Research Paper

Dielectric and ac Conductivity Studies of Sodium Alginate/ $FeCl_3$ and Carboxy Methly Cellulose/ $FeCl_3$ Composites

S. Suresha[1], R. Ashok Lamani[2] , H. S. Jayanna[2], V. S. Chathurmukha[2], B. S. Avinash[2] and B. M. Harish[2]

[1]Physics Dept., Govt. First Grade College, Holalkere Karnataka, India

[2]PG Studies Dept. and Research in Physics, Kuvempu University, Shankaraghatta-577451.Shimoga. Karnataka, India

Email: Ashok1571972@gmail.com

Abstract

The Sodium alginate(NaAlg), Carboxy methyl Cellulose (CMC), ferric chloride ($FeCl_3$) doped sodium alginate and Carboxy methyl Cellulose were prepared separately in the weight percent ratios (90:10) by solution casting. The lms were characterized by X-ray diractometer. Formations of single phase cubic structure of the lms were conrmed by X-ray diraction (XRD) technique. The dielectric measurements of all the samples were measured in the frequency range 100Hz-1MHz at room temperature. The AC conductivity obeys the power law of frequency and dielectric constant, dielectric loss of CMC/$FeCl_3$ increases. The dielectric constant of NaAlg/$FeCl_3$ decreases and dielectric loss increases, while AC conductivity increases with increase in frequency with substitution of $FeCl_3$ with Carboxy methyl cellulose and Sodium Alginate.

Keywords: Composites, Dielectric, Sodium Alginate, Carboxy methyl Cellulose.

1 Introduction

In polymer thin lms, eects due to connement and in-terfacial interactions are responsible for dierent physi-cal phenomena that change with lm thickness. They have high conductivity, and are light in weight, inexpen-sive and exible[1]. The interaction of biopolymers with conducting polymers may generate interesting biopoly-mer/conducting polymer composites, which nd applica-tions where electrical conductivity is desirable, such as in articial nerves, sensors and actuators [2]. Sodium Algi-nate (NaAlg) is a biopolymer sodium salt of Alginic acid, and it is a water-soluble anionic polymer. Alginate oc-curs in the cell wall of brown seaweed. Sodium Alginate (NaAlg) is a polyelectrolyte with good biocompatibility; however, it suers from limitations in fabrication. Their mechanical properties are often poor. In recent years, the modication of such natural polymers has received much attention for the production of new biomaterials with specic properties [3]. Carboxy methyl cellulose (CMC) is a polysaccharide comprising brous tissue of plants. Also, it has a number of sodium Carboxy methyl groups (eCH2COONa) which aids its solubility in water [4]. A Dielectric Study of Sodium Alginate and carboxy methyl cellulose in aqueous solution were reported by the authors [5-6]. Thus these properties of CMC and NaAlg have encouraged us to study dielectric properties of CMC/ $FeCl_3$ and NaAlg/$FeCl_3$. Composites are synthesized separately by solution casting method and then they are structurally characterized using XRD.

2 Experimental

2.1 Materials

Carboxy methyl cellulose, Sodium Alginate of analytical grade reagents were procured from S.D ne chemicals, Mumbai, India and ferric chloride was purchased from Nice Chemicals, Kerala, India.

2.2 Preparation of CMC/ FeCl3 and NaAlg/FeCl3 composites

Films of Sodium Alginate (NaAlg) doped with ferric chloride ($FeCl_3$) and Carboxy methyl cellulose (CMC) doped with ferric chloride ($FeCl_3$) with weight percentage of 90:10 each were prepared separately by using solution casting technique. NaAlg, CMC, $FeCl_3$ were dissolved separately in distilled water and the mixtures were stirred at room temperature for 3 days. The stirred solution was cast in dierent Petri dishes and allowed to evaporate slowly at room temperature for lms to form. Finally lms were carefully separated from the dishes.

3 Results and Discussion

3.1 X-ray Diraction Studies

XRD pattern of Carboxy methyl cellulose (CMC) shows a broad peak at 2 =20 indicating the amorphous nature of CMC which is well established by the published literature [4]. The XRD spectrum of NaAlg shows a broad hump at 2 =28 which indicates the amorphous nature of NaAlg which is also well established by the literature [2]. The XRD patterns of the composites show peak at 2 =32 indicating the single phase cubic structure of CMC/ $FeCl_3$ and NaAlg/$FeCl_3$ as shown in Figure 1.

