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Metal oxide nanostructure for sensor applications

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Abstract — **Over the years, metal oxide semiconductors are widely used in several sensor applications. Crystalline structure of various nanostructure materials is been employed. Various dimensions of the nanometric scale and their small crystalline size in a sensor performance. These nano-sensors are widely used because they are eco-friendly, low cost with good stability and with fast response and recovery time. Depending upon the recent development the nanostructure semiconductors metal oxides and the have various sensing properties in gas sensor, humidity sensors also ultraviolet sensor and biosensor. These sensors are based on various metal oxides such as zinc oxide, tin oxide, tungsten oxide, copper oxide etc and they have various properties correlated with each other such as their size, shape, and their doping mechanism. For fabrication various methods and techniqueareaddressedwiththeirfunctionalitywiththesensor.**

Keywords: metal oxide semiconductor, nanostructure material, crystalline size, sensors.

I. INTRODUCTION

1.1 Nanostructure

Nanostructures and nanomaterials are the age of the future and the nanoscience, nanotechnologyor nanostructure which is a foundation of usual science such a physics, chemistry, material science or biology. Nanotechnology consists of various novel technologies which is used to producing, designing of nano particles. In few metal oxides they have wide various morphologies such as nanobelts, nanowires, nanobelts and nanorings [1]. Production of new nanodevices are emerging in electronics, photonics and life science [2].

1.2 Structure

The nanostructure material is divided based on their dimensions of the structured material. Classification of those structured nanomaterials are 0-D (zero dimension), 1-D (one dimension), 2-D (two dimension) and 3-D (three dimension). The 0-D are onto larger than 100nm in a nanoscale, it is commonly used nanoparticles and they exhibit various form and shapes. The 1-D is completely outside the nanometric scale, these are needle shaped nanomaterials shaped as nanotubes, nanowires and nanorods. The 2-D nanomaterials have unique shape characteristics, they are nanofilms, nanocoating's, nano prism and nanolayers.Widely used insensor nanocontainers, reactors etc [3] [4]

They are made up of various chemical components and deposited in their substrate. The 0-D, 1-D and 2-D nanoparticles could be crystalline or polycrystalline also ceramic or metallic. The 3D nanomaterials are three times greater than 100nm and 3-D is animportance material as they are most widely used in the area od catalysis, magnetic materials etc.[4] They are nanocrystalline structure and they involve the structure of nanoscale with multiple arrangement of multiple nanosize crystals in different orientations, 3D nanomaterials ca contain dispersion of nanoparticles, bundle of nanowires and nanotubes in multi nanolayers [3].

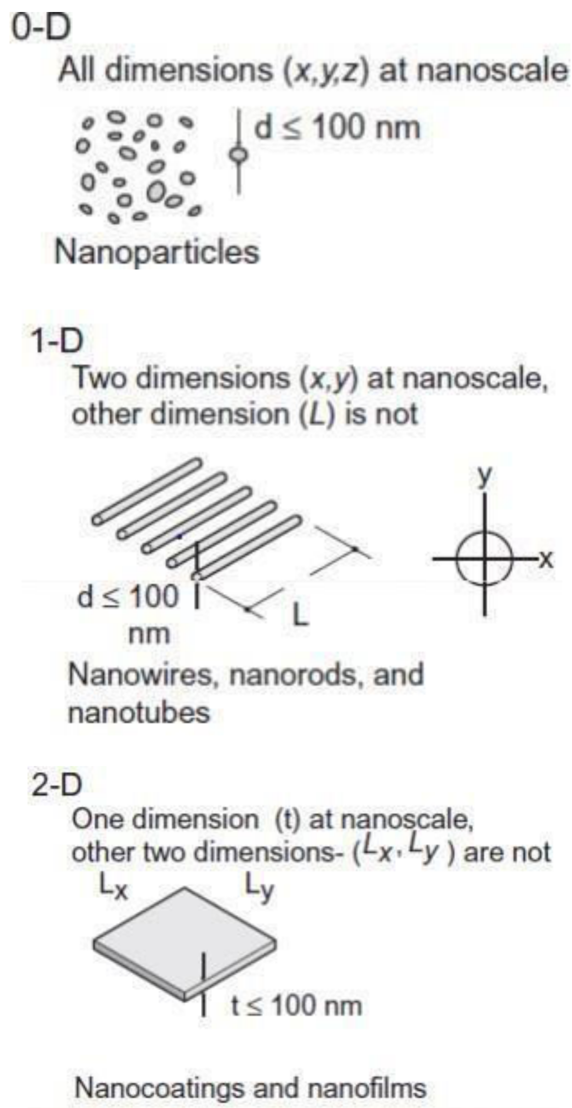

Fig.1 Different dimension of nanostructures material [3]

The three-dimension space showing the relationship among 0-D, 1-D, 2-D and 3-D structures nanomaterials. For 0-D the nanomaterials are fully confined, in 1-D and 2-D they are delocalization and confinement 3-D nanostructuresare fully delocalized all these are potentially made inside the walls.[3]

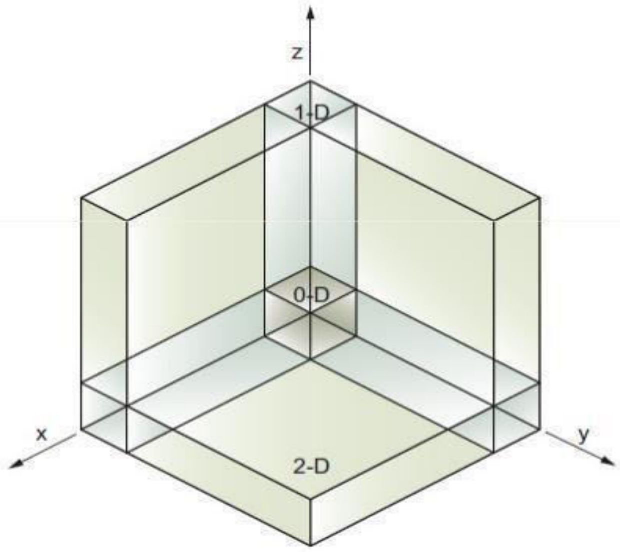

Fig. 2 Three-dimension spacing [3]

1.3 Synthesizing in Nanostructuredmaterials

Various technique arebeen used for synthesizing and fabricating of 0-D,1-D,2-D and 3-D nanosized material either by physical and chemical process. Physical processes such as evaporation technique , it is used for thin film deposition , the evaporated atoms has the collision with the gas atoms or molecules and undergo condensation to form atom cluster for cold powder collection surface , the formed clusters should be removed from the region of deposition.[4]

Sputtering technique are used for ejecting the atoms or clusters of designated materials by subjecting them to an accelerated and inert gas such as helium. [4]

Lithography is convertible implementing the process for different substrate, they are used for surface preparation in which a particular design is transferred from a photomask or reticle onto a substrate and multiple pack are made of one exposure.[4]

Hot and cold plasma, here the hot refers to fully ionized ions, they are powderedtype substance consists of a arc melting chamber and collecting system. They are remitted twice or thrice melting a piece of bulk substrate in a mixing gas atmosphere [4]. Few other physical processes are spray pyrolysis, inert gas phase condensation technique, pulsed laser ablation and sono-chemical reduction.

