Synthesis and Study of Electrical and Optical Properties of WO_3 thick films prepared by Screen Printing Method

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Abstract

Tungsten oxide (WO_3) nanoparticles are nano-sized particles of tungsten trioxide, a compound composed of tungsten and oxygen. These nanoparticles have gained significant attention due to their unique properties and potential applications in various fields. The present research work is focus on to synthesis of WO_3 nanoparticles by using precipitation method. The synthesised WO_3 nanoparticles were used for the preparation of WO_3 thick films. Thick films of WO_3 were prepared on glass substrate by screen printing method. The electrical properties of films were study by using half bridge method and the optical properties of prepared films were studied using homemade photo-luminous system. The films shows semiconducting behaviour. The films also shows good optical properties.

Keywords: Tungsten oxide, precipitation method, screen printing, half bridge, photo-luminous.

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1. Introduction

Nanotechnology is the science, engineering, and application of materials and devices with dimensions on the nanoscale, typically between 1 and 100 nanometers [1]. This field leverages the unique physical, chemical, and biological properties that materials exhibit at such small scales to create innovative solutions across various industries [1, 2]. It is a transformative field with broad applications in medicine, electronics, energy, environment, and materials science. It leverages the unique properties of nanoscale materials to develop innovative solutions and technologies, promising significant advancements across various industries. Nanoparticles play a crucial role in enhancing the performance and functionality of electrical and optical devices due to their unique properties that differ from their bulk counterparts. Nanotechnology enables the development of supercapacitors with high power density and rapid charge-discharge cycles [3, 4]. Combining nanoparticles with bulk materials to create stronger, lighter, and more durable composites. Nanoparticles, such as gold, silver, and copper, can significantly enhance the electrical conductivity of materials. For instance, silver nanoparticles are widely used in conductive inks for printed electronics [5].

Metal oxide optical sensors have emerged as a versatile and robust technology with a wide range of applications in various fields, including environmental monitoring, industrial automation, healthcare, and more [6, 7]. Metal oxide sensors are crucial in various fields for detecting and monitoring gases due to their high sensitivity, stability, and cost-effectiveness. Advances in nanotechnology and functionalization are expected to overcome current challenges and expand their applications further [8, 9]. Tungsten trioxide (WO_3) is a versatile material used in various applications due to its unique physical and chemical properties [10]. The molecular weight of WO_3 is 231.84 g/mol. It appears like a yellow crystalline powder (bulk form); can vary from yellow to blue in nanoparticle form, depending on particle size and doping [10, 11]. At different temperatures the WO_3 changes its crystal structure some common crystal structure of WO_3 are monoclinic, tetragonal, orthorhombic and hexagonal crystal structure [11, 12]. The melting point of WO_3 is 1473°C. The energy band gap of WO_3 is in the range of 2.6-2.8 eV. The refractive index of WO_3 is approximately 2.1. The resistivity or conductivity of WO_3 is varies significantly with temperature and doping. WO_3 is showing n-type semiconducting behavior [12, 13]. WO_3 nanoparticles possess distinct electrical, optical, and catalytic properties that make them suitable for a variety of advanced applications [14]. Their high surface area, tunable electronic properties, and ability to respond to environmental changes are particularly advantageous in fields like gas sensing, electrochromics, photocatalysis, and energy storage [15, 16]. WO_3 nanoparticles are used in electrochromic devices due to their ability to change color or opacity when an electric voltage is applied. This property helps in controlling light and heat transmission through windows, leading to energy savings in buildings and vehicles. WO_3 nanoparticles can enhance the performance of lithium-ion batteries and supercapacitors [17]. Their high surface area and electrochemical activity improve the energy storage capacity and cycle stability of these devices. WO_3 nanoparticles are effective photocatalysts under visible light, making them useful for applications in water splitting, degradation of pollutants, and other photocatalytic reactions. WO_3 nanoparticles are a key component in smart windows that can adjust their transparency in response to external stimuli like light and voltage. This helps in regulating indoor temperatures and reducing energy consumption for heating and cooling. Due to their unique optical properties, WO3 nanoparticles are used in optoelectronic devices to enhance brightness, contrast, and energy efficiency [18, 19]. They are particularly useful in applications requiring precise control of light. WO_3 nanoparticles exhibit nonlinear optical properties that can be exploited in applications such as frequency conversion, optical switching, and other advanced photonic technologies. The present work is discussed the electrical and optical properties of WO_3 nanoparticles synthesised by precipitation method [17-19].