3.2 Dielectric Studies

The dielectric measurement is a powerful tool for obtaining information about the ion-polymer interaction and conduction mechanism of polymer composites. Based on the concept of polarization, dielectric materials get electrically polarized when an electric eld is applied. The dielectric loss factor can be used to measure the strength and frequency of relaxation, depending on the characteristic properties of unipolar/dipolar relaxation [7].

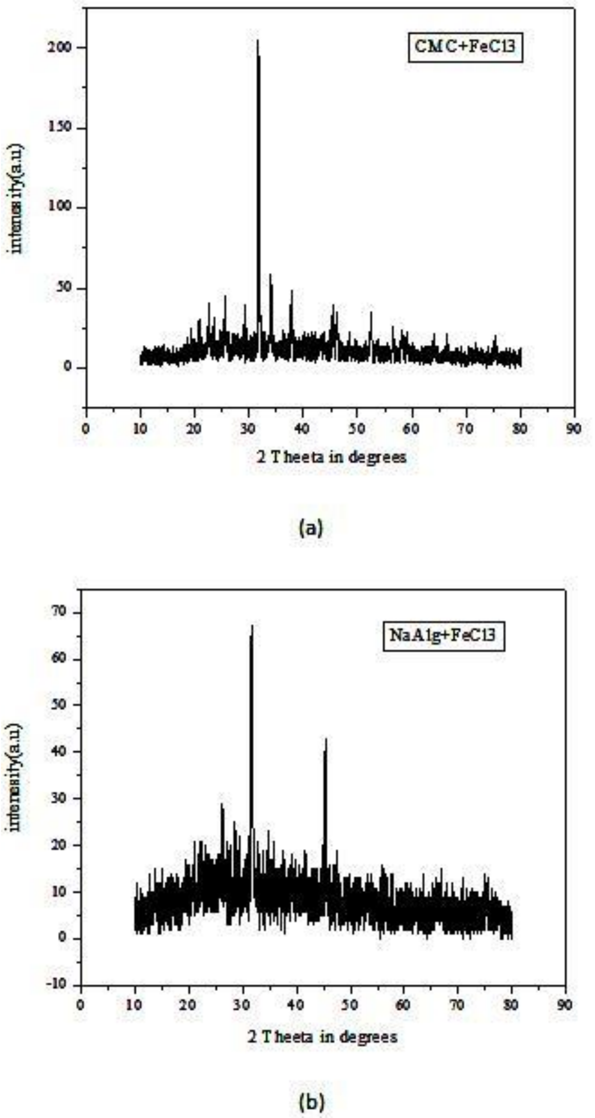


Figure 1: XRD patterns of (a) CMC/ $FeCl_3$ and (b) NaAlg/$FeCl_3$.

Figure 2 (a), (b) and (c) presents the frequency dependent dielectric constant (^{0}), dielectric loss (^{00}) and dielectric loss tangent (tan) of CMC/$FeCl_3$ at room temperature. In dielectric dispersion curves for CMC in aqueous solution at dierent concentrations, a high frequency increment is obtained. The cause of the high frequency increment is not known but several explanations have been discussed [8, 9]. It is evident from the Figure 2(a), (b) and (c) that the values of dielectric constants ,dielectric loss and dielectric loss tangent are low in the low frequency region. As the frequency increases ^{0} ' ^{00} and tan increase; and at lower frequencies the dielectric constants are almost independent of frequency, because at lower frequencies the charge carriers are able to orient themselves in eld direction.

$_0$ In the frequency dependence of the dielectric constant ( ) of Sodium Alginate, two kinds of relaxation processes were observed. The higher relaxation process is due to the uctuation of the bound counter ion(Ikeda et al., 1997), The experimental data were in good agreement with the best t curves using the Cole-Cole equation.