The various chemical processes are lyotropic liquid crystal templates they are of various nanometric size. The shape and size can be controlled using this method. Widely used in drug delivery, catalysis etc.

In electrochemical deposition they use electrical current to deposits the layers of nanostructured material.[4] Consequently there are various other chemical technique also.

The nanosized materials have various physical, chemical and mechanical properties, metals oxide components have positive and negative ions having numerous characteristics. Semiconductor metal oxides can be classified as p-type or n- type. The physical, electronic, mechanical and chemical properties of a nanomaterial dependupon their shape, size and composition by doping.Electronic structure range of a nanostructure matter is classified in two categories: transition and non-transition metal oxides. To improve the performance of a metal oxide effective doping done species, the technique for doped metal oxide is high purity and quality is not good. It is because of lack of sustainability for mass production.

The arc discharge method is used to produce several metal oxide nanostructures such as titanic dioxide, collected metal oxides are from the discharge chamber that have critical advantages in their sensor application from various difference such as diameter, grain size and length. They are easy and flexible method to dope.

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1.4Various sensorapplication

Sensor is an electronic device that defects and response from physical parameters to output. The sensors are used everywhere such as in houses, factories, stores, mall or in building premises. Using metal oxides, the sensors are used to detect the quality of water, monitoring air such as the speed of the wind. The gas sensor is rapidly used in metal oxides as the per literature study [5-6]. Portable and flexible metal oxides based are used in gas sensors. The gas sensors are classified in different types such as optical, electrochemical, capacitance based, calorimetric, acoustic based, and metal oxide-based gas sensor. They are classified based on their sensing method and are categorized in two: based on electrical properties and few variationson other properties. Comparison between various type of gas sensors is shown below.[7]

Parameters	Types of Gas Sensors				
	SMO Gas Sensors	Catalytic Combustion Gas Sensors	Electro Chemical Gas Sensors	Thermal Conductivity Gas Sensors	Infrared Absorption Gas Sensors
Sensitivity	E	G	G	P	E
Accuracy	G	G	G	G	E
Selectivity	F	P	G	P	E
Response Time	E	G	F	G	F
Stability	G	G	P	G	G
Durability	G	G	F	G	E
Maintenance	E	E	G	G	F
Cost	E	E	G	G	F
Suitability to portable instru-ments	E	G	F	G	P

E: excellent, G: good, F: Fair, P: Poor.

Table 1: Comparison between different gas sensors [7]

The gas sensors can be analyzed in various categories such as their response time, sensitivity, recovery time etc. The response time is the time when the gas concentration reaches a specific value that a sensor generates a corresponding signal. Recovery time is the time that is required for a sensor signal to return to its initial value after a step concentration.[7] The metal oxide semiconductor based gas sensor have prioritized applications, they are used for human breath as medical diagnosis and also as gas detection.[8] The sensor maintains the structure stability in the fabrication process. Gas sensors are most widely used in automotive industries.

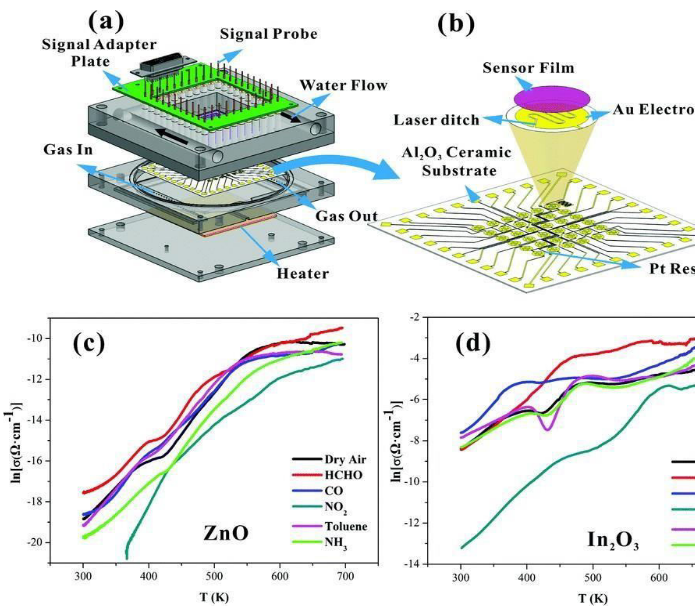
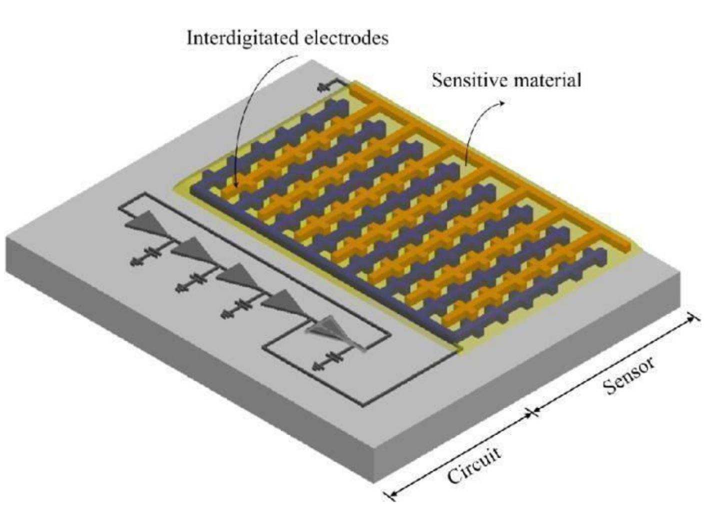


Fig 3 Metal oxide gas sensor (Royal society of chemistry) [8]

The humidity gas sensor consists of a ring-shaped oscillator circuit on a chip, they consist of sensitive film and integrated electrodes onto them. Sensitive films are made of zinc oxide and they are prepared using the sol-gel method.[8] Humidity sensors are widely used in medical, industrial and another domestic environment. These devices are employed in automobile and microelectronics industry [10]. In Fig 4b the capacitance of a humidity sensor is different temperature is shown with their variation in Fig 4c the output frequency of different temperature in the form of graph. The humidity sensors are showcased based on their properties such as morphology, surface area, pore size, sensing material etc.[10]

The gas sensor and the humidity sensor have similar features such as high sensitivity, constant response time, high stability, operating range etc.[12] Ahumidity sensor chip consist of a humidity sensor of capacitive type. [12] The UV sensors and the photodetectors are also used widely in medical, environmental safety, flame detection and few others. They detect the light in the UV wave formrange.

a)



b)

