International Journal of Thin Films Science and Technology

http://dx.doi.org/10.18576/ijtfst/130306

A Comprehensive Review of Preparation Methods, Parameters and Deposition Analysis of CuO/ZnO Thin Films

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Received: 14 Mar. 2024, Revised: 24 Jun. 2024, Accepted: 28 Jul. 2024
Published online: 1 Sep. 2024

Abstract: The purpose of this review paper is to present an analysis of the various thin film deposition methods, parameters, advantages and disadvantages and deposition analysis of copper and zinc oxide thin films. A thin film is a very thin effective layer of material ranging from a few nanometers to several micrometers in thickness. Thin film deposition methods are classified commonly in two categories. The first one is physical deposition methods, and the second one is chemical deposition methods. This research paper describes various physical and chemical deposition methods and conditions for copper and zinc oxide thin film preparations. From our review work, various deposition parameters are analyzed which are useful for deposition of high-quality low-cost metal oxide thin film.

Keywords: Thin films, Deposition conditions, Physical methods, Chemical methods, Copper oxide, Zinc oxide.

1 Introduction

Over the past century, thin films have become an intrinsic part of everyday life. The visible applications are wide-ranging across many fields; from microelectronics to automobile parts, and from windows on skyscrapers to the metallic coatings on the insides of bags of potato chips [1]. Nowadays, the use of thin films to enhance the physical and chemical properties of materials is the most common practice in almost all the fields. Thin solid films have been used in many types of engineering systems and have been adapted to fulfill a wide variety of functions. For example, important and great developments in thin film technology were achieved allowing a rapid development of miniaturization of electronic devices [2].

Table 1: Applications of Thin Film Technology

Category	Applications
Optics	Reflective and anti-reflective coatings; Anti corrosive films; Interference and band filters; Polarizer; Protective glasses; Building and airplane smart windows; Beam splitter.
Electronics	Active and passive thin film elements (Transistors / Resistors); Rectifiers; Semiconductor devices; Insulation; Conduction; Integrated circuits; Wireless communications; Telecommunications; Flat-panel displays; Computer chips.
Optoelectronics	Photo detectors; Photo conductors; Liquid crystal display (LCD); Thin film transistors (TFT); Optical memories; Solar cells; Light-emitting diodes (LED); Electro-optic coatings.
Cryotechnics	Superconducting switches; Superconducting memories; Superconducting interference devices (SQUIDS).
Chemistry	Electro and Bio and Photo catalysis; Diffusion barriers; Protection against oxidation and corrosion; Gas and liquid sensors.
Mechanics	Tribological coatings; Hard coatings; Adhesion providers; Friction reducers; Micro- electromechanical systems (MEMS); Multifunctional emerging coatings.
Magnetics	Audio and video systems; Computer memory discs; Magnetic read and write heads; compact discs; Magneto optic discs; Magneto-optic Memories.

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Thin films have been used in a wide range of applications in a wide range of fields. It can be summarized as shown in Table 1.

Thin film deposition methods are classified commonly in two categories. The first one is physical deposition methods, and the second one is chemical deposition methods. It can be summarized as shown in Figure1.