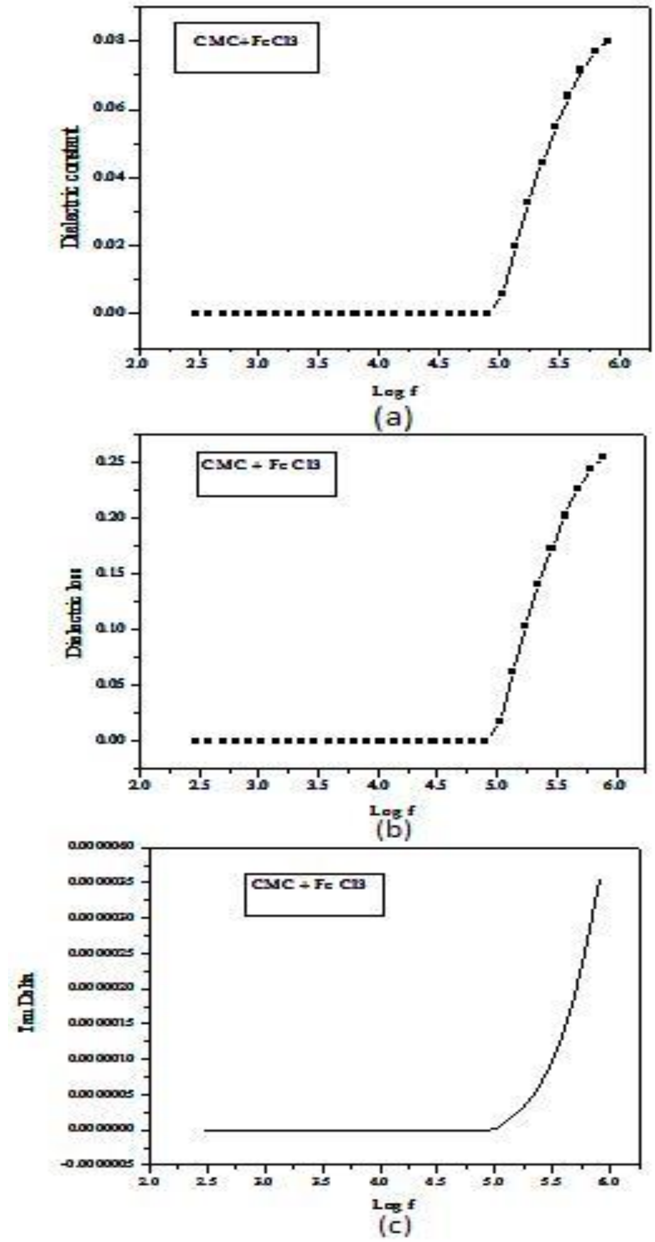
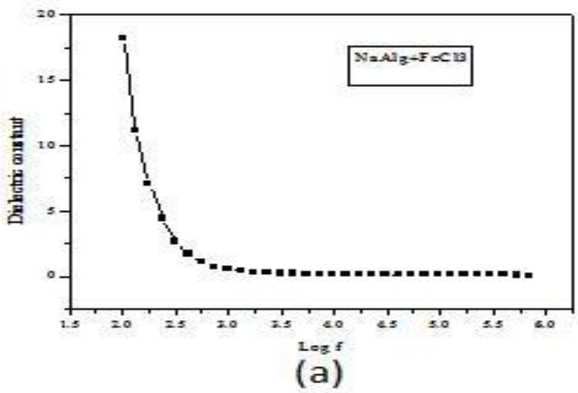


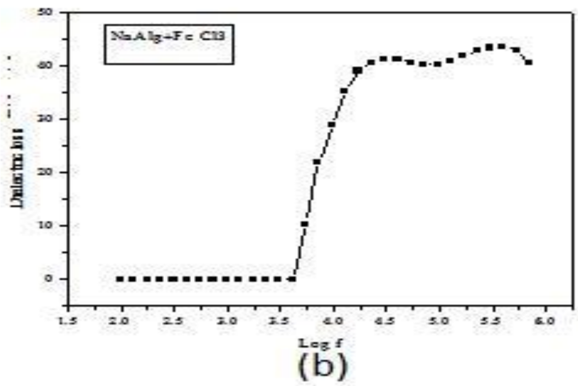
Figure 2: Variation of (a) dielectric constant (b) dielectric loss and (c) tan with frequency at room temperature for CMC/ $FeCl_3$.