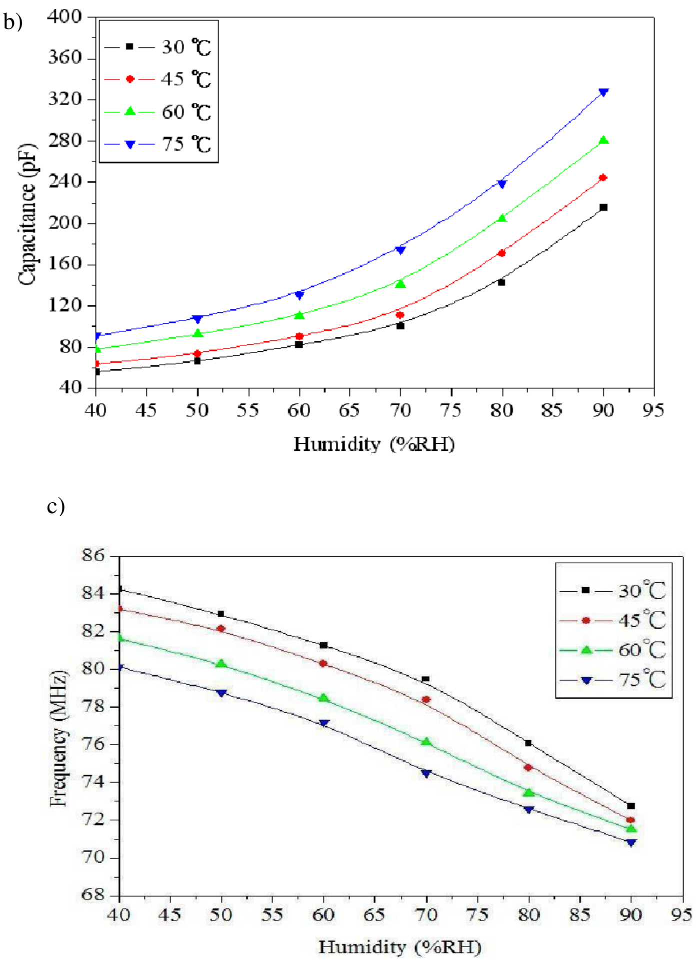


Fig 4 a) Humidity sensor b) capacitance of humidity sensor at different temperature c) output frequency [9][10]

Electrodes used in biosensors convert the biological signal into readable output and these are implemented for biological elements such as cells, DNA etc. The electrochemical biosensors are used for biomedical purposes, agricultural food and analysis of environment. [11]

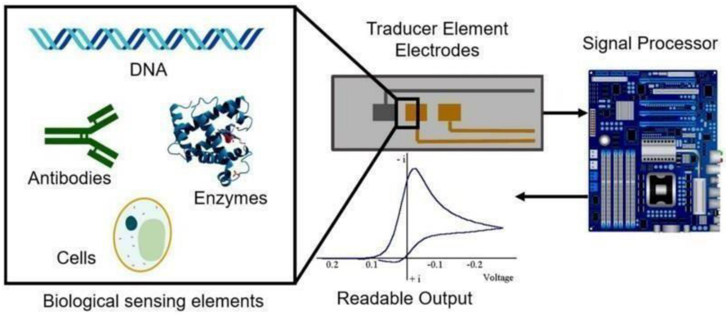


Fig 5 Biosensor coupled with electrodes [11]

A silicon-basedphotodetector for ultraviolet light and spectral dependence occurs due to its absorption coefficient Ag. The Ag acts as gate electrode and the Ag photodetector has maximum responsivity when compared to PIN structured photo-detector.[13] Ellipsometer is used to measure the thickness of oxide, a thin metal is stacked via evaporation with a background pressure. The Ag metal is deposited for its band selection and they are evaporated on the bottom of its substrate. It is also a mechanism of tunnelingprocess.[13]

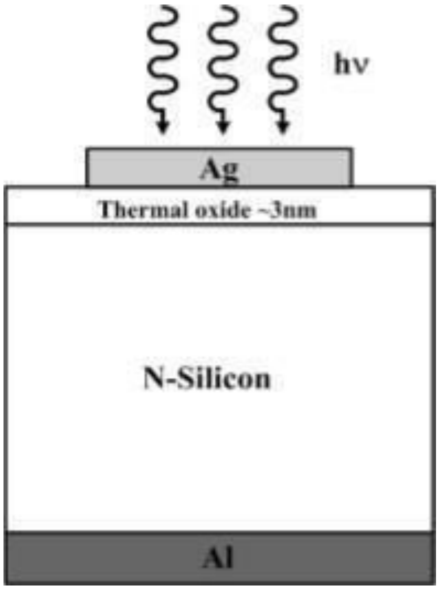


Fig 6 Structure of metal oxide semiconductor using UV sensor

In biosensor the metal oxide nanostructures are widely used as sensing devices that includes a transducer as shown in Fig 5 with few specific components. Such as bioreceptor.[10] The analysis of proteins,DNA, glucose, [11] bacteria and many others.Biosensors are powerful analysis tools in medical diagnostics for detecting of diseases and virus for food quality and safety . There are various type of biosensors and they are classified as bioreceptors and transducers.The most powerful biosensor is the glucose biosensor which is used to monitor the blood glucose level of patients.[10]

Recently, the metal oxide materials have been implemented in electron-transfer kinetics and strong absorption capability and this improves the biosensing properties and depend upon biomolecules with chemical binding and physical absorption [10]

II. Metal Oxide Nanostructure

The metal oxide nanostructures are widely used in optical electronics and electronics that consists of transducer, capacitors, transistors. Mostly used for sensing and gases and vapors They are of p-type and n-type semiconductors. In n-type semiconductor titanium dioxide, zinc oxide, tin dioxide, tungsten dioxide and p-type semiconductors copper oxide and tin mono-oxide[10]. and these semiconductors are implemented in few sensors such as gas, humidity, biological and UV sensor and are exhibited in various terminals [10]. They are showcase in various nanoscale, nanowires, nanospheres andnanosheets [10][6].

A. Tungstendioxide

The Tungsten diode (WO_3) is a n-type semiconductor material with a wide energy band gap. WO_3 have various crystalline structure such as tetragonal, triclinic, hexagonal, cubic and few other [10]. Tungsten is one of the best sensing materials for detecting the toxic gases in solid semiconductors [14].They are of surface-controlled type.

As per study earlier gas sensor was coated with tungsten oxide nanostructure on the alumina substrate which is attached to electrodes[14] and the WO_3 has high sensitivity gas-sensing materials which were used to detect the hazardous gases. The tungsten diode nanostructure is synthesized in different concentration as shown in Fig 7.

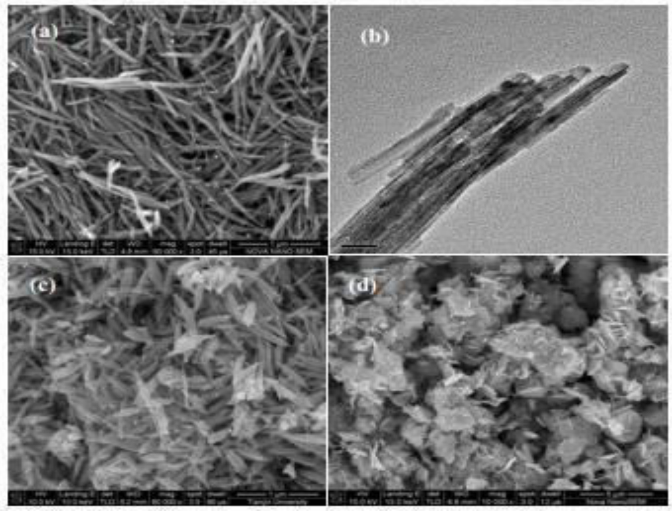


Fig 7 a) c) d) SEM images of WCl_6 concentration of 0.01M, 0.013M and 0.015M, b) TEM image [14]