2. Experimental work

The synthesis process of WO_3 nanoparticles was carried out using the precipitation method, and AR grade chemicals were purchased from Loba Chemie Pvt Ltd, Mumbai, India. Ammonium tungstate para pentahydrate $(NH_4)_{10}W_{12}O_{41}5H_2O$ is used as a source of WO_3, and nitric acid (HNO_3) is used as a solvent. Tungstate salt was dissolved in double-distilled water, and the resulting solution was brought to room temperature. After that, the resultant solution was kept on a magnetic stirrer for 1–3 hours. During stirring, nitric acid was added drop-wise to the solution after the 30-minute interval. The yield of the precipitating product was obtained after 3 hours of continuous stirring. After that, the precipitates were allowed to settle at room temperature for more than 12 hours. The obtained precipitate was washed with ethanol. This washing procedure was carried out for up to 5 minutes. After that, the precipitate was sintered at 400 ºC for 3 hours using a muffle furnace. Then the resultant yield was continuously graded using a mortar and pestle for 3–4 hours. After that, WO_3 nanoparticles were obtained [20, 21].

The synthesised WO_3 nanoparticles were used to prepared thick films using screen printing method. The steps of preparation of WO_3 thick films are shown in Fig. 1.

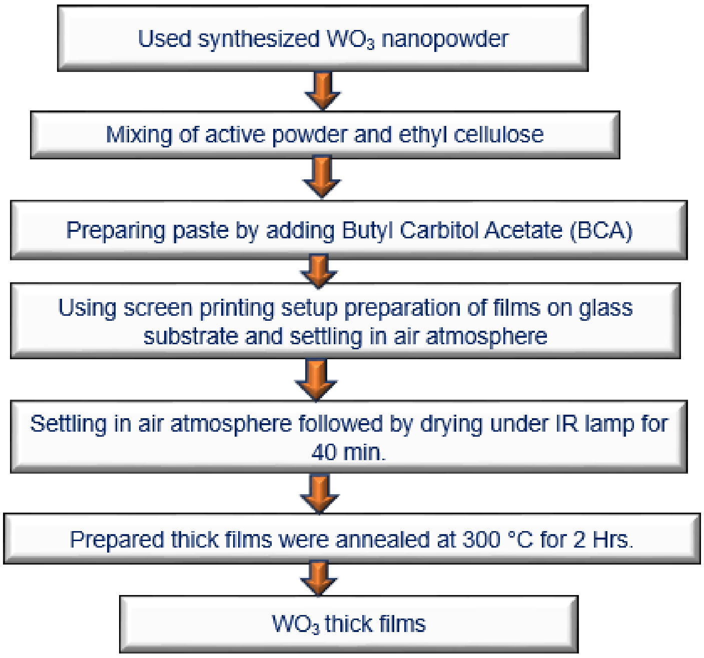

Figure 1: Steps of preparation of WO_3 thick films using screen printing method

3. Result and discussion

The resistance of WO_3 films was measured using half-bridge method [22]. It is a type of Wheatstone bridge circuit, is commonly used for precise resistance measurement, particularly in strain gauges and temperature sensors. It provides a way to measure small changes in resistance accurately by balancing two legs of a bridge circuit. The half-bridge method is a versatile and accurate technique for measuring small changes in resistance. The half-bridge method is an efficient and accurate technique for measuring the resistance of thick-film resistors [23, 24]. By balancing the bridge circuit and measuring the voltage difference, it provides precise resistance measurements the schematic of half-bridge method is shown in Fig. 2.

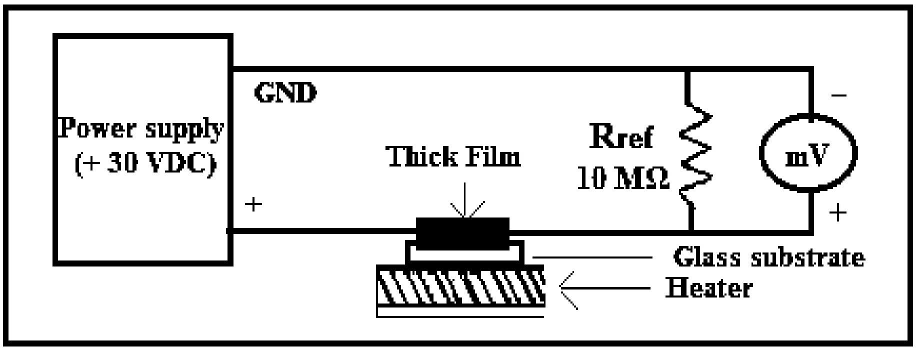

Figure 2: Schematic of half-bridge method

Fig. 3 shows the I-V plot of WO_3 thick film sample. From Fig. 3, it is confirmed that the prepared film shows the semiconducting nature of material or film [25]. It is also observed that, the resistance of films is decreased as surrounding temperature increases suggesting negative temperature coefficient of the films [25, 26].