Figure 3(a) shows that the values of (^{0}) is high in the low frequency region, conrming the non-Debye type behavior due to the contribution of charge accumulation at electrode-electrolyte interface. As the frequency increases the dielectric constant decreases. The dependence of the ^{00} and tan on frequency of NaAlg/$FeCl_3$ is shown in Figure 3(b) and (c) which shows that ^{00} and tan value increases with increasing frequency. This indicates that the probability per unit time increases with salt concentration. The dispersion observed at low frequencies could be attributed to the interfacial-polarization mechanism.

3.3 AC Conductivity

The dielectric measurements were carried out at room temperature using high precision LCR meter/impedence analyser over a wide frequency range (model N4L-numetriq PSM 1735) In Figure 4(a) and 4(b) are the dependence of AC conductivity on the frequency for CMC/ $FeCl_3$ and NaAlg/$FeCl_3$, AC conductivity behavior of all the prepared samples was investigated over the frequency range 100Hz-1MHz. ac = 2 f 00 , where f is frequency, is the permittivity of free space, and is the dielectric loss.





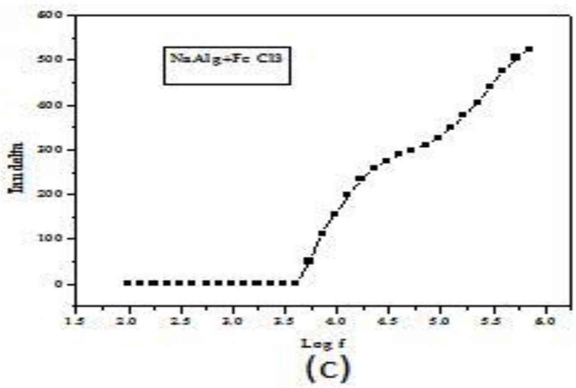
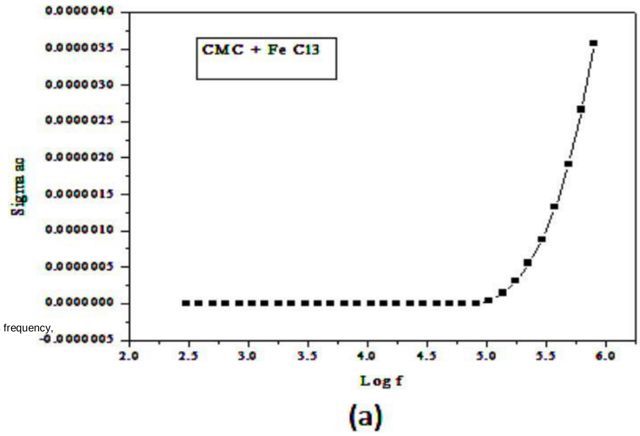
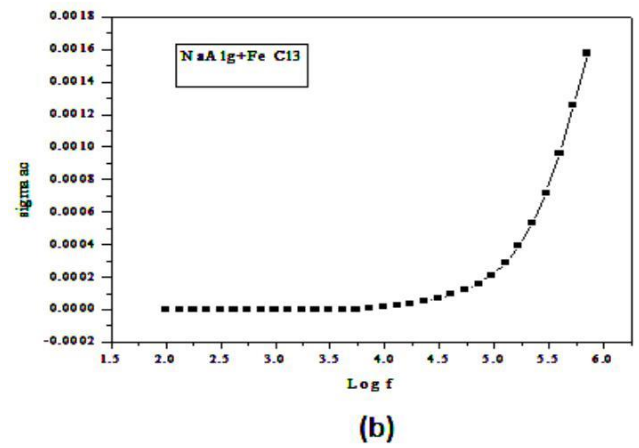
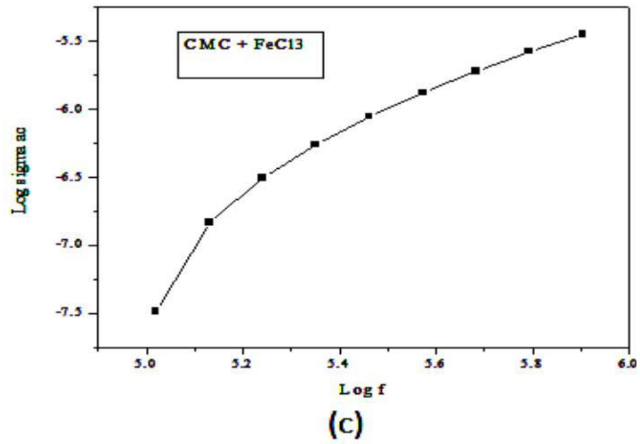