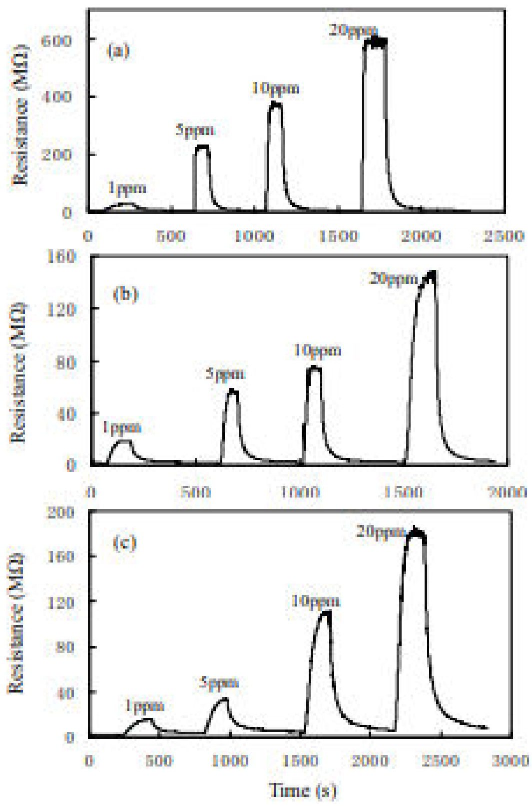


Fig 8 Dynamic response of WO_3 various concentration a) 0.01M, b)0.013M, c)0.015M

In Fig 8 the dynamic response of the sensor is shown in various concentration, the nanowires bundle became shorter and thicker as the concentration increased and the longer and thinner nanowire had quicker response as per the study in [14] as it has highest sensitivity to various concentration. Tungsten oxide and zinc oxide pure are composed and prepared in various concentration[5].

B. Zincoxide

Zinc oxide is a type of semiconductor that is used to optoelectronic devices, piezoelectric and pyroelectric. They are very potential and used in various fields such as LED (light emitting diode), solar cells, photo detectors and laser cells and few other more [16]. ZnO films have transparent properties.
In Fig 9 the tetrahedral coordinates of Z_n^{2+} and O^{2-}. The Zinc oxide are known to be unique because they inherit dual semiconductor and piezoelectric properties.[15]

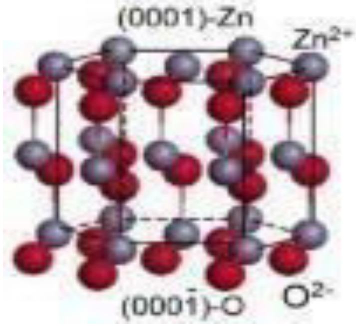


Fig 9Tetrahedral coordinates of Z_n 2+ and O2- [16]

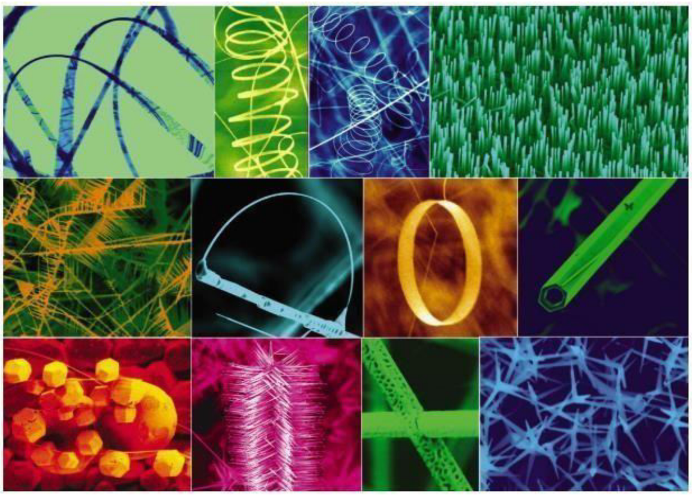


Fig 10 Collection of ZnO nanostructures in different formations [16]

ZnO have divine structures and in [15] the formation of nano helixes, nano bows, nanowires, nano propellers and nanocages of ZnO. They are also used in gas sensors to detect few gases. The Zinc oxide are crystalline in shape and have the formation of hexagonal, tetrahedral or cubical shape. In tetrahedral semiconductors the ZnO have higher piezoelectric properties. Basically zinc, have higher refractive index[16]. One among the popular method for improving the performance of ZnO is by doping, alike as gas sensor. There are many authors who have made a study on ZnO metal oxides performance and characteristics such as in [14-16].

ZnO is a n-type semiconductor merged with various crystal surface for increasing its conductivity. Electronics transfer from ZnO n-type electrode to NiO p-type electrode ad that would lead to hole depletion into the surface of the electrodes. When a zinc oxide is used it is absorbed at the sensors surface and has low hysteresis, with high sensitivity and recovery time[10].

The Zinc oxide nanoparticles have different morphologies, shape, size and various types of parameters, for synthesizing.[17] For synthesizing the sol-gel method most widely used in ZnO and after collision the solid particles turns into liquid [9]. There is various technique for morphology of zinc oxide as shown in Table 2.

Method	Materials	Size (nm)	Shape
Hydrothermal	Zinc acetate dihydrate, polyvinylpyrrolidone (PVP)	L: 5000, D: 50–200	Nanorods
	Zinc acetate dihydrate, zinc chloride, sodium hydroxide	60	Nanorods
Microwave decomposition	1-Butyl-3-methylimidazolium bis (trifluoromethylsulfonyl) imide [bmim][NTf2], zinc acetate dehydrate	37–47	Sphere
Co-precipitation	Zinc acetate, double distilled water	D: 30–60, L: 80	Nanorods
	Tetrahydrated zinc nitrate, ammonium hydroxide	20–40	Crystals
Micro-emulsion	Zinc acetate dihydrate, ethylbenzene acid sodium salt (EBS), xylene, dodecylbenzene sulfonic acid sodium salt (DBS), ethanol and hydrazine	D_{DBS}: 300 D_{EBS}: 80	Nanorods
	$Zn(AOT)_2$, heptane, diethyl oxalate, chloroform, methanol	10–20	Quasispherical
Solvothermal	Zinc acetate dihydrate, polyethylene glycol, absolute ethanol	10–20	Quasispherical
	Triethanolamine, zinc acetylacetonate monohydrate, 1-octanol, and absolute ethanol	L_{rod} ~100 D_{sphere} ~20	Rods (ethanol without triethanolamine—TEA) spherical (ethanol with TEA)
Sol-gel	Oxalic acid dihydrate, zinc acetate dihydrate, hydrochloric acid, ammonia, and absolute ethanol	20	Spherical
Sonochemical	Potassium hydroxide, zinc nitrate hexahydrate, and cetyltrimethylammonium bromide	200–400 wide, a few nm thick	Flakes
Chemical vapor deposition	Zinc acetate dihydrate, ethanol	Average D: 90 and L: 564	Nanorods
Electrochemical	Oxalic acid dihydrate purified, Zn electrode, potassium chloride, nitric acid, and sodium hydroxide	$D_{spherical}$: 50–100 $L_{cylindrical}$: 150–200	Spherical and cylindrical particles

Table 2: Morphology of zinc oxide (ZnO)[17]

The hydrothermal method is synthesized by ZnO and they vary upon temperature and concentration. The crystal growth includes the ability to create crystalline phases from solid to melting point.They grow material at higher vaporpressure when closer to melting point. The disadvantage of this method is that they are expensive.Sonochemicaltechnology are used in wide materials of material science. Few researchers have used this method to defined different / new shapes of zinc oxide nano-crystalline structures[19].