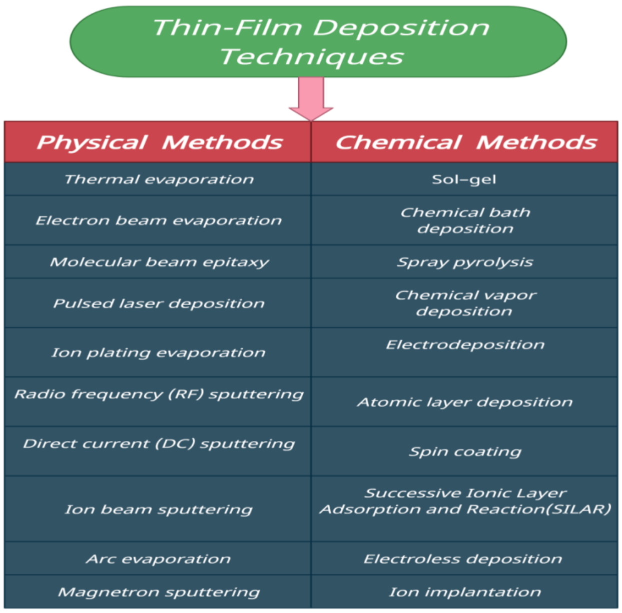

Fig. 1: Classifications of Thin-Film Deposition Technique

2. Preparation Analysis of Copper Oxide and Zinc Oxide Thin Films by Physical and Chemical Methods:

2.1 Copper oxide:

In recent years, copper oxide thin films have attracted much interest due to their potential applications for solar cells and gas sensor. Cuprous oxide (Cu_2O) and cupric oxide (CuO) are the two main semiconductor phases of copper oxide with narrow band gap [3].

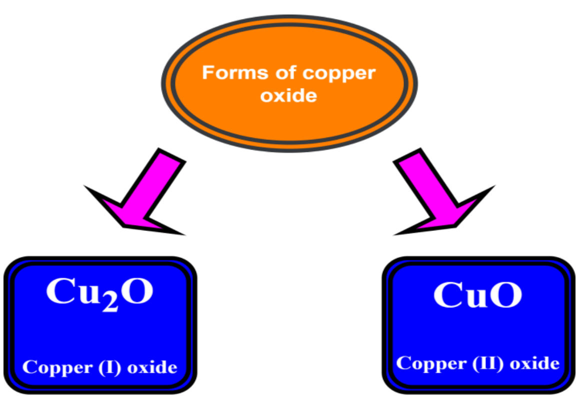

Fig. 2: Two forms of copper oxides

Cupric oxide (CuO) is a *p*-type semiconductor having a band gap of 1.21–1.51 eV and monoclinic crystal structure. Cuprous oxide (Cu2O) is also a *p*-type semiconductor having a band gap of approximately 2.0 eV and a cubic crystal structure [4]. In general, the copper oxides are studied for applications such as solar cells, high temperature superconductors, solar light modulation, window coatings for solar control, gas sensors, photo catalyst, electrochromism, lithium batteries, hetero junction for transparent conducting oxides, low friction coatings, and other electronic devices [5].

2.2 Zinc oxide:

ZnO is a bio-safe material available in the form of white powder, which is insoluble in water. Its high thermal and mechanical stability at room temperature makes it a potential material for multipurpose applications [6].

Recently, zinc oxide (ZnO) has attracted substantial attention due to its superior physical properties and potential technological applications. ZnO is an II–VI compound semiconductor with a wide direct-band gap of 3.37 eV. ZnO has a large exciton binding energy of 60 meV, which favors efficient excitonic emission processes at room temperature and enables devices to function at a low threshold voltage [7].

Zinc oxide has been successfully included in the transparent conducting oxides used in modern solid-state technology (e.g. Solar cells, optoelectronic devices, sensors, and heat reflecting mirrors) [8].

The parameters of the copper and zinc oxide thin film can be listed in the following table 2.

Table 2: The various properties of CuO & ZnO

Parameters	Cuprous oxide	Cupric oxide	Zinc oxide
IUPAC Name	Copper (I) oxide	Copper (II) oxide	Zinc oxide
Definition	Cuprous oxide is an inorganic chemical compound composed of the metallic cuprous ions Cu^{+1} and the nonmetallic oxygen ion O^{-2}.	Cupric oxide is an inorganic chemical compound composed of the metallic cupric ion Cu^{+2} and the nonmetallic oxygen ion O^{-2}.	Zinc oxide is an inorganic chemical compound composed of the metallic zinc ion Zn^{+2} and the nonmetallic oxygen ion O^{-2}.
Chemical Formula	Cu_2O	CuO	ZnO
Appearance	Brownish-red solid	Black to brown solid	White solid
Molar mass	143.09 g/mol	79.545 g/mol	81.406 g/mol
Melting point	1,235 °C	1,326 °C	1,974°C
Boiling point	1,800 °C	2,000 °C	2,360 °C
Density	6 g/cm³	6.31 g/cm³	5.606 g/cm³
Solubility	Insoluble in water	Insoluble in water	Insoluble in water
Band gap	2.137 eV	1.2 eV	3.2 eV
Crystal structure	Cubic	Monoclinic	Wurtzite

2.3 Deposition analysis of CuO and ZnO thin films:

Various physical and chemical methods have been used for copper oxide and zinc oxide thin films depositions namely: Thermal evaporation, Electron beam evaporation, Molecular beam epitaxy, Pulsed laser deposition, Ion beam sputtering, Radio frequency (RF) sputtering, Direct current (DC) sputtering, Sol–gel, Chemical bath deposition, Spray pyrolysis, Chemical vapor deposition, Electro deposition, Atomic layer deposition, Spin coating and SILAR. These methods are explored and discussed in tables 3, 4, 5 and 6 below.

