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Investigation of Optical and Electrical Property of Polyaniline-Zinc Ferrite Nanocomposites

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Abstract: *Zinc Ferrite nanoparticles are synthesised by solution combustion method with urea as fuel. The prepared ferrite nanoparticles are added to the Polyaniline polymer during chemical oxidative polymerization to get Polyaniline-Zinc ferrite nanocomposites in different weight ratios(10%, 30% and 50%).XRD confirms the formation of the nanocomposite as the XRD spectrum of the composite has Characteristic sharp peaks of zinc ferrite and the characteristic broad peak of Polyaniline. From the UV-Vis absorption data, the optical direct band gap is estimated with the help of Tauc plot and the obtained optical band gaps are found to decrease as the content of Zinc ferrite inpolyaniline composites increases. DC conductivity increases as the percentage of zinc ferrite increases in the polyaniline matrix.*

Keywords: Zinc Nano-ferrite, Chemical oxidative polymerization, Composites, Optical direct band gap,DC conductivity

I. INTRODUCTION

Polymers are a class of materials which are widely studied. Polymers can be embedded with different inorganic or organic materials to get polymer nanocomposites which have their own properties. Polymers embedded with nanoparticles can lead to enhancement of various properties in the composites. Among polymers there are few conducting polymers like Polyaniline, Polythiophene, Poly-pyrrole which have good electrical conductivity [1-3]. Polyaniline is a conducting polymer with very good electrical conductivity with unique properties such as good electrical and optical properties, good chemical stability, easily synthesisable, low cost of synthesis etc. The electrical properties of polyaniline can be altered by oxidation levels and also the other factors likethe ratio of oxidant to that of monomer, the nature of dopantand also the temperature kept during its synthesis.[4]Polyaniline in different composites have important applications like in batteries[5], photovoltaic cells[6], sensors[7], LED [8]corrosion devices, fuel cells[9] to name a few.The composites are developed to have many desired properties and materials in one compound. Among the composites of polyaniline, the composites of polyaniline with magnetic ferrite particles are emerging as ferrite particles have magnetic properties. Polyaniline- ferrite composites have mainly applications like electromagnetic shielding [10], microwave absorption [11] etc which are need of the day in the present electronic world. Ferrite studied in the present work is zinc ferrite which has spinel structure. Zinc ferrite is widely studied among ferrites and has applications such as temperature sensor[12], biomedical applications[13],environmental remediation etc.The nanoparticles of zinc ferrite are synthesised by solution combustion method (SCM). SCM is an one step efficient method of synthesis of ferrites. The nanoparticles of zinc ferrite are embedded into the polyaniline matrix during the polymerization of aniline by chemical oxidative method in different weight ratio (10%, 30% and 50%). The DC electrical conductivity and optical properties are studied.

II. EXPERIMENTAL

A. Method of Synthesis of Zinc ferrite Nanoparticles.

Zinc ferrite nanoparticles were prepared by one step method of low temperature Solution combustion method. Zinc Nitrate Hexahydrate ($Zn(N0_3)_2.6H_20$) and Ferric Nitrate Nonahydrate ($Fe(N0_3)_2.9H_20$) are taken in stoichiometric ratio in 100 ml deionised water and to it fuel urea is added and stirred with a magnetic stirrer to get clear solution. The clear solution is then placed in silica crucible and heated in Muffle furnace at 500 ^{0} C to get porous and voluminous powder. The obtained sample is then calcined.[14]

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B. Synthesis of Nanocomposites of Polyaniline Zinc Ferrite

