1. Introduction
Conjugated polymers have attracted lot of attention due to their unique electrical properties and have been defined as “the polymers, which have a frame work of alternating single and double carbon–carbon (sometimes carbon–nitrogen) bonds” [1]. The transport properties of conducting polymers are strongly dependent on the structural disorder arising from sample quality, doping procedure and aging. Conducting polymers generally display a wide variety in their unique electrical properties and have been defined to their morphology and being partially crystalline and partially amorphous as “the polymers, which have a frame work of alternating single and double carbon–carbon (sometimes carbon–nitrogen) bonds” [1]. The transport properties of conducting polymers are strongly dependent on the structural disorder arising from sample quality, doping procedure and aging. Conducting polymers generally display a wide variety in morphology and being partially crystalline and partially disordered. Even if the polymer chains are well-ordered, macroscopic transport is not possible unless the charge carriers are localized, so they should move in material by hopping over or tunneling through the potential barriers between the localized states. Variable range hopping (VRH) is the most common charge transport mechanism and this model assumes that carriers tunnel through the energy barriers between the localized states with help of phonon thermal energy [21]. 3D-VRH occurs in disordered polymers with structures similar to the amorphous semiconductors, where charges can choose a most easy hop in any direction. Quasi-1D VRH occurs in the polymers where charges move along the polymer chain, with sudden inter-chain hops [22]. In some cases polymerization and protonation leads to creation of small conducting islands distributed in non-conductive matrix. In such case charges tunnel between these regions according to charged energy limited tunneling (CELT) mechanism [23]. In the present paper, the preparation of polyaniline / Dysprosium oxide (PANI / Dy2O3) composites, its characterization through XRD, FTIR & SEM, transport properties such as ac conductivity is reported.

2. Experimental
All Chemicals used are analytical grade (AR) and were procured, used as received. The monomer aniline was doubly distilled prior to use. Synthesis of Polyaniline / Dysprosium oxide (Dy2O3) composites has been carried out by single step in situ polymerization technique. 0.1 mol of aniline was dissolved in 1 M of Hydrochloric acid to form aniline hydrochloride. Finely grinded powder of Dysprosium oxide (Dy2O3) is added in the weight percent of 10, 20, 30, 40 and 50 to the above solution with vigorous stirring to keep its characterization through XRD, FTIR & SEM, transport properties such as ac conductivity is reported.

**ABSTRACT**
The conducting polyaniline / Dysprosium oxide (PANI / Dy2O3) composites were synthesized by single step in situ polymerization technique by placing finely grinded powder of Dy2O3 during the polymerization of aniline. The formation of mixed phases of the polymer together with the conducting emeraldine salt phase was confirmed by spectroscopic techniques like XRD, FTIR & SEM images indicated a systematic morphological variation of particles aggregated in the composite matrix as compared to the PANI. AC conductivity of these composites were investigated in the frequency range 50 Hz to 5MHz. It is found that AC conductivity obeyed the power law index and the variation of conductivity with wt% of Dy2O3 could be related to conductivity relaxation phenomenon.

**KEYWORDS**
Polyaniline, Dysprosium oxide, AC conductivity

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**Research Paper**

**AC Conductivity Study of Polyaniline / Dysprosium Oxide (PANI / Dy2O3) Composites**

**Physics**

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**ABSTRACT**
The conducting polyaniline / Dysprosium oxide (PANI / Dy2O3) composites were synthesized by single step in situ polymerization technique by placing finely grinded powder of Dy2O3 during the polymerization of aniline. The formation of mixed phases of the polymer together with the conducting emeraldine salt phase was confirmed by spectroscopic techniques like XRD, FTIR & SEM images indicated a systematic morphological variation of particles aggregated in the composite matrix as compared to the PANI. AC conductivity of these composites were investigated in the frequency range 50 Hz to 5MHz. It is found that AC conductivity obeyed the power law index and the variation of conductivity with wt% of Dy2O3 could be related to conductivity relaxation phenomenon.
3. Results and discussions

Figure 1. Shows X-ray diffraction pattern of Polyaniline. Careful analysis of X-ray diffraction of polyaniline suggests that it has semi-crystalline nature with a broad peak centered around 2θ = 270°. XRD spectra of pure PANI, shows a broad reflection at lower Bragg angle 2θ value of 25.38° corresponding to (200) diffraction plane of ES-I structure of HCl doped PANI (Joo et al 1998).

Figure 2. shows the X – Ray diffraction pattern of Polyaniline - Dy2O3 composite (50 wt % Dy2O3 in PANI). By comparing the XRD pattern of composite with that of Dy2O3 (ICPDS No. 22-0612) the prominent peaks corresponds to 2θ = 29.59° i.e. first peak no change, 31.09° shifted to 34.12, 48.55° and 58.64° corresponds to (211), (222), (422) and (433) planes of Dy2O3 respectively. By comparing the XRD patterns of the composite and Dy2O3, it is confirmed that Dy2O3 has retained its structure even though dispersed in PANI during polymerization reaction. The semi sharp peak of PANI at 2θ has widened this is due to doping Dy2O3 in PANI.