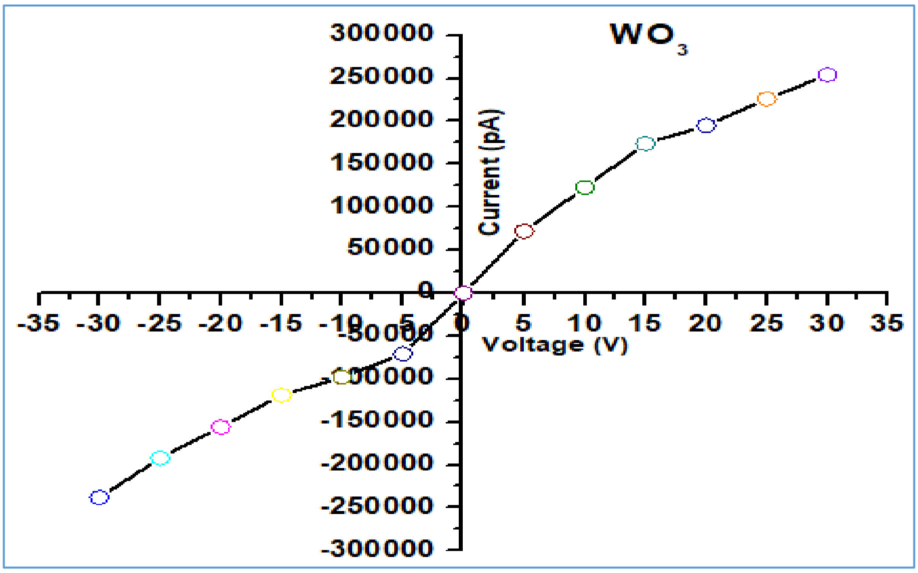

Figure 3: I-V plot of WO_3 thick film sample

Table 1: Electrical outcomes of WO_3 thick films

Resistivity (Ω.m)	**TCR** (/°C)	**Activation Energy** (eV)	
		HTR	**LTR**
2.3651	-0.00356	0.12354	0.08956

An optical photoluminescence system is an essential tool in materials science, providing detailed insights into the electronic and optical properties of various materials. By analyzing the light emitted from excited states, researchers can gain valuable information about material composition, quality, and behavior, which is crucial for both fundamental research and technological applications. The basic working principle of system is based on sample is illuminated with the excitation light, which has enough energy to promote electrons from the valence band to the conduction band in semiconductors or from the ground state to an excited state in molecules. The schematic of homemade photoluminescence system is illustrate in Fig.4. The photoresponses characterisation static system consists of a fixed power supply of +5VDC, a color filter holder, a sample holder, a 5 Watt light source, and a distance adjustment function. In this arrangement, the light intensity-dependent change in current was investigated by rotating the thick film light source [27].