Table 3: Physical deposition methods of copper oxide thin films

Physical deposition methods (PDM) / Copper oxide thin film deposition					
Thin film	**Methods**	**Source material / Substrate**	**Conditions for deposition parameters**	**Quality of film / Cost**	**Ref.**
CuO film	Thermal evaporation	Red Cu_2O Powder / Glass tantalum SiO_2	Base pressure: 5×10^{-4} Pa Substrate temperature: 300 °C Annealing temperature: 500 °C for 3 h deposition rate : 0.1 nm/s.	Moderate / High	9
Cu_2O film	Thermal evaporation	CuO powder / sapphire	Base pressure: 1.5×10^{-5} mm Hg Substrate temperature: 700 °C oxygen partial pressure: 1×10^{-4} mm Hg Deposition time: 3 h	Moderate / High	10
CuO and Cu_20 films	Ultrahigh vacuum molecular beam epitaxy (UHVMBE)	Cu, O_2 / MgO	Incident O^+ beam energy: 50 eV Substrate temperature: 100–400 °C Cu flux: 2.5×10^{13} to 1.6×10^{14} atoms/cm^2 s Base pressure: 3×10^{-10} Torr Total pressure: 3×10^{-9} to 2×10^{-8} Torr O^+ flux: 2.7×10^{14} atoms / cm^2 s O^+ ion current: 45 micro ampA	Excellent / High	11
CuO film	Plasma-assisted molecular beam epitaxy (PAMBE)	Cu, O_2 / MgO	oxygen partial pressure: 2×10^{-5} mbar Deposition time: 90 min O_2 flux : 2×10^{-5} mbar Temperature: 500 °C	Excellent / High	12
CuO and Cu_20 films	Pulsed laser deposition	Cu_2O / Glass	Substrate temperature: 300 and 500°C Chamber vacuum pressure: 10^{-3} mbar target-substrate distance: 4 cm Deposition time: 10 to 20 min	Excellent / High	3
Cu_2O film	Pulsed laser deposition	Cu, O_2 / Quartz glass, ITO, NaCl, Si	Substrate temperature: 25–400 °C oxygen partial pressure: 0–10 mTorr target-substrate distance: 5 cm Base vacuum of the chamber : $\leq 10^{-5}$ Torr	Excellent / High	13
CuO film	Radio frequency (RF) magnetron sputtering	Cu, O_2 / Glass	Chamber base pressure: 1×10^{-6} Torr DC power supply: 200 W Deposition time: 600 to 1800 sec with an step size of 600 sec Ar gas flow rate: 10 sccm O_2 gas flow rate: 15 sccm Sputtering pressure :5×10^{-3} Torr target-substrate distance: 14cm	Excellent / High	14
CuO, Cu_2O, and Cu_4O_3 films	Radio frequency (RF) magnetron sputtering	Cu, O_2 / Glass	Chamber background pressure: 3×10^{-4} Pa RF power supply: 50 W Deposition time: 60 min Substrate temperature: 300 °C Ar gas flow rate: 10 sccm O_2 gas flow rate: 0–2 sccm Sputtering pressure :1.7–1.8 Pa target-substrate distance: 80 mm	Excellent / High	15