The schematic diagram of synthesis method is shown in fig.1.The Aniline monomer is added to HCl in a beaker and stirred to get aniline hydrocholoride. Ammonium persulphate (Oxidiser) is added drop by drop continuously to the aniline hydrochloride solution till the colour of the solution changes from brownish to dark green. The beaker is kept in ice bath maintained at 0-5^0 C. The solution is stirred continuously and kept for polymerization. Whatman filter paper is used to filter the solution and the resulting precipitate obtained was washed with distilled water and acetone multiple times to remove any impurities. The precipitate was dried in air and then dried in hot air oven at 60^0 C. Polyaniline as final product was obtained. The prepared Nano-ferrite powder is added during thepolymerization of Polyaniline by above mentioned method in different weight percentages to get Nanocomposites of Polyaniline Zinc ferrite as reported in our earlier work [14]

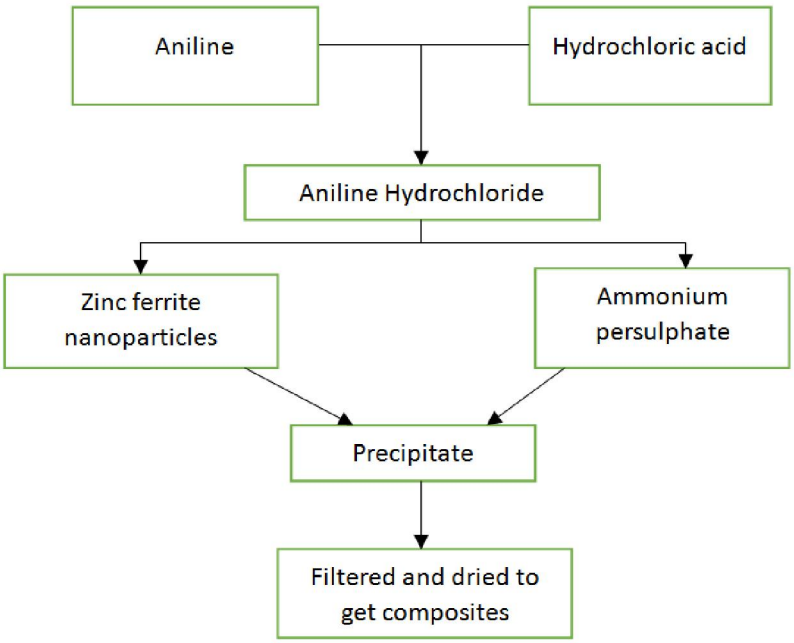

Fig.1 Schematic method for synthesis of Polyaniline-zinc ferrite composites

III. RESULTS AND DISCUSSION

A. XRD Analysis

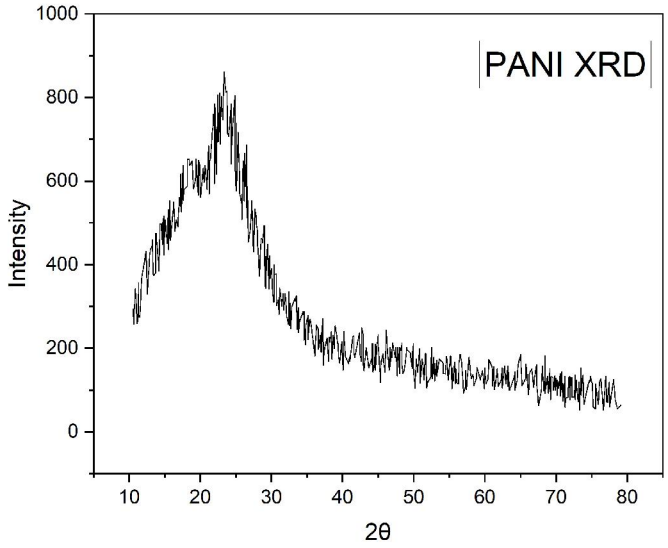

Fig.2 XRD Spectrum of Polyaniline

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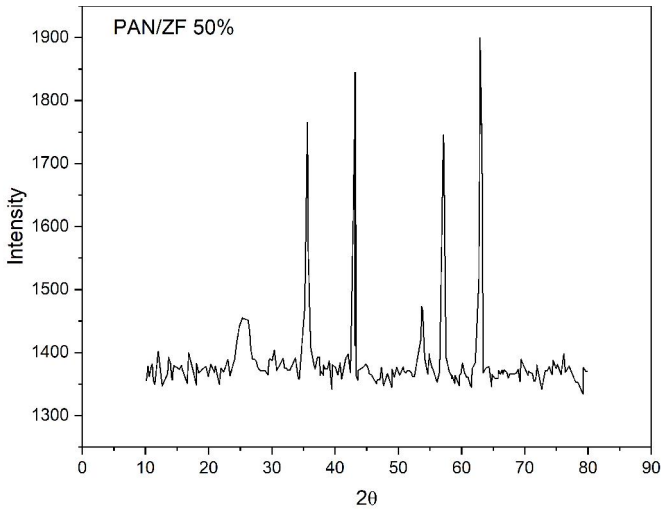

Fig.3 XRD spectrum of Polyaniline-Zinc ferrite 50% composite