Microemulsion method is used to define its isotropy they are numerously applied in chemical and biological fields.In the first picture below shown in Fig 11the microemulsion method where energy triggering and one micro emulsion method is used, when energy is triggered the reaction is initializedwith a triggering agent [20]. In microemulsion plus reactant they direct react to pure reactant which are in liquid or gaseous state and so they are firstdissolved.

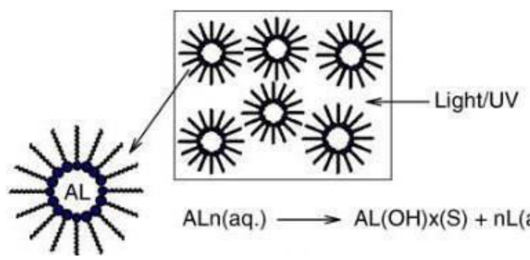


Fig 11Microemulsion: Energy triggering method [20]

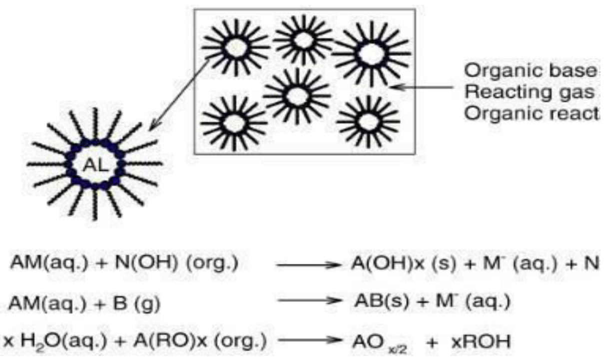


Fig 12 Microemulsion: plus, reactant method[20]

The solvothermal method is similar to hydrothermal method and they prepare a wide range of materials such as polymers, semiconductors, ceramics and metals.[18]The presence of solvents in a materials changes at its higher temperature such as their boilingpoint. They prepare both crystalline oxide and non-oxide materials. Solvothermal can exhibits in various quantum dot effects.

The deposition of solid film on a heated surface by a chemical reaction in a gas or vaporstate this method is knownas chemical vapor deposition (CVD), types of CVDs are photo-laser CVD, laser CVD, plasma CVD, and few others[21]. The Microfabrication technique is most widely used for deposit monocrystallinematerials [21].

Co-precipitation method have inorganic zinc and alkalis. In this method to achieve nanoparticles, calcination is done [17].In Fig 13(a) pure ZnO nanoparticles are shown in Fig 15(b) the co doped ZnO particles are shown and the co doped ZnO nanoparticles are reduced in size when compared to pure ZnO .This reduction is due to distortion.

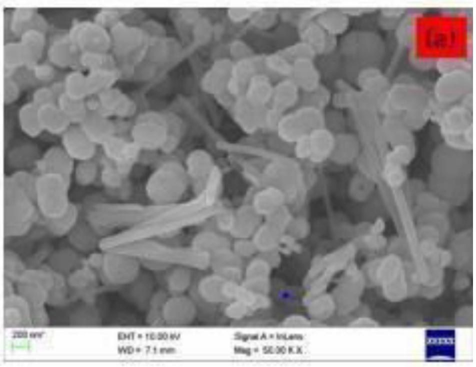


Fig 13 (a) Field emission scanning electron microscopic analyzes(a) Pure ZnO [22]

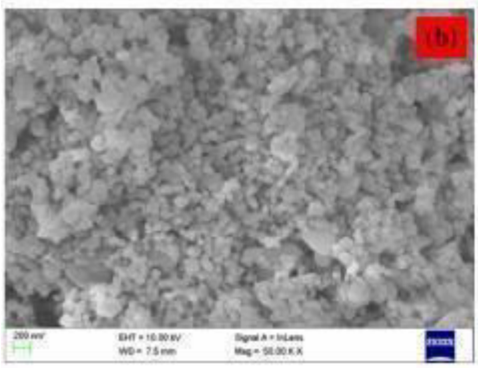


Fig 13 (b) Field emission scanning electron microscopic analyzes (b) Co doped ZnO nanoparticles [22]

The microwave assisted method is simple and doesn't cause thermal gradient effects and they are used to produce hydroxide, oxide and few other nanoparticles[17].

Green synthesis is very energy-efficient,low cost and eco-friendly [17].It is used as an alternative method for chemical and physical method instead of biological method. They exhibit in various shape and size. Reducing the metal ions could reduce the stability of the nanoparticles that are risked. Here nanoparticles with biocompatibilityare produces and agents are natural present producing biological organisms [23].

C. Titanium Dioxide

The titanium Dioxides are photocatalysis, they are used as creams and coatings that absorb UV without any coating. Titanium Dioxide are molecules of one atom of titanium with two oxygen atoms. They are nanotubes and molecules are bonded in cylindrical shapes, which result in cylindrical lattice with oxygen and twotitanium.

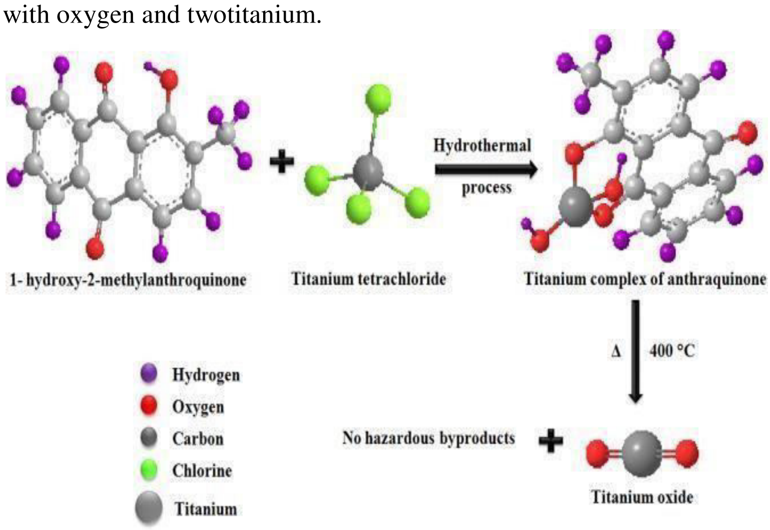


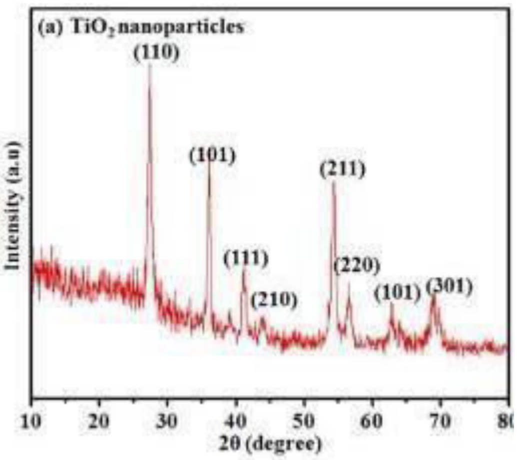
Fig14 MechanismofTiO₂nanoparticles[24]

TiO_2 nanoparticles are characterized by X-ray diffraction.In fig 1 the mechanism of titanium oxide nanoparticles is synthesized. TiO_2 is a n-type semiconductor and have wide energy band gap and they can engage by adding more nanostructures to it or structural defects or by doping nonmetal elementals and these have higher refractive index with high dielectric current passing throughthem [10][24].