Cu_2O film	Radio frequency (RF) magnetron sputtering	Cu, O_2 / Glass	Deposition time: 5 min Base pressure: 10^{-6} Torr Substrate temperature: room temp. Ar gas flow rate: 50 sccm O_2 gas flow rate: 1-4 sccm RF power supply: 150,200 and 200W Chamber pressure : 2,3,6 and 12 mTorr	Excellent / High	5
Cu_2O film	Reactive direct current (DC) magnetron sputtering	Cu, O_2 / Glass	Deposition pressure: 6.3×10^{-3} torr Base pressure: 6×10^{-6} Torr DC power supply : 60 W Ar gas pressure: 20 sccm oxygen partial pressure: $1.1, 1.5, 1.8 \times 10^{-3}$ and 8.0×10^{-4} Torr Substrate temperature: 473K	Excellent / High	16
CuO and $Cu_{2}0$ films	Reactive direct current (DC) magnetron sputtering	Cu, O_2 / Corning glass	O_2 gas flow rate: 10 sccm DC sputtering power : 10-40 W Ar gas flow rate: 15 sccm target-substrate distance: 500 mm Substrate temperature: 300 °C Deposition time: 222-57 min for 10-40 W	Excellent / High	17
CuO film	Direct current (DC) magnetron sputtering	Cu, O_2 / Glass	Substrate temperature: 623K Deposition time: 20 min target-substrate distance: 5 cm DC sputtering power : 600 V at 1.2 mA / cm^2 System pressure: 5.2×10^{-3} Torr	Excellent / High	18
CuO and $Cu_{2}0$ films	Io beam sputtering	Cu, O_2 / Si and glass	Working and background pressure: 4×10^{-3}&8×10^{-4} Pa Ar ion beam current: 400 micro Amp Deposition time: 20 min to 3 h target-substrate distance: 6 cm Annealing temperature: 200- 600 °C for 1-7 h in a 1 h step	Excellent / High	19

Table 4: Chemical deposition methods of copper oxide thin films

Chemical deposition methods (CDM) / Copper oxide thin film deposition					
Thin film	**Methods**	**Source materials / Substrate**	**Conditions for deposition parameters**	**Quality of film / Cost**	**Ref.**
Cu_2O film	Sol–gel	Copper (II) acetate, Isopropyl alcohol, Diethanolamine, Glucopon, polyethylene glycol, ethylene glycol / Indium tin oxide (ITO) coated glass	Temperature: 60 °C for 10 min Rotating speed: 3000 rpm for 40s Annealing temperature: 350 °C for 1 h in 5% H_2 + 95% N_2 atmosphere.	Good / Low	20
CuO film	Sol–gel	Cupric chloride, methanol, diethanolamine, Monoethylene glycol, glucopone / TiO_2	Rotating speed: 2000 rpm for 40s Annealing temperature: 200 - 400 °C for 7 h air and N_2 atmosphere Temperature: 25-30 °C	Good / Low	21
CuO film	Chemical bath deposition	Copper (II) chloride, ammonia, water / Glass	Temperature: 90 °C Deposition time: 7 min Annealing temperature: 400,500°C for 2 h pH: 3.80-10.0	Excellent / Low	22

