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A Mini Review on Electrical properties of un-doped and boron doped ZnO with their preparation methods:

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ABSTRUCT

The objective of this review paper is that the investigated reports and discussions about various syntheses of thin films and electrical properties of III A group Boron doped Zinc Oxide by using various syntheses. The synthesis of ZnO doped materials have been analyzed by many researchers by using X-Ray diffraction (XRD) and they have confirmed that the obtained crystal structure of dopes film shows hexagonal wurtzite structure. Researchers use application of this material to increases the materials properties when they dope. The various synthesis techniques and electrical properties of doped thin films of III A groupBoron and was analysed. ZnO material has very useful physical properties, which is sharply enhanced by doping. The properties of this material keep very important place in electronics and opt-electronic devices. In this paper electrical property of doped ZnO of III group Boron and its synthesis method have been discussed.

Keywords: ZnO, Electrical properties, 13th group, dip coating, sputtering, sol gel, boron doped.

INTRODUCTION

Zinc oxide (ZnO) is a very useful semiconductor materials for optoelectronic application that comes to fore among the II-VI because it has direct wide band gap of 3.37 eV. ZnO usually exhibits n-type conductivity but its electrical and optical properties are not stable and the extrinsic doping process effects to control and improve the electro-optical and structural properties of ZnOnanomaterials. In III group (B, Al, In and Ga) doped ZnO reveals low resistivity and n-type conductivity but among these boron doping can be more suitable [1]. The studies about ZnO nanomaterial have been going on since the starting of 1900s [2] . These prepared films have various industrial applications and it can be prepared by various methods such as spray pyrolysis, thermal evaporation, r.f. magnetron sputtering and sol–gel methodetc[3].Chen et al. reported the degradation effect with time of ZnO and ZnO:B films grown by metal-organic chemical vapor deposition (MOCVD). Steinhauser et al. reported that heavily doped ZnO:B films deposited by lowpressure chemical vapor deposition (LPCVD) exhibited more stable resistivity after 800 h of damp heat treatment. Shah et al. also reported that LPCVD ZnO:B films passed the standard damp heat test [4]. In this review paper, 10 research papers have been collected for reviewed so that it could be useful and only electrical properties have been discussed.

Table 1 A Description of Various Terms Associated with Nanomaterial:

Sn.	Term	Description
1.	Nanotechnology	Nanotechnology refers to technology at the Nanoscale level in which materials, devices, or systems are developed via controlling matter at the Nanoscale length to stimulate the unique
2.	Nano scale	Properties of the material at the Nano-level. A scale covering 1–100 nm.

3.	Nanomaterial	A material is called a nanomaterial if it has at least one dimension in the Nanoscale range of1–100 nm.
4.	Nanoparticle	An object or particle is called a Nanoparticle when all of its dimensions are in the Nanoscalerange.
5.	Nano rod	The term Nanorod is used when the shortest and longest axes have different lengths. Nano rodshave a width in the range of 1 to 100 nm and an aspect ratio greater than 1.
6.	Nanofiber	A Nano-object with two dimensions in the Nanoscale range and a third dimension that isSignificantly larger.
7.	Nanowire	Nanowires are analogues to Nano rods, but with a higher aspect ratio.
8.	Nanotube	Hollow nanofibers are called nanotubes
9.	Nanostructured material	This is a term used for materials that have structural elements, molecules, crystallites, or clusters with dimensions in the range of 1–100 nm.