TiO_2 can be produced in various methods such as solvothermal synthesis, thermal evaporation, sputtering, and various other technique. This nanomaterial is exhibit in various form not only in nanotubes such as in nanowire, nanosphere, nanorods etc. and these are non-toxic and eco-friendly [24]. These are high quality sensor and have good sensitivity with short response, recovery time, and longer life cycle.

In the graph below the X-ray diffraction for Titanium oxide nanoparticles with its comparative pattern of synthesized and standard nanoparticles. TiO_2 are photoactive layer of gas sensor when doping is done between small metal clusters then point defects occur. Combining several oxides have limitation onto them.

In humidity sensor, TiO_2 have superior sensitivity as a result of low surface-to-volume ratio. When compared to UV photodetector the TiO_2 films have various difference in structural characteristics . TiO_2 nanoparticles are used a composite with graphene oxidenanosheets.



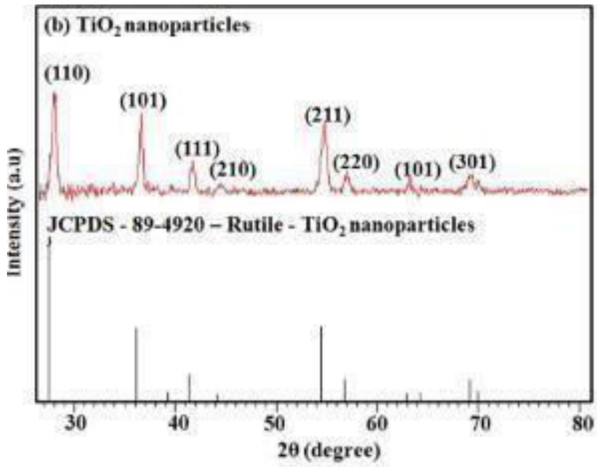


Fig 15 (a) Synthesized TiO_2 nanoparticles (b) Synthesized and standard TiO_2 nanoparticles [24]

The different types of titanium nanoparticles are shown in Table 2. There are three different forms namely anatase, rutile and brookite, when heating anatase and brookite convert to rutile which always stable. The Properties of anatase and rutile phase is shown below

Property	Anatase	Rutile
Molecular weight (g/mol)	79.88	79.88
Melting point (°C)	1825	1825
Boiling point (°C)	2500–3000	2500–3000
Specific gravity	3.9	4.0
Light absorption (nm)	λ ≤ 385 nm	λ ≤ 415 nm
Mohr's hardness	5.5	6.5 to 7
Refractive index	2.55	2.75
Dielectric constant	31	114
Crystal structure	Tetragonal	Tetragonal
Lattice constants (Å)	a = 3.784 c = 9.515	a = 4.5936 c = 2.9587
Density (g/cm³)	3.79	4.13
Ti—O bond length (Å)	1.937 (4) 1.965 (2)	1.949 (4) 1.980 (2)

Table 3 Properties of anatase and rutile of TiO_2[25]

In TiO_2, the photocatalysis very efficient and have high activity in the photodegradation for organic and inorganic materials. In various research it is told that TiO_2 have certain properties such as they have particular shape, size etc. They are good photovoltaic materials. With differentquality [25].

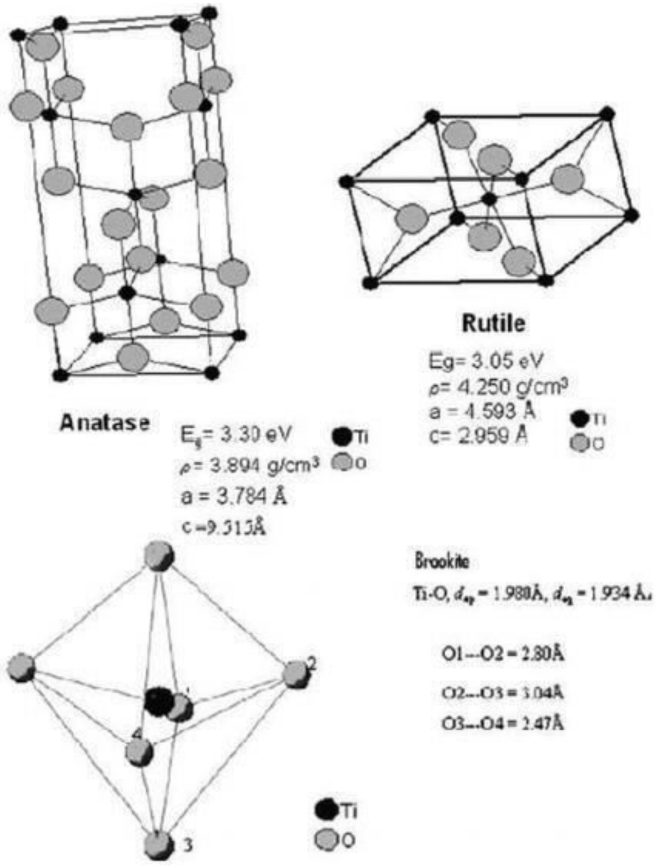


Fig 16 Different forms of TiO_2[25]

D. Copper oxide

Nanomaterials such as nano shuttles, nano disks and nanoparticles are exhibited by hydrothermal and wet chemical method. CuO is a p-type semiconductor with a narrow bandgap [26]. They are categorized based on their thermal conductivity, photovoltaic properties, high stability, and few others [27].

Copper oxide are widely used as gas sensors, active catalyst, metal conductivity as they have good selectivity in nanomaterials. Compared to other nanostructures CuO has unique magnetic and superhydrophobic characteristics, they have various morphologies such as their shape, size and various dimensions depend on physical and chemical properties[27]. Water is a pure solvent and are of low cost and safest so CuO utilizes waster as solvent. In fig 17 the crystalline structure of CuO isshown.

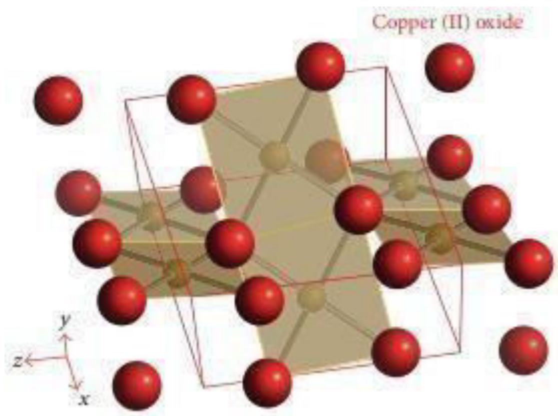


Fig 17 Crystalline structure of CuO [27]