The powder of the samples are subjected to powdered XRD analysis in the 2θ range of 10 to 80^0 to study the nature of the samples. XRD spectrum of Polyaniline has broad diffuse peak at 2θangle of 23.15^0indicating the amorphous nature of Polyaniline as shown in fig.2[15].Fig.3 is the XRD spectrum of the composite of Polyaniline- zinc ferrite 50% and it showsthe broad peak of Polyaniline and sharp peaks of that of zinc ferrite and thus confirms the formation of the composite. Zinc ferrite hassharp intense peaks at 2θ angles of 35^0, 43^0, 53^0, 57^0, 62^0 which correspondingly could be indexed to (hkl) planes of (311), (400), (331), (422), and (511)[16]

B. DC conductivity

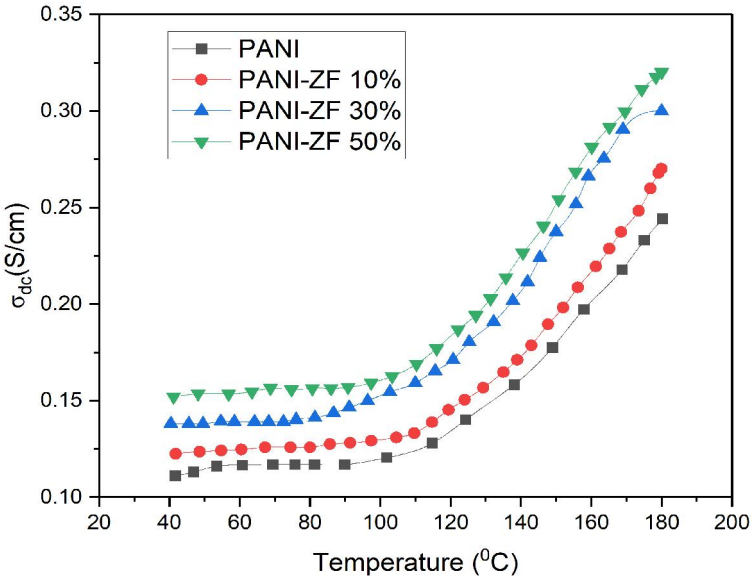

Fig. 4Variation of DC conductivity of samples as a function of temeprature

The powdered samples were made into pellets using hydraulic press and DC conductivity measured with Keithley 6514 electrometer in the temperature range of 40 ^{0} C to 180 ^{0} C. The DC conductivity was measured for Polyaniline and all polyaniline-zinc nanoferrite composites (wt% of 10%, 30% and 50%) and is shown in the fig. 4. In all the samples we see the DC conductivity increasing as function of temperature, signifying the semiconductor nature of the samples [17]. Conduction occurs due to the hopping of charge carriers and the efficiency of charge transfer between the ferrite particles and polymer chain increases with increases of temperature.The highest DC conductivity is seen at 50wt % with a value of 0.325 S/cm.