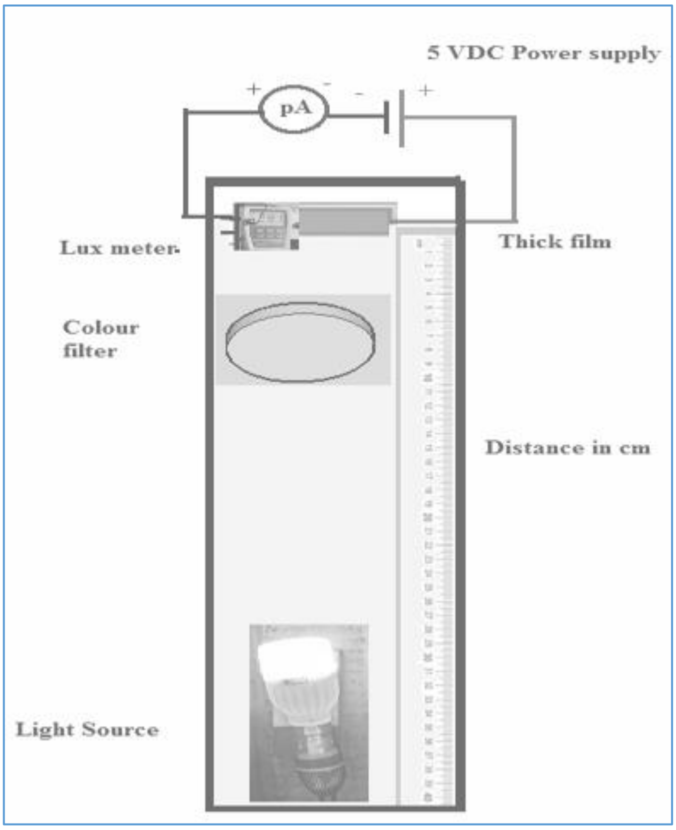

Figure 4: Schematic of homemade photoluminescence system

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The current response of WO_3 thick films to several color filters is depicted in Fig.4. The current response of WO_3 thick films to several color filters with distance is depicted in Fig.5. A shift in film current with an intensity variation across a range of 2 to 40 cm was found using a Lux meter. By positioning the filter next to the WO_3 film, shifting it to a different spot, or changing the distance from the light source, and monitoring the photocurrent response, the photocurrent through the film was measured.

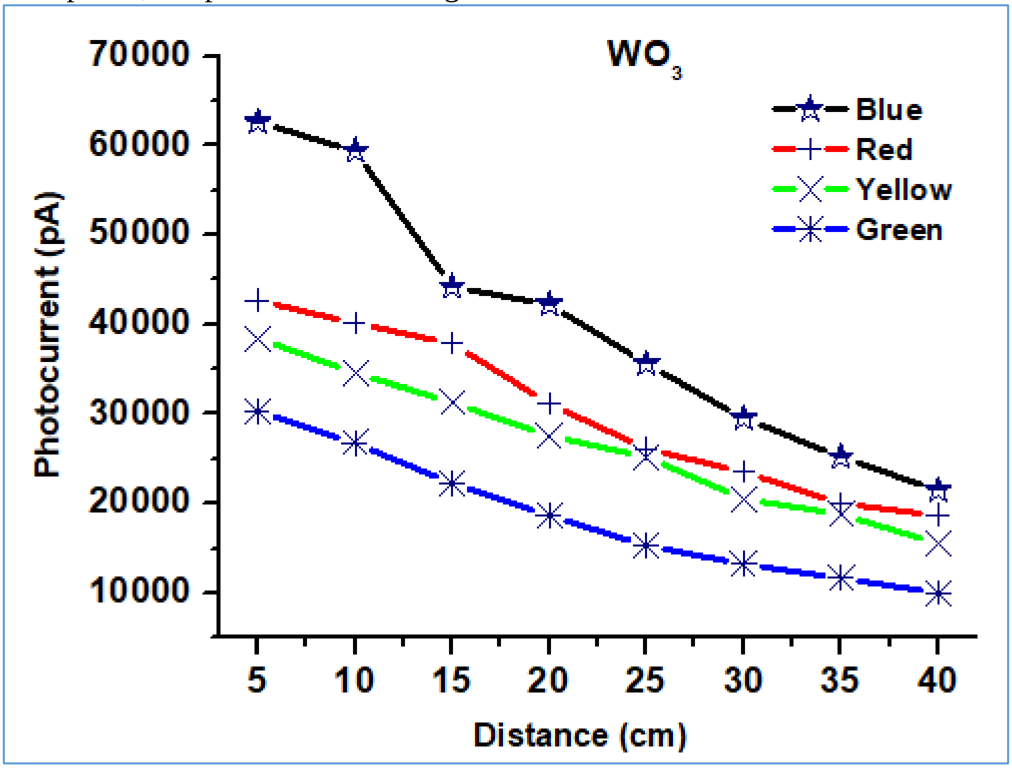

Figure 5: Distance versus photocurrent plot of WO_3 thick film

At different wavelengths of 650, 550, 500, and 450 nm, the light sensing characteristics of developed thick films were examined using color filters of red, yellow, green, and blue as well as a photoluminescence characterization system. As the distance was increased, the photocurrent of the films decreased, as seen in Fig. 5. The films shows maximum current response to blue filter as compare to other selected filters. This plot shows that the prepared WO_3 thick film can be used to construct optical devices because of its optical or illumination response [27, 28].

Conclusions

1. WO_3 nanoparticles were successfully synthesis using precipitation method.
2. WO_3 thick films were prepared using screen printing method.
3. The prepared WO_3 films shows good electrical as well as optical properties.

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