Morphology	Size	Solvent	Starting materials	Surfactant	Method
Hierarchical superstructure	Diameter: 200 nm; length: 600 nm SEM	Distilled wate	$Cu(CH_3COO)_2$ NaOH	Ethylene diamine-te tra-acetic acid disodium	Sonochemical
Cubic	230 nm	Water	$Cu(CH_3COO)_2$ NaOH	Without surfactant	Microwave
Sphere	40 nm, 90 nm, and 140 nm (as the concentration of salt increases)	Ethylene glyc		PVP, CTAB	
Nanoparticle	50 nm XRD	Water	$CuCl_2$, NH_4OH	Thiourea	Chemical and annealing
Nanoparticle	5–8 nm TEM and XRD	Ethanol	$Cu(CH_3COO)_2$ NaOH, methanol, and NH_4OH	No	Alcothermal
Nanoparticle	44 nm (XRD) 80 nm (TEM)	Deionized (D	$Cu(NO_3)_2$	Citric Acid; ethylene glycol	Sol-gel
Nanorod	Diameter: 50–100 nm Length: microns	2-Propanol	$Cu(NO_3)_2$	No	Solvothermal
Nanosheet	Width: 1-2 mm; thickness: 20 nm	Ethanol			
Nanoparticle	22 nm 10 nm	Deionized wa Ethylene glyc	$CuSO_4$	Ascorbic acid $NaBH_4$ PVP	Chemical reduction
Flower-like	400–600 nm	Deionized W	$Cu(CH_3COO)_2$	No	Hydrolyzing method
Nanoparticle	3–9 nm (XRD) 11 nm (TEM)	Alcohol	$Cu(CH_3COO)_2$	No	Alcohol thermal
Nanoplatelet	Lengths: 4-5 μm; thickness: 65–80 nm (SEM)	1-Butyl-3-met imidazolium [BMIM]BF	$Cu(NO_3)_2$ NaOH	($[BMIM]BF_4$). It serves both as solvent and as surfactant	Hydrothermal
Nanoneedle	Length ~100 nm Diameter 10–20 nm (TEM)	Water	$Cu(NO_3)_2$ NaOH	Oleic acid Sodium oleate	Coprecipitation
Nanobelt	Length: 2.5–5 μm Width: 150–200 nm	Distilled wate	$CuSO_4$ NaOH	H_2O_2	Hydrothermal
Nanoparticle	100 nm (SEM)	Ethylene glyc	$Cu(CH_3COO)_2$ urea	No	Microwave

Table 4: Different Morphology of CuO nanomaterials [27]

Unlike, other nanomaterials, CuO also imposes various method such as solvothermal, sol-gel, sono-chemical method and few others, for preparation the nanoproduct [27]. At high temperature solvothermal process is used and they take longer time as high pressure is invoked, On the other side sol-gel method is difficult and there are various parameters to be measured and controlled [27]. Because of the high temperature the form a homogenous gradient and reduce the reaction time and they form into small particles of uniform size andshape.

As shown in Fig 17, CuO have monoclinic structure and of square planar configuration of 110. Compared to other properties such as field emission, electrical conductivity or optical property have less conductivity [27]. Also, the band gap depends upon their quantum size in different CuO nanostructures. Consequently, CuO is different from antiferro magnetic transition metal monooxides.

CuO nanostructures are widely used in material science and engineering, as have unique properties and understand the synthesis process and fundamental properties, they are transition metal oxides, enhancing super thermal conductivity, high stability and few other properties.

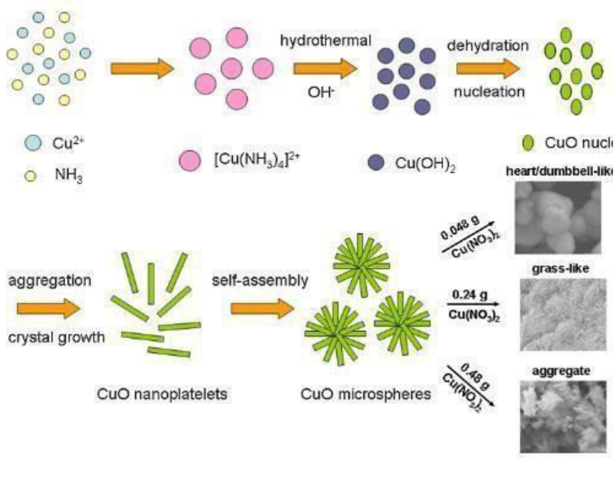


Fig 18 Formation of different CuO nanostructures [26]

In Table 4 different formation of CuO nanostructures with their solvents and surfactant and morphology are show. By hydrothermal reaction the crystal growth increases and ion size depending upon their room temperature and they grow to 1D nanostructures where nanoparticles are aggregated nanoparticles and rearrange themselves because of their intrinsic anisotropic property.[26] The nanoparticles combine with each other to form dumbbell like structure and they grow grass like structure with well-arranged nano leaves that are the nanoplatelets as shown in fig18.

In Fig 19, the SEM images of different CuO nanostructures in different concentration is sown where a and d are Dumbbell shaped CuO, b and e are grass shaped CuO and c and f are aggregated CuO[26].

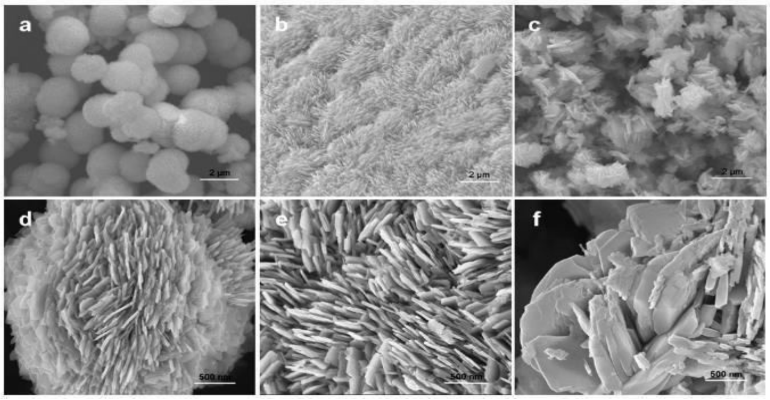


Fig 19 SEM image of different CuO nanostructures in different concentration [26]

E. Tin Oxide

They represent the important class of crystalline semiconducting nanomaterials with wide band gap. Tin oxide are n-type semiconductor and these materials are used as catalysts, sensors and few other [28]. To control their band gap modification can bedone. They exhibit low electric resistance and have good electrical conductivity for gas sensing based on the nanostructures size. SnO_2 have few parameters depending upon their crystal size of nanocrystalline and have good crystalline that is defined by hydrothermalsynthesis.

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Synthesis of nanomaterial with controlled morphology, size, chemical composition and crystal structure [29]. The different synthetic is processed using methods like vapor synthesis and solid-state synthesis. The crystalline structure of tin oxide is shown below.

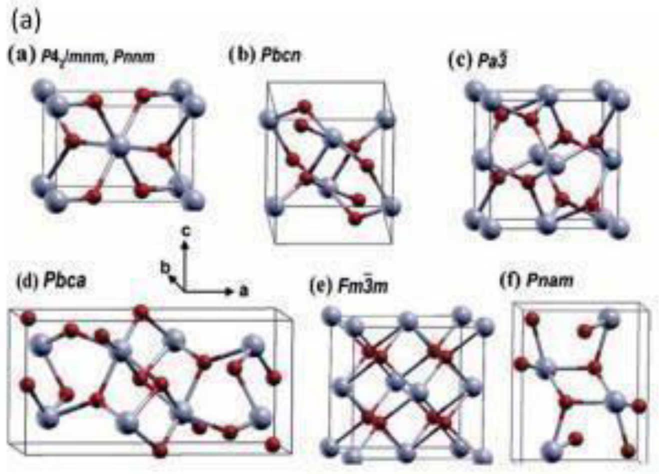

Fig 20) Crystalline structures of the SnO2 p (a) Rutile and $CaCl_2$ (b) R-PbO_2, (c) pyrite, (d) ZrO_2, (e) fluorite, and (f) cotunnite [29]

Various chemical synthesis method is such as sol-fel method, hydrothermal method, precursor compound method and emulsion technique for the synthesis of metal oxide nanoparticles. The sol-gel method is a technique where the gelling of a solution containing the metal salts, they result in the formation of tin oxide nanoparticles with large surface area.[29]

They grow in the form of 1D nanostructure and form in tube, belts and road or wires.[30] They have high impact as these are used in novel structures in next generation sensor and nanodevices they have higher integration with low power consumption and also eco-friendly with low power cost [30].The SnO_2 consist of two metal ions and fouroxygen atoms each Tin oxide atom is placed in between six oxygen atoms which results in forming octahedron[29]. Oxygen atoms are covered by three Sn atoms and they for Sn-O-Sn in a triangle like structure.