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C. Activation Energy

The activation energy is measured for all the polyaniline-zinc ferrite composites. Activation energy for dc conductivity is calculated with Arrhenius equation given below[18]

$$\sigma_{dc} = \sigma_0 \exp\left[\frac{-E_a}{2k_B T}\right]$$

Where σ_0 is the pre-exponential factor and $E_a$is the activation energy,K_B is the Boltzmann constant and T is the absolute temperature. The activation energy is calculated by taking the slope of linear fitted Arrhenius plot of Log(σ_{dc}) vs 1000/T as plotted in fig. 5 and these take values of 0.37eV, 0.36 eV and 0.35 eV for 50%, 30% and 10% composites.The activation energy is highest in Polyaniline-Zinc ferrite 50%.

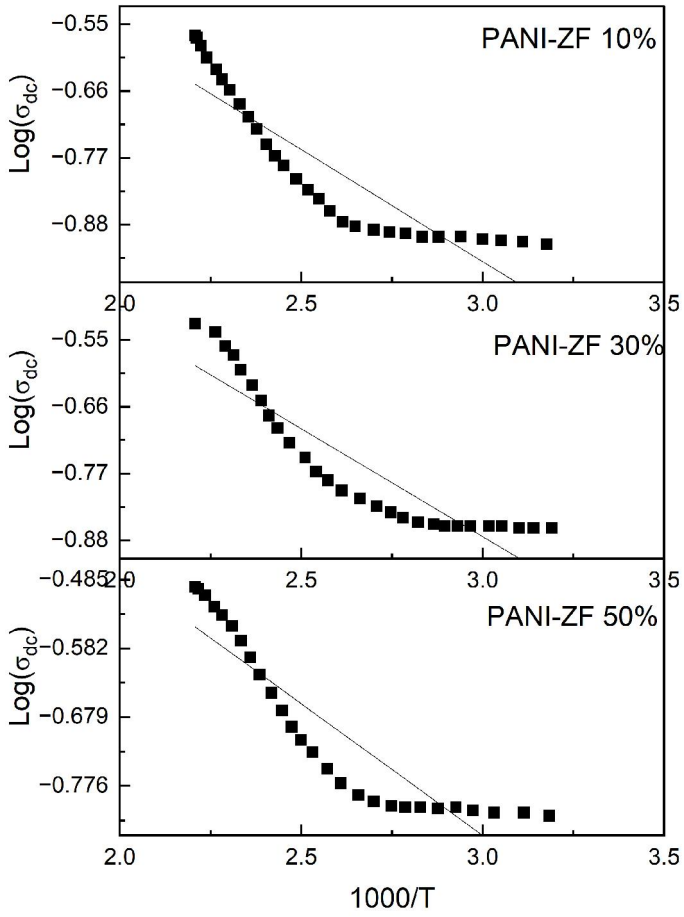

Fig 5.Arrhenius plot Ln(σ_{dc}) vs 1000/T for Polyaniline Zinc ferrite composites

D. Optical Bandgap

Optical properties of the samples are studied with UV-visible absorption spectrometer in the wavelength range of 200-800 nm at room temperature. The powdered samples are dissolved in the solvent and placed in cuvette for UV-Visible spectrometer analysis.From the absorption data the optical band gap values are calculated by extrapolating the x -axis on a graph of $(\alpha h\nu)^2$vs hv(Tauc plot). Where α is the absorption coefficient, h is Planck's constant and v is the frequency.The direct optical band evaluated from Tauc plot seen in fig.6 and these take values of 2.79 eV, 2.68 eV and 2.55 eV. The direct band gap decreases with increase of Zinc ferrite content in Polyaniline matrix which is due to the electronic structure change with the creation of new levels as the defects increase as polyaniline matrix gets doped with ferrite.