Cu_2O film	Chemical bath deposition	copper sulphate, sodium sulfate, Sodium hydroxide / Glass	Temperature: 70 °C Deposition time: 20 sec Annealing temperature: 200-400°C for 1 hr	Excellent / Low	23
CuO film	Chemical spray pyrolysis	Copper (II) chloride / Glass	Substrate temperature: 300°C Air pressure : 0.4 kg cm^{-2} Precursor flow rate : 10 ml min^{-1}	Excellent / Low	24
CuO film	Ultrasonic spray pyrolysis	Copper (II) chloride / Glass	Substrate temperature: 300°C Deposition time:20 min Solution flow rate: 10 to 30 ml/h with a step of 5 ml/h.	Excellent / Low	25
CuO ,Cu_2O films	Atmospheric-pressure chemical vapor deposition	Copper dipivaloylmethanate, oxygen / Borosilicate glass plate	O_2flow rate: 1 and 300 cm^3 min^{-1} N_2flow rate: 599 and 300 cm^3 min^{-1} Temperature: 300 and 500 °C oxygen partial pressure: 1.689 × 10^2 and 5.07 × 10^4 Pa	Excellent / Low	26
Cu_2O film	Low temperature chemical vapor deposition	(N, N′-di-sec butylacetamidinato)copper (I), water / silicon wafers or glassy carbon or silica glass	Substrate temperature: 125–225°C Process pressure: 1–10 torr N_2flow rate: 40 sccm	Excellent / Low	27
CuO ,Cu_2O films	Hot wall chemical vapor deposition	Copper (II) acetylacetonate, oxygen / sapphire and MgO	Reactor pressure &temperature: 20 mbar & 175°C Substrate temperature: 350–500°C O_2flow rate: 5-200 sccm	Excellent / Low	28
Cu_2O film	Metal organic chemical vapor deposition	Copper (II) hexafluoroacetylacetonate, oxygen gas, water vapor/ ZnO coated glass	Substrate temperature: 300–400°C Process pressure: 2 torr Ar flow rate: 5 sccm O_2flow rate: 300 sccm H_2O vapor flow rate: 120 sccm	Excellent / Low	29
CuO ,Cu_2O films	Electro deposition	copper sulphate, lactic acid, Sodium hydroxide / Copper	Temperature: 40 and 60 °C pH: 11.5-12.5 Applied potential: −0.45 to −0.65V Deposition time: 10-50 min Copper sulphate con. : 0.15-0.25 M	Excellent / Low	30
Cu_2O film	Electro deposition	Copper(II) acetate, Sodium acetate trihydrate / indium-doped tin oxide (ITO) glass	Temperature: 20–80 °C Deposition time: 2–80 min NaCl con.: 0–10 mM Potential: −0.1 to −0.4 V	Excellent / Low	31
Cu_2O film	Atomic layer deposition	Copper(II) acetate monohydrate, Copper(II) acetate anhydrous, water vapor / soda lime glass (SLG), Si	Temperature: 180–220 °C N_2 , H_2O and O_2 flow rate: 400 sccm Deposition cycles: 500–7000 Rector pressure: 10 mbar	Excellent / Low	32
CuO film	Atomic layer deposition	copper (II)-bis-(-dimethylamino-2-propoxide), ozone / SiO_2/Si	Substrate temperature: 112–165°C Deposition cycles: 500–10000 oxygen partial pressure: 34 Pa Rector pressure: 200-260 Pa	Excellent / Low	33

CuO film	SILAR	Copper chloride, ammonia/ Glass	Annealing temperature: 200 - 400 °C for 30 min SILAR cycle: 80 times Immersion Time: 30&60 s for anionic and cationic precursor Rinsing time: 7&30 s for anionic and cationic precursor pH: 3 Volume of precursor: 100 mL for anionic and cationic con of cationic precursor: 0.1M	Excellent / Low	34
CuO ,Cu_2O films	SILAR	copper sulphate pentahydrate, sodium thiosulfate, Sodium hydroxide / Glass	SILAR cycle: 80 times Immersion& Rinsing Time: 20&10 s for anionic and cationic precursor con of cationic & anionic precursor: 1M Annealing temperature: 200 - 400 °C for 1 to 4 hr	Excellent / Low	35
Cu_2O film	Spin coating	Copper (II) acetate, Ethanol/ Soda-lime glass	Annealing temperature: 275 to 500°C for 2 h in N_2 atmosphere Temperature: 150 °C Spin coating speed:1500&3000 rpm for 15&30s	Excellent / Low	36
CuO film	Spin coating	Cupric acetate, methanol/ Glass	Temperature: 300 to 700°C for 1 h in air Annealing temperature: 100 °C for 10 min Spin coating speed: 3000 rpm for 40s	Excellent / Low	37

Table 5: Physical deposition methods of zinc oxide thin films

Physical deposition methods (CDM) / Zinc oxide thin film deposition					
Thin film	**Methods**	**Source materials / Substrate**	**Conditions for deposition parameters**	**Quality of film / Cost**	**Ref .**
ZnO film	Thermal evaporation	ZnO Powder / Glass	target-substrate distance: 6 cm Chamber base pressure: 10^{-7} mbar Thermal Oxidation Temperature: 200 - 500 °C for 2 h Annealing temperature: 523K, 623K and 723K Film Thickness: 60 nm & 130 nm	Moderate / High	38
ZnO film	Thermal evaporation	ZnO Powder / polyethylene terephthalate	Chamber vacuum pressure: 3×10^{-5} Torr Film Thickness: 100 to 300 nm Heated Direct Current: 3.0 to 8.0 A	Moderate / High	39
ZnO film	Laser-molecular beam epitaxy (L-MBE)	ZnO Powder, polyvinyl alcohol binder, water / SI- InP	target-substrate distance: 6 cm Laser pulse energy: 250mJ Repetition rate: 10 Hz Substrate temperature: RT, 300 and 300°C Chamber evacuated pressure: 1×10^{-6} Torr O_2 pressure: 1×10^{-5} Torr	Excellent / High	40
ZnO film	Plasma-assisted	Zn, O_2 / Si and porous	Substrate temperature: 350 °C Deposition time: 5 to 30 min	Excellent / High	41