SnO is formed when Sn is in oxidation and it is in metastable phase that converts to SnO_2 even in the absenceof oxygen if exposed to a certain temperature [10]. SnO_2 aredoped materials with electrical and optical properties. The electrical properties of SnO depends on oxygen stoichemistry[30].

SnO and SnO_2 are used in widely in Li-on batteries, waster splitting, transistors with thin films, photocatalysis [27-30]. Tin oxide are also used for detection of various gases such as H_2, O_2, NO_2, NH_3 and CO and these have fast response speed with high chemical stability and low cost [10].

In fig 21 of SnO2 at different ammonia feed rate is shown and in table 5 synthesis of tin oxide nanoparticles using various methods is displayed.

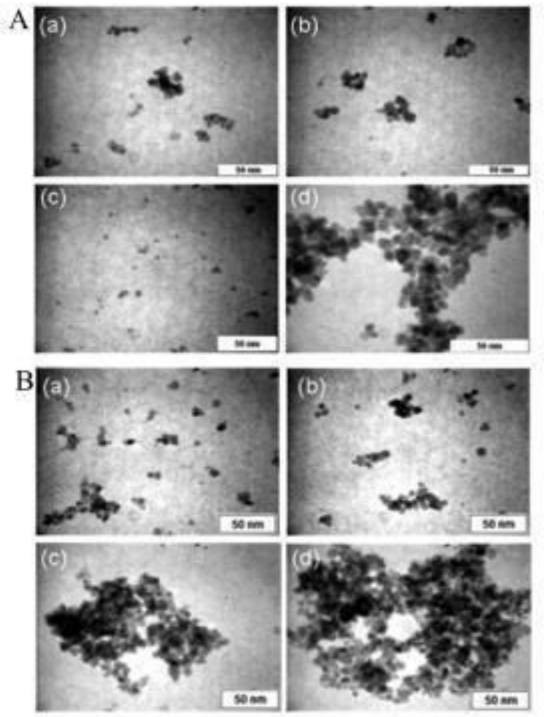

Fig 21 TEM micrographs of SnO2 at different ammonia feed rate[29]

Methods	Solvents	Precursors/surfactants	Temperature	Morphology	Average crystallite size
Solution processing method					
Sol–gel	Water		200 °C	Spherical	2.5 nm
			400 °C	Spherical	3.5 nm
			800 °C	Spherical	18.2 nm
	Ethanol		450 °C	Spherical	20 nm
	Ethylene glycol		195 °C	Spherical	20 nm
Solvothermal	Water		200 °C	Spherical	5.5 nm
	Isopropanol		600 °C	Spherical	10–30 nm
Precursor compound method		Organometallic	135 °C	Spherical	20 nm
		Carboxylate precursor	295 °C	Spherical	5.2 nm
		Polyacrylate precursor	600 °C	Spherical	15 nm
		Poly(propyleneimine)		Flower like	2.5 nm
		Poly(amidoamine)		Flower like	4–5 nm
Amino acid mediated synthesis	Water		200 °C	Nearly spherical	10–20
Microemulsion method		SDS surfactant		Floral petal	8 nm
		CTAB surfactant		Florets of cauliflower	11 nm
		PEG surfactant		Sheets and rods	13 nm
Microwave irradiation	Acidified water		200 °C	Spheres irregular shape and size	6 nm
			400 °C		9 nm
			600 °C		21 nm
			800 °C		33 nm
Sonochemical	Water		80 °C	Irregular shape	3 nm
Vapour phase synthesis					
Laser ablation			900 °C	Nanowire	20 nm (diameter)
Arc plasma				Nearly spherical particles of irregular size	5 nm
Flame spray			200 °C	Nearly spherical particles of irregular size	20 nm
Solid state synthesis					
Mechanical pressing			25 °C	Nearly spherical	3–15 nm
Ball milling, 4 h, 600 rpm			600 °C	Nearly spherical	25–40 nm
Focused solar irradiation				Nearly spherical	20–60 nm
Bio-synthesis	Water	Plant/bacteria extract	150 °C	Spherical	~30 nm

Table 5 Tin oxide nanoparticles synthesized via various methods [29]

III. Performance of metal oxidesensors

The comparison between different metal oxides and their sensing devices is discussed. As per study the metal oxides have been largely integrated in gas sensors with various concentration onto them. The temperature also various for each metal oxide. The widely used metal oxide gas sensors are ZnOand TiO_2 as they have high chemical stability and are of low cost. Practically they are very fast at recovery and response rates. Deep investigation is been done for all metal oxide semiconductors and it is also noting that ZnO nano structures.

have fast response rare when doping is done. WO_3 are eco-friendly and are safely monitored. Sensitivity of WO_3 have limitation and the operation temperature is lower when compared to ZnO and TiO_2, as these two have fast recovery and response time.

Copper oxide-based gas sensors are formed by p-n hetero-junctions as per study and copper oxides have p-type characters and they are eco-friendly, nontoxic with wet-chemical synthesis. Cu_2O oxides are unstable and they can be easily converted to CuO. SnO_2 is used for the detection of different gases, such as H_2, O_2, CO, NO_2 and NH_3, as they have fats response and recovery time and they are eco-friendly with low cost.

The nanostructured metal oxide-based humidity sensors are used to detect the humidity change and they have good detection range the only drawback of this sensor is that they have limited sensitivity improvement. In humidity sensor the tin and copper oxides are not widely used but they have good response, recovery andstability.

After the analysis of biosensor, it is also observed that ZnO and WO_3 nanostructures are most used. The Zinc oxide and copper oxide are widely used for the detection of glucoses they have high sensitivity with low concentration and are also of low cost. TiO_2 and SnO_2 are also used in biosensing and have low detectionlimit.[10]

IV. Conclusion

In review summarization of various sensing technique on different sensors such as gas sensor, humidity sensor, UV sensor and biosensors. Different nanomaterial types where explained with example such as nanowires, nanotubes, nanofibers, nanosheets, nanosphere, nanocubes, and few other. Various sensing mechanism and properties of metal oxide is beendiscussed.

Limitation of various metal oxide material with their sensor are addressed with various approaches, the impact of doping exhibiting on semiconductors was addressed. Usage and application of each gas sensing technique with their properties are show in a form of graph as a review. Different dimensionof nanostructures isbuilt and discussed, their properties, limitation and performance of each nanomaterials isfocused.

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