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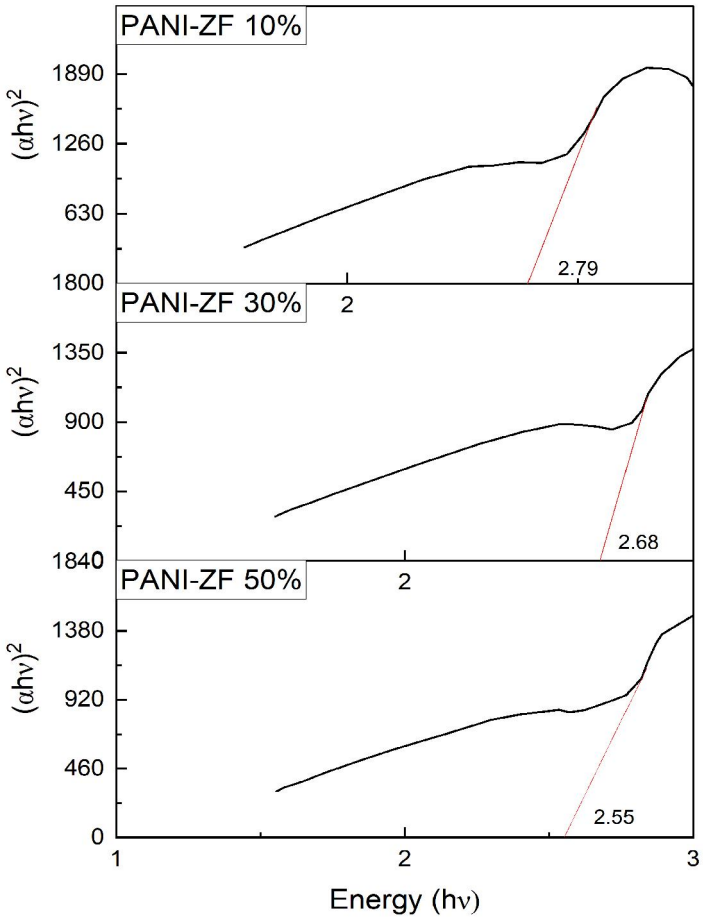

Fig.6 Tauc plot of Polyaniline-Zinc ferrite composites

IV. CONCLUSION

Zinc ferrite is prepared by solution combustion method using urea as fuel. Polyaniline-Zinc ferrite composites are prepared by insitu chemical oxidative polymerization. XRD spectrum of polyaniline confirms its amorphous structure and the XRD spectrum of Polyaniline-zinc ferrite 50%confirmed the formation of the compositeas it has sharp peaks of zinc ferrite along with peak of polyaniline. DC conductivity of the composites increased in the composites and is seen highest in Polyaniline-Zinc ferrite 50%. From the UV-Vis data using Taucplot Optical band gap for the composites are evaluated and it is found to decreases in the composites as percentage of zinc ferrite content increases

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REFERENCES

[1]. McManus PM, Cushman RJ, Yang SC. Influence of oxidation and protonation on the electrical conductivity of polyaniline. Journal of Physical Chemistry. 1987 Jan;91(3):744-7.

[2]. Samuelson LA, Druy MA. Kinetics of the degradation of electrical conductivity in polypyrrole. Macromolecules. 1986 May;19(3):824-8.

[3]. Furukawa Y, Akimoto M, Harada I. Vibrational key bands and electrical conductivity of polythiophene. Synthetic Metals. 1987 Feb 1;18(1-3):151-6.

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[4]. Boeva ZA, Sergeyev VG. Polyaniline: Synthesis, properties, and application. Polymer Science Series C. 2014 Sep;56(1):144-53.

[5]. Bhadra S, Khastgir D, Singha NK, Lee JH. Progress in preparation, processing and applications of polyaniline. Progress in polymer science. 2009 Aug 1;34(8):783-810.

