ISSN:2319-6602
International Journal of Chemical and Physical Sciences

Study of Structural and Electrical Characteristics of Screen Printed MoO_3 Thick Films

A.V.PATIL[1], D. K. HALWAR[2]

[1]Dept. of Electronics, L.V.H. College, Panchavati, Nashik-422003(M.S.) , India
[2]Dept. of Electronics, M.S.G. College, Malegaon-Camp Dist. Nasik (M.S.) , India
Corresponding Author - halwardk9@gmail.com

ABSTRACT

Thick films of MoO_3 were prepared by screen printing method on alumina substrate and fired at 600^0C in air. Current flowing through the films was measured in air atmosphere at different temperatures. The films were showing decrease in resistance with increase in temperature indicating semiconductor behaviour. The resistivity, activation energy and temperature coefficient of resistance (TCR) are evaluated. The structural behaviour, surface morphology was studied by XRD, SEM and EDAX techniques respectively. From XRD the crystallite size was calculated using Scherer's formula and observed as 19.97nm. From SEM the particle size was observed as 45nm to 156nm.EDAX analysis shows non- stoichiometric behavior of the films. It may be due to the oxygen deficiency in the compound. The resistivity of films was calculated as $82.5x10^4\Omega m$.The TCR was evaluated as $0.00997/^oC$. From Arrhenius-type plots, the activation energy was determined. Arrhenius-type plots for the electrical conductivity indicate the presence of at least two different conduction mechanisms. The activation energy at low and high temperature region was observed as 0.109 eV and 0.68 eV respectively.

Keywords: Screen Printing; MoO_3; XRD; SEM; Resistivity, TCR

INTRODUCTION

In modern era of electronic equipment, metal–oxide–semiconducting thin films have played a very important role. Transition metal oxides have potential applications as catalysts and sensors. TiO_2, WO_3, and MoO_3 are the most popular photochromic and electrochromic materials. [1]

Molybdenum trioxide (MoO_3) is one of the most promising inorganic materials having potential technological application in the fields of large area display devices [2, 3], high density memory devices [4] and optical smart windows [5]. Moreover, it can be used as a potential electro-active material for high energy density secondary lithium batteries [6, 7].

In the present study MoO_3 films were prepared by screen printing method. Screen printing method was employed for film preparation since the method is relatively easy and low cost. [8] Structure and morphology were also studied using XRD and SEM. EDAX analysis was carried out to find out wt. % and atomic % of the elements present in the film. Electrical properties such as resistivity, TCR and activation energy were also studied.

EXPERIMENTAL WORK

Materials and Methods

All materials used for the thick films were of AR grade and no further purification was carried out. MoO_3 powder used for the film preparation was of Merck with 99.98 purity. Ethyl Cellulose, Butyl Carbitol Acetate and glass frit were the other materials used for film preparation.

Organic to Inorganic material ratio was maintained to be 70:30. Glass frit was used as permanent binder while BCA was used as temporary binder. The mixer was crushed in a mortar pastel and 7-8 drops of BCA were added to prepare a paste. Prepared paste was screen printed on Alumina substrate. Printing paper of 140 mesh was used for screen printing. Films were dried under IR lamp for about 15 min. Further the films were calcined at 600^0C for 1 hr. in air atmosphere.

Material was found to be well stuck to the alumina substrate.

XRD

Structural properties of MoO_3 films were studied by X-ray diffractometer analysis. The average crystallite size was calculated from XRD pattern using following Debye Scherer's formula [9],

$$D = \frac{0.9\lambda}{\beta Cos\theta} \qquad \text{…………..} \qquad (1)$$

Where β = Full angular width of diffraction peak at the at half maxima peak intensity.
λ =wavelength of X-radiation.

SEM & EDAX

Morphological properties were studied with SEM. Elemental analysis was confirmed using EDAX.

The thickness of the grown films were measured by Surftest SJ 301 profilometer.

Electrical Properties

Electrical properties of the films were studied using half bridge method. In this method DC resistance of the sample was measured against temperature variation for the MoO_3 thick films. Temperature coefficient of resistance, resistivity and activation energy of the sample were calculated.