	molecular beam epitaxy (PA-MBE)	silicon (PS)	Film Thickness on Si: 50,85,220 and 320 nm Film Thickness on PS: 50,100,150 and 270 nm		
ZnO film	Pulsed laser deposition	ZnO Powder / ITO coated glass	target-substrate distance: 50 nm Chamber background pressure: 4 × 10^{-3} Pa Oxygen pressure: 5 or 50 mTorr Deposition Temperature: 50–650°C Incident Laser pulses: 5000 Laser frequency: 8 Hz Laser beam power density: 0.85 J cm^{-2}	Excellent / High	42
ZnO film	Pulsed laser deposition	ZnO ceramic plate / Glass	target-substrate distance: 6 cm Chamber base pressure: 10^{-7} Torr oxygen partial pressure: 50 and 100 mTorr Substrate temperature: 250 °C Energy per pulse: 300 mJ Incident Laser pulses: 6000 and 24000	Excellent / High	43
ZnO film	Radio frequency (RF) magnetron sputtering	Zn, O_2 / Corning Glass	RF power supply: 150 W target-substrate distance: 50 mm Deposition Temperature: 500°C Sputtering pressure : 1.0 Pa Chamber evacuated pressure: 5 × 10^{-4} Pa Argon: oxygen ratio: 2sccm:18sccm, 6sccm:14sccm, 10sccm:10sccm and 14sccm:6sccm.	Excellent / High	44
ZnO film	Direct current (DC) magnetron sputtering	ZnO / Glass	Deposition Temperature: RT to 450°C Deposition pressure : 12 mTorr to 25 mTorr Film thicknesses: 150 nm to 700 nm target-substrate distance: 70 mm Chamber base pressure: 2 × 10^{-6} Torr Deposition time: 10 to 70 min	Excellent / High	45
ZnO film	Direct current (DC) magnetron sputtering	ZnO / Corning Glass	Target-substrate distance: 7 cm Ar Flow Rate: 26 -28 sccm Substrate Temperature: 27 °C Sputtering Power: 100 W Deposition Time: 10 min Deposition pressure : 12 mTorr to 20 mTorr	Excellent / High	46
ZnO film	Ion beam sputtering	ZnO / Si and FSD	Working and background pressure: 6.5×10^{-4} & 3×10^{-6} Torr Total Ar & O_2 gas flow rate: 15 sccm Ar & O_2 ratio: 10/0 to 5/5 Substrate Temperatures: 125,190,250 and 300 °C Ion beam voltage & current: 800V & 150 mA Deposition Time: 90 min	Excellent / High	47
ZnO film	Ion beam sputtering	Zn, O_2 / Si	Chamber base pressure: 5 × 10^{-6} Torr Ar Flow Rate: 10 sccm Ion beam voltage & current: 1000V & 20 mA oxygen partial pressure: 2 to 20 10^{-5} Torr	Excellent / High	48