Methods and electrical properties: Mini Review

S.D. Senol et al.Theyprepared Boron doped ZnO Nano powder by hydrothermal method via different concentration of boron doping (0-11) at % and electrical properties of doped ZnO has been investigated. As base materials Zinc acetate dehydrates (Zn $(CH_3COO)_{22}H_2O$) (Merck), hex methylene tetra amine (HMT) (Merck) and boric acid (H3BO3) Merck) were taken. Zinc acetate and MT were made solution (equimolar aqueous). After it with different concentration boric acid were contributed which concentration quantities are (x=0.0, 0.05, 0.07, 0.11) and those prepared solution for stirring kept it under magnetic for 1. Prepared solutions were transfers into Teflon-lined autoclave and kept if under oven at 95 95oC for 12 h. then using centrifuge B doped ZnO powders were separated from the solution and washed by deionized water and dried in air. The obtained powder was with boric acid sources of Zn1-xBxO (x=0.0, 0.05, 0.07, 0.11) were labeled and calcined 750 °C to obtain white Zn1-xBx. They reported the electrical properties (resistivity, carrier concentration, mobility) was measured by temperature dependent van der Pauw method with Ecopia HMS-5000 Hall-effect measurement system in the temperature range of 180–350 K .Wile electrical measurement's some values were applied sample size about 1×1 cm^2 and the four corners were soldered by silver blobs for the Ω contacts magnetic field of 0.55 T and constant current of 5 mA were applied wile electrical measurement.After investigating electrical properties ofB doped ZnO ($Zn_{1-x}B_xO$) powder. The carrier concentration increases from $0.11x10^{14}$ cm^{-3} (0 at. %) to $4.08x10^{14}$ cm^{-3} (11 at. %) as increases B doping concentration because of substitution of Zn^{+2} by B^{+3} ions and diffusion of B^{+3} into interstitial positions in the ZnO lattice, the Hall mobility decreased from 5.61cm^2 V^{-1} s^{-1} to 1.22 cm^2 V^{-1} s^{-1} and with increases B concentration 0 % to 7 % during the carrier concentration increases $0.11x10^{14}$ cm^{-3} to $2.06x10^{14}$ cm^{-3} .Electrical resistivity decreased from 10.89×10^4 Ω cm to 1.25×10^4 Ω cm while B doping concentrations increase and the electrical resistivity is observed to decrease with both the increase in dopant concentration and the temperature in the range of 180–350 K.[1]

T. HurmaHe prepared solutions by dissolvin of compound containin Zn and B element at 0.05 molarity in deionized water . For Zn and B source $Zn(CH_3COO)_2.H_2O$ salt and H_3BO_3 salt was used .For each film 150 ml of solution in all solution was mixed as given below :-

Table1. Precursor solutions of the ZnO and ZnO:B films

Film(ml)$Zn(CH_3COO)_2.H2O$ (ml)	H_3BO_3

ZnS150.00	0.00	
ZnO:B 3%	145.50	4.50
ZnO:B 6%	141.00	9.0
ZnO:B 9%	136.5	13.5

and 1 bar was used as carrier gas.The glass substrate temperaturs were up to 350±5°C and prepared solution were sprayed on tem for 30 min Atomization velocity was set as 5cc/min. He observed that photovoltaic application its an importance anoter parameter for semiconductor films and for tis te electrical resistance value suld be low. For electrical properties of undoped and B doped ZnO films were calculated at room temperature and for electrode and calculated impedances old (Au) and om's law were used.Rapetations were done between 0 to 100 V range. From I-V rap it was obtained tat te all films sowed omic conductivity . Te reistance of ZnO films decreased as increases te dopin rate of B . Resistance of the un-doped ZnO film was found as 1.37×103 Ω cm. This value is around the same level of the values reported by Muiva et al. as 5.39×103 Ω cm and Bacaksiz et al. as 2.23×103 Ω cm. The B doped ZnO (3, 6, 9) % resistances were respectively obtained as 9.28×102 Ω cm, 3.97×102 Ω cm and 1.36×102 Ω cm. Concentration of electron increased and might have decreased as a result of replacement of Zn^{+2} host atoms by B^{+3} atoms added in the ZnO films.[2]