RESULT AND DISCUSSION

XRD

Figure.1 shows the X-ray diffractometer plot for MoO_3 thick films. Plot shows 3 major peaks. The peaks were compared with JCPDS card no. (05-0508 & 21-0569). This comparison confirmed the presence of MoO_3 in considerable pure form. The permanent also binder melted away quite nicely. [2 1 0] was found to be the most preferred plane among the planes. From XRD the crystallite size was calculated using Scherer's formula and observed as 19.97nm

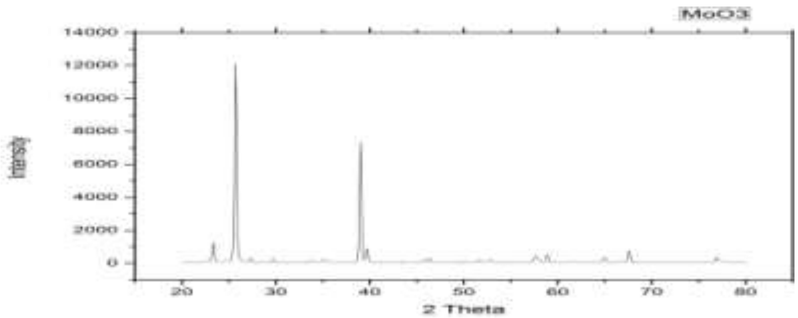

Fig.1 XRD Pattern of MoO_3 films

Table:1 shows all the information calculated from XRD data. From XRD the crystallite size was calculated using Scherer's formula and observed as 19.97nm. Structure for MoO_3 was confirmed by comparison with JCPDS data to be orthorhombic.

Table:1 Data calculated from XRD peak analysis

2 θ	d-spacing	[h k l]	counts	Intensity	FWHM
23.37	3.80338	[1 1 0]	1233	10.2	0.262
725.7	3.46378	[2 1 0]	12089	100	0.225
38.998	2.30775	[1 5 0]	7336	60.7	0.243

SEM

Figure 1 shows SEM image of MoO_3 thick films. It shows cylindrical (rod-like) structure with prominent voids in between. The microstructure is with significant porosity. It also shows that the binders have been properly melted due to the calcination. From SEM the particle size was observed as 45nm to 156nm.

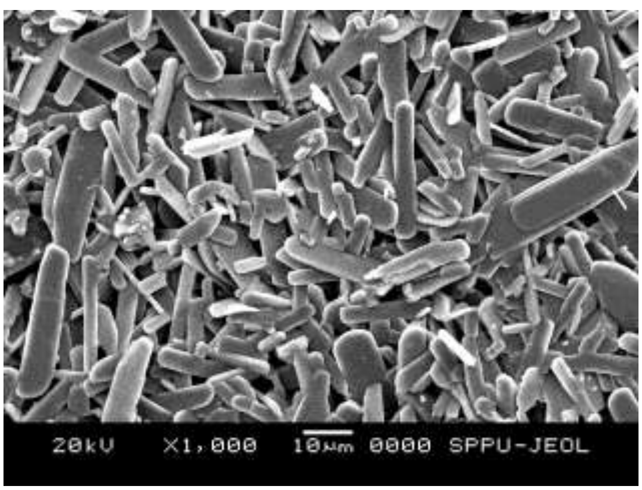

Figure 1 SEM image of MoO_3 thick films

EDAX:

Figure:2 shows spectrum of energy dispersie analysis of X-ray (EDAX). Elemental composition of MoO_3 thick films was analyzed.

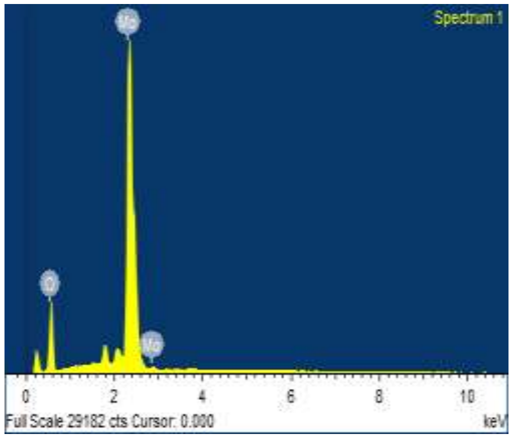

Table:2 tabulates quantative composition of elemental analysis of MoO_3 thick films. L. E. Firment et al. have shown that O/Mo atomic ratio should be 2.85 ± 0.12 on heaing to 600^0C[10]. EDAX analysis shows non- stoichiometric behavior of the films. It may be due to the oxygen deficiency in the compound.