Table 6: Chemical deposition methods of zinc oxide thin films

Chemical deposition methods (CDM) / Zinc oxide thin film deposition					
Thin film	**Methods**	**Source materials / Substrate**	**Conditions for deposition parameters**	**Quality of film / Cost**	**Ref.**
ZnO film	Sol–gel	zinc acetate dihydrate, ethanol, ethanolamine / Glass	Rotating speed: 3000 rpm for 60s Pre & post Annealing temperature: 300 & 800°C for 1 h in air atmosphere precursor concentrations: 0.5 M to 1 M	Good / Low	49
ZnO film	Sol–gel	zinc acetate dihydrate, ethanolamine, ethanol / Si	Rotating speed: 1000, 2000, 3000 rpm precursor concentrations: 0.75 M pre Annealing temperature: 300°C for 10 min in air atmosphere Post Annealing temperature: 400°C for 3 hr in N_2 and air atmosphere	Good / Low	50
ZnO film	Chemical bath deposition	zinc chloride, ammonia / Glass	Bath solution concentrations: 0.1 M pH: 8.24 Temperature: 80 to 85 °C Annealing temperature: 400°C for 1 h Bath time: 15 min to 1 hr	Excellent / Low	51
ZnO film	Chemical bath deposition	zinc nitrate, ammonia / Sodium Glass	Temperature: 80 °C Deposition time: 30 to 120 min zinc nitrate & ammonia concentrations: 0.1M & 0.1M,0.05M,0.01M Annealing temperature: 500°C for 1 hr in 1°C / min rates	Excellent / Low	52
ZnO film	spray pyrolysis	Zinc acetate dehydrate / Glass	solution concentrations: 0.05M Substrate nozzle distance: 30 cm Spraying rate: 0.5 ml/min Spraying time: 10 min Substrate temperature: 473K to 673K Annealing temperature: 673K for 2 hr	Excellent / Low	53
ZnO film	spray pyrolysis	Zinc acetate dehydrate / Glass	Substrate temperature: 350°C solution concentrations: 0.1 M Substrate nozzle distance: 28 cm Spraying rate: 3 ml/min Annealing temperature: 450°C for 1 hr in 10°C / min rates	Excellent / Low	54
ZnO film	chemical vapor deposition	ZnO & graphite powders, O_2 / Silicon, sapphire	Substrate temperature: 720, 820 and 920°C Deposition time: 1 hr O_2flow rate: 100,500 & 1000 sccm	Excellent / Low	55
ZnO film	Metal organic chemical vapor deposition	Diethylzinc, O_2 / sapphire	Substrate temperature: 300 to 600°C Reactor pressure: 30 & 60 Torr Growth pressure: 50 Torr Rotation speed: 600 to 1200 rpm	Excellent / Low	56

	(MO-CVD)				
ZnO film	Electro deposition	Zinc nitrate hexahydrate, sodium thiosulfate pentahydrate / Cu and ITO-coated glass	Temperature: 90 °C Film Thickness: 350 nm pH: 5.74 Applied potential: -0:60 V for 30 min Annealing temperature: 100°C in air	Excellent / Low	57
ZnO film	Electro deposition	zinc chloride, potassium chloride / FTO glass	Temperature: 70 °C Film Thickness: 350 nm pH: 5.74 Applied potential: -0.1 V for 10 min Annealing temperature: 400°C for 1 hr	Excellent / Low	58
ZnO film	Atomic layer deposition	Diethylzinc, water / Si or SiO_2/Si	Growth temperatures: 150 to 400 °C Rector pressure: O.6 Torr Ar flow rate: 1600sccm Deposition cycles: 100–300	Excellent / Low	59
ZnO film	Atomic layer deposition	Diethylzinc, water / Si	Deposition temperature: 100 to 280°C Deposition cycles: 10–1200 N_2 flow rate: 20 sccm	Excellent / Low	60
ZnO film	SILAR	zinc sulphate heptahydrate, ammonia / Glass	Annealing temperature: 100 °C for 16 hr Deposition cycles: 25,50,75 and 100	Excellent / Low	61
ZnO film	SILAR	zinc sulphate, sodium hydroxide / FTO coated glass	Rinsing temperature: 70 °C pH: 6 Number of cycles: 150 con of cationic & anionic precursor: 0.1M Immersion Time: 30 s	Excellent / Low	62

3. Conclusion:

Thin film is an important branch of emerging technology and science. In this review, the preparation of copper and zinc oxide films by using various physical and chemical deposition methods will be investigated and the deposition conditions of each method have been analyzed in detail. From our research work we are able to gain a clear understanding of the deposition of low-cost high-quality copper and zinc oxide thin films. Finally compared to physical methods, it is clear that chemical methods are used to produce high quality thin films at low economic cost.

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