Mujdat Caglara et al.
They preparedundoped and B doped ZnO films, using sol-gel metod onto indium tin oxide (ITO) coated glass substrate. Using as startin materials and solvent and sabilizer , Zinc acetate dehydrate [$Zn(CH_3COO)_2{\cdot}2H_2O$] (ZnAc), 2-Methoxethanol ($C_3H_8O_2$) and ethanolamine [C_2H_7NO] (MEA) were used. Trimethyl borate [$(B(OCH_3)_3)$] used as dopant source of boron. The ratio of molar was 1:1 of MEA to ZnAc and TMB. The boron and Zn normal ratio was 1% and 5% .Using magnetic stimulating solution was stirred at 60 ◦C to yield (et) homogeneous and transparent solution. using an ultrasonic cleaner the ITO substrates were cleaned by detergent then methanol and acetone .The coated solution was dropped into ITO substrate and rotate at 3000 rpm for 30s by spin coater and after it films were dried at 300 C for 10 min in a furnace to evaporate the solvent and for removing organic residuals it repeated for 10 times and finally annealed at 500^0C for 1 in air. This process was repeated for all the films. Film thickness was obtained with mettle Toledo MX5 microbalance by weighting method and got 546, 487 and 640nm for ZnO, 1% B doped ZnO (ZnO:1% B) and 5% B doped ZnO (ZnO:5% B), respectively. They determined Electrical conductivity of boron doped ZnO (5%) in dark and furnace at 300 to 460 k temperatures. The conductivity with temperature dependency shows two different regions because of concentrations. If temperature increases the conductivity also increases for B (5%) doped ZnO because as donor care carrier electron. As temperature increase more care carrier electron increases. The temperature dependent of the conductivity can be represented by the formula

$$\sigma = \sigma_o \exp(-E/kT)$$

where and σ_o is the pre-exponential factor, T is absolute temperature The activation energies of shallow and deep donor levels were obtained as 0.160 eV and 0.850 eV, respectively. From the forward bias I–V measurements, k is Boltzmann constant and E is the activation energy corresponding to the energy difference between donor level and conduction level.[3]

Chien-YieTsay et al.
They took as starting materials, solvent and stabilizer, Zinc acetate dehydrates (ZnAc), 2-methoxyethanol (2-ME), and di-ethanolamine (DEA), respectively. Trimethyl borate (TMB) was used as boron source. By dissolving ZnAc and TMB in a mixture of 2-ME and DEA, the precursor solution was prepared with varied B doping concentrations 0 to 5 at% ([B]/ [ZnO:B]). The molar ratio was kept 1.0 between sol stabilizer and metal ions wit 0.5 M concentration of metal ions. Each solution was stirred in 60 ^{0}C with help of magnetic stirrer for 2 to yield a clear and homogeneous solutions after that to adjust PH values to 7.0 glacial acetic acid was added. Now the resultant solution was kept in air for 72 hours at room temperature. Doped and boron doped (ZnO: B) films were prepared by spin coating the precursor solution onto pre-cleaned alkali-free glasses (NEGOA-10, dimensions: 50mm X 50 mm X 0.7 mm) at 1000 rpm for 30s.They found that the electrical conductivity of doped ZnO films is more stable than pure ZnO films at high temperature. For 1% doping film shows best electrical properties. Hall mobility (m) of 17.9 cm^2/V s, electron concentration (n) of 1.2 x 10^{15} cm^3, and resistivity (r) of 2.2 x 10^2 Ω cm. In doped ZnO films B^{3+} into Zn^{2+} site, provide a care carrier as donor for conduction between ZnO lattices even all mobility and electron concentration decreases as increases B doping up to 1 to 5 at % and for resistivity it just opposite effect because n type semiconductor materials are having an inverse relationship electron concentration (r p 1/n). The reason of decreasing the electron concentration higher than 1% can be explained. The Nano structural prepared tin films were passed via to trap electron through greater number of an generating rain boundaries and excess B doping concentration from neutral defect (such as clusters and precipitates) rather than generating carriers. The polycrystalline conducting oxide and oxide semiconductor tin film depend upon rain size and it is an important mechanism specially if rain size is small .The barrier potential from rain boundary and trapped electron or mobility

of cares decreasing conductivity. Hall mobility of 17.9 cm^2 /V and the lowest electrical resistivity of 2.2 x 10^2 Ω cm were obtained at the optimal boron doping concentration of 1% .Such as-prepared transparent oxide semiconductor thin films could be used as the active layer in functional transparent electronics.[4]