Table:2 Data of EDAX analysis

Element	Weight %	Atomic %
Mo	148.49	14.93
O	141.05	85.07

Electrical Properties

Figure: 3 shows variation of MoO_3 film resistance with temperature. Current flowing through the films was measured in air atmosphere at different temperatures. The films were showing decrease in resistance with increase in temperature indicating semiconductor behavior.

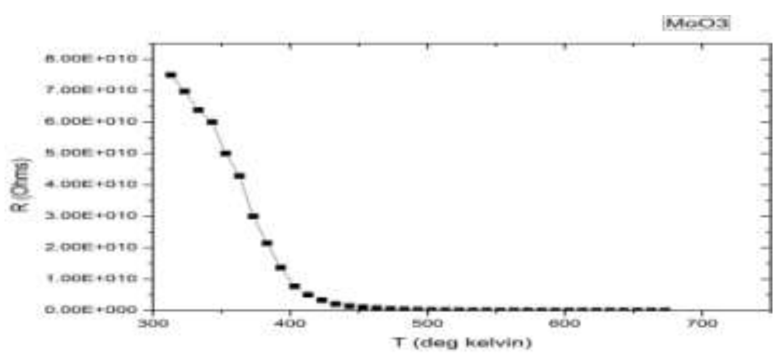

Figure:3 Variation of MoO_3 film resistance with temperature

The resistivity, activation energy and temperature coefficient of resistance (TCR) are evaluated. The resistivity of films was calculated as $82.5x10^4\Omega m$. The TCR was evaluated as $-0.00997/^oC$. Figure: 4 shows the Arrhenius plot for MoO_3 thick film.

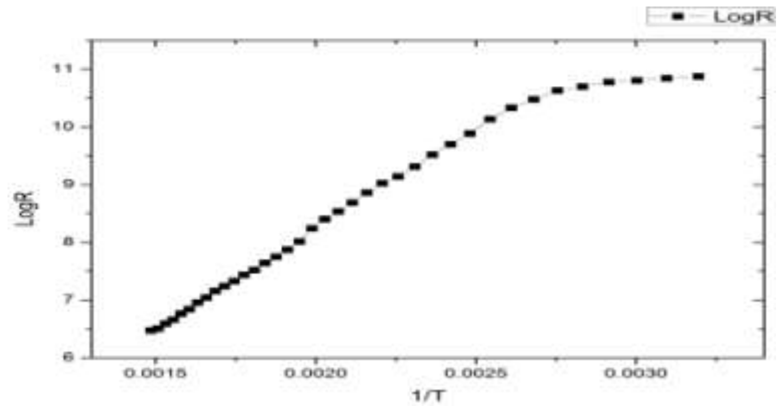

Figure: 4 Log R vs 1/Temperature for MoO_3 film

It clearly shows two regions, one is the high temperature region and the other is low temperature region. Arrhenius-type plots for the electrical conductivity indicate the presence of at least two different conduction mechanisms.[11,12] The activation energy at low and high temperature region was observed as 0.109 eV and0.68 eV respectively.

CONCLUSIONS

From the results obtained, following conclusions can be made for the performance of MoO_3 thick films

i. Uniform and porous films of MoO_3 can be formed using screen printing method. This make films suitable for gas sensing mechanism.
ii. The resistivity of MoO_3 thick films at 30^0C was $82.5x10^4\Omega$m.
iii. The TCR was evaluated as -0.00997 /^{o}C.
iv. The activation energy at low temperature region was observed as 0.109 eV.
v. The activation energy at high temperature region was observed as 0.68 eV.
vi. MoO_3 thick films showed n-type semiconductor like behavior.

ACKNOWLEDGMENTS

The authors thank to Management of M. S. G. College, Malegaon and M. G. Vidyamandir, Nashik.

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