[6]. Badi N, Roy AS, Al-Aoh HA, Alghamdi SA, Alatawi AS, Ignatiev A. Synthesis of Hybrid Polyaniline–Graphene oxide–Sulfur Nanocomposite Fibers Through Ice Nucleation as a Cathode Materials for Lithium-Sulfur Battery. Materials Science for Energy Technologies. 2023 Mar 16.

[7]. Borode T, Wang D, Prasad A. Polyaniline-based Sensor for Real-time Plant Growth Monitoring. Sensors and Actuators A: Physical. 2023 Mar 23:114319.

[8]. Koventhan C, Chung YC, Lo AY, Weng HC, Hung WH. Development of a polyaniline/CMK-3/hydroquinone composite supercapacitor system. Materials Chemistry and Physics. 2023 Jan 12:127369.

[9]. Kumar S, Fu YP. ZnCo-layered double hydroxides coupled polyaniline-derived porous carbon: An efficient electro-catalyst towards supercapacitor and fuel cells application. Journal of Energy Storage. 2023 Jun 1;62:106862.

[10]. Rashid IA, Hamza A, Asim S, Zubair K, Shakir HF, Afzal A, Zubair Z. Achieving enhanced electromagnetic shielding by novel flexible rubber based nanocomposite with the incorporation of nickel spinal ferrites and polyaniline. Synthetic Metals. 2023 May 1;295:117339.

[11]. Liu X, Ji R, Yang M, Chen W, Chen H, Song X, Liu J, Zhang M, Zhang L. Facilitating enhanced microwave absorption properties of barium hexaferrite/polyaniline composites based on tunable interfacial polarization by rare earth doping. Journal of Alloys and Compounds. 2023 Mar 15;937:168391.

[12]. Singh A, Singh A, Singh S, Tandon P, Yadav BC, Yadav RR. Synthesis, characterization and performance of zinc ferrite nanorods for room temperature sensing applications. Journal of Alloys and Compounds. 2015 Jan 5;618:475-83.

[13]. Yang Y, Liu X, Yang Y, Xiao W, Li Z, Xue D, Li F, Ding J. Synthesis of nonstoichiometric zinc ferrite nanoparticles with extraordinary room temperature magnetism and their diverse applications. Journal of Materials Chemistry C. 2013;1(16):2875-85.

[14]. Kolhar P, Sannakki B. Investigation of the electrical properties of synthesised polyaniline-magnesium ferrite composites. Materials Today: Proceedings. 2023 Mar 11

[15]. Hefnawy MA, Medany SS, El-Sherif RM, Fadlallah SA. NiO-MnOx/Polyaniline/Graphite Electrodes for Urea Electrocatalysis: Synergetic Effect between Polymorphs of MnOx and NiO. ChemistrySelect. 2022 Mar 29;7(12):e202103735.

[16]. Pund SN, Nagwade PA, Nagawade AV, Thopate SR, Bagade AV. Preparation techniques for zinc ferrites and their applications: A review. Materials Today: Proceedings. 2022 Mar 5.

[17]. Rashid IA, Hamza A, Asim S, Zubair K, Shakir HF, Afzal A, Zubair Z. Achieving enhanced electromagnetic shielding by novel flexible rubber based nanocomposite with the incorporation of nickel spinal ferrites and polyaniline. Synthetic Metals. 2023 May 1;295:117339.

[18]. Zeshan M, Ali M, Alanazi MM, Abdelmohsen SM, Khosa RY, Al-Sehemi AG, Ansari MZ, Tayeb RA, Farid HM, Rahman MM. Study of SrEr0. 04Fe1. 96O4/PANI nano-composites for high-frequency applications. Ceramics International. 2023 Mar 24.

[19]. Patil R, Roy AS, Anilkumar KR, Jadhav KM, Ekhelikar S. Dielectric relaxation and ac conductivity of polyaniline–zinc ferrite composite. Composites Part B: Engineering. 2012 Dec 1;43(8):3406-11