Properties of Silver Nanoparticle, Silver Nanoparticles - Fabrication, Characterization and Applications, chapter12, July 2018, DOI: 10.5772/intechopen.75682

17. E. M. Alkoy and P. J. Kelly, Vacuum 79, 221 (2005)

18.Ag doped CuO thin film prepared via pulsed laser deposition for 4-nitrophenol degradation
19. A.A.Menazea, Ayman M.Mostafa, Journal of Environmental Chemical Engineering Volume 8, Issue 5, October 2020, 104104
20. Sayantan Das and T. L. Alford, Structural and optical properties of Ag-doped copper oxide thin films on polyethylene napthalate substrate prepared by low temperature microwave annealing, Journal of Applied Physics 113, 244905 (2013); https://doi.org/10.1063/1.4812584
21. Dian M. Felicia, R. Rochiem, and Standley M. Laia, The effect of silver (Ag) addition to mechanical and electrical properties of copper alloy (Cu) casting product, AIP Conference Proceedings 1945, 020075 (2018); https://doi.org/10.1063/1.5030297

22.S. C. Ray, Sol. Energ. Mater. Sol. C. 68, 307 (2001)

23.A. A. Ogwu, T. H. Darma, and E. Bouquerel, JAMME 24, 172 (2007)

24. Lee S, Tou TY, Moo SP, Eissa MA, Gholap AV, Kwek KH, Mulyodrono S, Smith AJ, Suryadi, Usada W, Zakaullah M (1988) A simple facility for the teaching of plasma dynamics and plasma nuclear fusion. Am J Phys 56: 62-68

25.Ahmad S, Hussain SS, Sadiq M, Shafiq M, Waheed A, Zakaullah M (2006) Enhanced and reproducible neutron emission from a plasma focus with pre-ionization induced by depleted uranium (U238). Plasma Phys Controlled Fusion 48(6):745–755
26. Hassan M, Qayyum A, Ahmad R, Murtaza G, ZakaullahM (2007) Nitriding of titanium by using an ion beam delivered by a plasma focus. J Phys D Appl Phys 40(3):769–777
27. Rawat R et al (2001) Room temperature deposition of titanium carbide thin films using dense plasma focus device. Surf Coat Technol 138(2):159–165
28.Rawat R et al (2003) Deposition of titanium nitride thin films on stainless steel—AISI 304 substrates using a plasma focus device. Surf Coat Technol 173(2):276–284
29.Mohanty S et al (2006) Energetic ion irradiation of American diamond in a plasma focus device and characterization of irradiated material. Nucl Instrum Methods Phys Res, Sect B 243(1):113–118