Soaram Kim et al.
Sol-gel dip-coating technique was taken, to prepare un-doped and Boron doped ZnO thin films. quartz glass substrates were used. Zinc acetate dehydrate ([$Zn(CH_3$- $COO)_2.2H_2O$], Môn ethanolamine (MEA, [C_2H_7NO], and 2-methoxyethanol ([$CH_3OCH_2CH_2OH$] were used as a starting material, stabilizer, solvent respectively. Triisopropyl borate ([$((CH_3)_2CHO)_3B$] was used as source of dopant. They dissolved the 0.6 M zinc acetate dehydrate and Triisopropyl borate in the mixture of solvent and stabilizer and the molar ratio of B/ZO was varied 0-2.5 at%. The solution was stirred at 60^0C for 2 h then aged at RT for 24 h then cleaned the substrate by distilled water, acetone and ethanol respectively under ultrasonic irradiation and dried by N_2 then dip-coated and BZO films were grown on the glass substrate. They reported the resistivity (ρ) of un-doped and boron doped ZnO thin films with various doping concentration. The ρ depended on the Boron doping concentration that was lower than of un-doped ZnO thin films. The q values were 1411, 74.3, 105.7, 371, 510, and 649 X cm for 0, 0.5, 1.0, 1.5, 2.0, and 2.5 at.% B, respectively. These results were different from Tahar et al.[5]

Li Gao et al.
They used radio frequency-magnetron sputtering (RF-MS) method and reported that they wanted to obtain target material with about 2 wt% B_2O_3 and the target were prepared from ZnO powder then doped B_2O_3 with 4wt%. They compered resistivity of un-doped ZnO films that was 6.3 X 10^2 Ω and obtained low resistivity of BZO films which were 9.2 X 10^{-3} Ω and 7.5×10^{-3} Ω cm respectively due to increase in carrier concentrations.[6]

Lian-Hong Wong et al.
In this work they studied BZO films at temperature from 300^0C to 600^0C. Reagent-grad zinc oxide and boron oxide, using this BZO ceramic target prepared and mixed with weight ratio of 97:3. Ball milling of ZnO/B_2O_3 mixture was carried out in alcohol for 0.5 h and the dried mixture was pressed into stainless-steel mold. They reported Hall measurement identified all the films as n-type and obtained the lowest resistivity o5.64 X 10^{-3} Ω cm of BZO films at 400^0C.[7]

Gilho Kim et al.
Using liquid source misted chemical vapor deposition (LSMCD) method, un-doped and B doped ZnO films were grown. They use Zinc acetate ($(C_2H_3O_2)_2Zn$) and boric acid [$B(OH)_3$] as precursor. These were dissolved into H_2O: methanol (15:85 v/v) mixture and stirred at room temperature and the B concentration were varied from 1 to 4 at %.they found 2 at% concentration the film had lower resistivity (≈ 10^{-2}) than ZnO.[8]

Snigdha Bhattacharjee et al.
They studied boron doped ZnO nanostructure thin films and used zinc acetate dehydrate, 2-methoxethanol and ethanolamine as starting material, solvent and stabilizer sequentially. Boric acid was used as dopant source. The molar ratio of zinc acetate with 2-methoxethanol and ethanolamine and boric acid were maintained 1:1. The concentrations of B/ZO were 0, 1, 1 and 5 at % and ITO substrate with spin coating at 3000 pm for 30s, used. They reported the linear current–voltage (I–V) characteristics under both forward and reverse bias exhibit ohmic metal–semiconductor contacts.[9]