SEM micrograph of conducting polyaniline synthesized by chemical oxidative method is shown in figure 3. It can be clearly seen that the micrograph of polyaniline is smooth and homogeneous. Since Hydrochloric acid is used as protonic acid in the preparation of polyaniline, the presence of micro-crystalline structure can be seen that is not homogeneously distributed throughout. The presence of microcrystalline structures in polyaniline in this particular samples can be confirmed from XRD studies. Since conducting polymers are very sensitive to the temperature, due to the interaction between electron and the sample, considerable amount of heat is generated which causes the development of mall crackening in the sample during SEM recording. A granular morphology of the microcrystalline structures is measured and is found to be about 200 – 600 Å in diameter for polyaniline which is consistent with other reports [10-15]. The contrast in the image is a result of differences in scattering from different areas of the surface as a result of geometrical differences.

Figure 4. Shows the SEM of polyaniline – Dy2O3 composite (50 wt % of Dy2O3 in polyaniline). Among the five composites that were synthesized using Dy2O3 with different wt % (10, 20, 30, 40 and 50), a composite of polyaniline – Dy2O3 with 50 wt % of Dy2O3 in polyaniline is selected to obtain the SEM micrograph.

From SEM micrograph it clearly indicates highly branched chain structure (or fibrillar morphology). The presence of Dy2O3 has a strong influence on various electrical parameters such as conductivity. The contrast in the image is due to the difference in scattering from different surface areas as a result of geometrical differences between polyaniline and Dy2O3.

Figure 5. Shows the IR spectra of Polyaniline where the transmittance is plotted as a function of wave number (cm⁻¹). Careful analysis of the spectra from the figure 5 reveals the presence of intensity peaks 1578 cm⁻¹, 1486 cm⁻¹, 1300 cm⁻¹, 1239 cm⁻¹, 1140 cm⁻¹ and 880 cm⁻¹. The intense peaks at 1578 cm⁻¹, 1486 cm⁻¹, 1300 cm⁻¹ and 1239 cm⁻¹. The intense peaks at 1578 cm⁻¹ and 1486 cm⁻¹ may be attributed due to the presence of quinoid rings. This is further supported by the FTIR spectra of vacuum-deposited polyaniline thin film. The characteristic signature of polyaniline structure is visible in the FTIR spectra of the thin film. The FTIR spectra of the thin film confirmed the presence of amino group.

The IR spectra of polyaniline – Dy2O3 composite (50 wt % of Dy2O3 in PANI) is shown in Fig 6. The characteristic stretching frequencies are observed at 3450 cm⁻¹, 2919 cm⁻¹, 2845 cm⁻¹, 1739 cm⁻¹, 1647 cm⁻¹, 1573 cm⁻¹, 1486 cm⁻¹, 1387 cm⁻¹, 1295 cm⁻¹, 1245 cm⁻¹, 1165 cm⁻¹, 1140 cm⁻¹, 1116 cm⁻¹, 1011 cm⁻¹, 887 cm⁻¹, 819 cm⁻¹, 707 cm⁻¹, 618 cm⁻¹, 598 cm⁻¹ and 504 cm⁻¹. By comparing the IR spectra of polyaniline and polyaniline – Dy2O3 composite, it is observed that in the composite the characteristic stretching frequencies are shifted toward higher frequency side which may be attributed due to the Vander walls kind of interaction between Dy2O3 and polyaniline chain.

Figure 7. Show the variation of ac conductivity as a function of frequency for polyaniline – Dy2O3 composites (for different weight %). It is observed that in all the cases, σac remains constant up to 10⁴ Hz. In case of composites with 10, 20, and 30 wt % of Dy2O3 in PANI, the conductivity slightly increases after 10⁴ Hz and in case of composites with 40 and 50 wt % the conductivity increase after 10⁵ Hz. The anomaly in the conductivity behavior of these composites is due to the variation in the distribution of Dy2O3 in PANI i.e. weight % of Dy2O3 in PANI.

Figure 8. Show the variation of σac as a function of wt% of Dy2O3 in polyaniline at three different frequencies at room temperature. It is observed that in all the composites the conductivity increases up to 40wt % of Dy2O3 in polyaniline and then decreases rapidly for 50wt %. This may be due to the extended chain length of polyaniline, which facilitate the hopping of charge carriers when the content of Dy2O3 is up to 40wt %. Further the decrease in conductivity for 50wt % is attributed due to the trapping of charge carrier hop.

4. Conclusion

Polyaniline composites with different weight percentages of Dy2O3 in PANI were synthesized by chemical oxidative polymerization of monomer aniline. Detailed characterizations of the composites were carried out using XRD, SEM and IR techniques. The result of XRD and SEM reveals the semi crystalline nature of the PANI / Dy2O3 composites. The signature of Dy2O3 has been observed in the PANI / Dy2O3 FTIR spectra. The results of ac conductivity show a strong dependence on the weight percent of Dy2O3 in polyaniline. The values of conductivity of these composites are found be in the semi-conducting range.
Figure 3 SEM Micrograph of Polyaniline

Figure 4 SEM Micrograph of Polyaniline - Dy₂O₃ (50 wt %)

Figure 5 FTIR spectra of pure PANI

Figure 6 FTIR spectra of PANI /Dy₂O₃ composite (50 wt %)

Figure 7 Variation of ac conductivity as a function of frequency for Polyaniline Dy₂O₃ Composites

Figure 8 Variation of ac conductivity as a function of wt % for Polyaniline Dy₂O₃ at different frequencies

REFERENCE