Dojalisa Sahu et al.
Zinc acetate and Boric acid were taken to grow the films as starting and doping source materials then dissolved them into deionized water and stirred for 30 min. The doping concentrations were 0.001, 0.002, 0.003, 0.004 and 0.005 and using ultrsonication method the samples were obtained. They reported the Hall measurement showed interesting properties like with initial boran doping concentration as resistivity deceased, conductivity and mobility increased but obtained for higher doping concentration it seemed reverse in the film samples.[10]

CONCLUSION

In this review various types of methods have been summarized to prepare un-doped and boron doped zinc oxide (ZnO).Zinc oxide is a low cast and non-toxic semiconductor materials which is very useful for many applications. In this review the electrical properties of un-doped and boron doped ZnO materials prepared by various methods have been investigate with various dopant concentration.

REFERENCES

[1]. S. D. Senol, O. Ozturk, and C. Terzioğlu, “Effect of boron doping on the structural, optical andelectrical properties of ZnO nanoparticles produced by the hydrothermal method,” Ceram.Int.,vol. 41, no. 9, pp. 11194–11201, 2015, doi: 10.1016/j.ceramint.2015.05.069.

[2]. T. Hurma, "Effect of boron doping concentration on structural optical electrical properties of nanostructured ZnO films," J. Mol. Struct., vol. 1189, pp. 1–7, 2019, doi:10.1016/j.molstruc.2019.03.096.
[3]. M. Caglar, S. Ilican, Y. Caglar, and F. Yakuphanoglu, "Boron doped nanostructure ZnOfilmsonto ITO substrate," J. Alloys Compd., vol. 509, no. 6, pp. 3177–3182, 2011,doi:10.1016/j.jallcom.2010.12.038.
[4]. C. Y. Tsay and W. T. Hsu, "Sol-gel derived undoped and boron-doped ZnO semiconductor thinfilms: Preparation and characterization," Ceram. Int., vol. 39, no. 7,pp.7425–7432,2013,doi:10.1016/j.ceramint. 2013.02.086.
[5]. S. Kim, H. Yoon, D. Y. Kim, S. O. Kim, and J. Y. Leem, "Optical properties and electrical resistivity of boron-doped ZnO thin films grown by sol-gel dip-coating method," Opt. Mater.(Amst)., vol. 35, no. 12, pp. 2418–2424, 2013, doi: 10.1016/j.optmat.2013.06.048.
[6]. L. Gao, Y. Zhang, J. M. Zhang, and K. W. Xu, "Boron doped ZnO thin films fabricated by RF-magnetron sputtering," Appl. Surf. Sci., vol. 257, no. 7, pp. 2498–2502,2011,doi:10.1016/j.apsusc.2010.10.009.
[7]. L. H. Wong and Y. S. Lai, "Substrate temperature dependence of material, optical, and electronic properties of boron-doped ZnO thin films," Opt. Mater. (Amst)., vol. 115,no.April,p.111052,2021,doi:10.1016/j.optmat.2021.111052.
[8]. G. Kim, J. Bang, Y. Kim, S. K. Rout, and S. I. Woo, "Structural, electrical and optical properties of boron doped ZnO thin films using LSMCD method at room temperature," Appl. Phys.AMater.Sci. Process., vol. 97, no. 4, pp. 821–828, 2009, doi:10.1007/s00339-009-5317-9.
[9]. S. Bhattacharjee, M. Basu, and A. Roy, "Optical and electrical properties of undoped and boron doped zinc oxide synthesized by chemical route," AIP Conf. Proc., vol. 1675,2015,doi:10.1063/1.4929165.
[10]. D. Sahu, A. Palai, and N. R. Panda, "Electrical conduction mechanism in nanocrystalline ZnOinduced by donor/acceptor doping," J. Mater. Sci. Mater. Electron., vol. 33, no. 11, pp. 8504–8518,2022,doi:10.1007/s10854-021-06408.