Figure 3: Variation of (a) dielectric constant (b) dielectric loss and (c) tan with frequency at room temperature for NaAlg/$FeCl_3$.







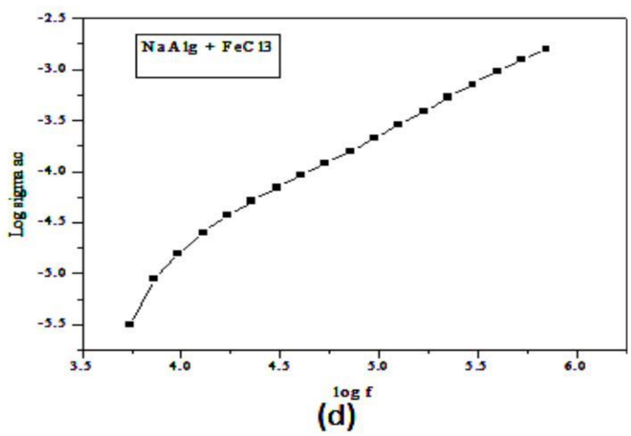


Figure 4: Dependence of AC conductivity on frequency at room temperatures. (a), (c) CMC/ $FeCl_3$ and (b), (d)NaAlg/$FeCl_3$.

The diagrams σ_{ac} versus logf of the lms exhibit similar behavior. The conductivity is lower at lower frequen-cies. The plateau region appeared, as shown in Figure 4(a) and 4(b). This behavior suggests that the hopping mechanism might be playing an important role in the conduction process.

The frequency dispersion of σ_{ac} has been observed to follow a universal power law of ac conductivity.

$$\sigma_{ac}(\omega) = A\omega^{S}$$

where ω is the angular frequency, A and s are experimentally determined material constants, and $\sigma_{ac}(\omega)$ is the frequency dependent conductivity, measured taking the logarithm of Eq. $\sigma_{ac}(\omega) = A\omega^{S}$. In Figure 4(c) and (d) values of the exponent (s) were calculated from the slopes of these lines from the relation between log σ_{ac} ver-sus logf of the higher frequencies. According to the above measurements, it can be noticed that AC conductivity in-creases with increase in frequency. Hence the study has conrmed the AC conductivity obeyed the power law of frequency.

4 Conclusion

In the present work, CMC/ $FeCl_3$ and NaAlg/$FeCl_3$ composites were prepared separately in the weight ratios (90:10) by solution casting. The single phase cubic structure of composites were conrmed by XRD spectra. The frequency dependent dielectric constant (ϵ'), dielectric loss (ϵ'') and dielectric loss tangent tan δ of CMC/$FeCl_3$ are low in the low frequency region. As the frequency in-creases ϵ', ϵ'' and tan δ increase and at lower frequencies they are almost independent of frequency. The dielectric constant (ϵ') of NaAlg/$FeCl_3$ is high in the low frequency region and ϵ'' and tan δ value increase with increasing frequency. The study has shown that the AC conductivity obeyed the power law of frequency.

References

[1] K. Sreelalitha and K. Thyagarajan, "Electrical properties of pure and doped (KNO_3 & $MgCl_2$) polyvinyl alcohol polymer thin lms", IJETCAS, Vol. 4, no. 3, pp. 308-312, 2013.

[2] Y. T. Ravikiran, S. Kotresh, S. C. Vijaya Kumari,
K. C. Sajjan, B. S. Khened and S. Thomas, "AC conductivity studies of p-toluenesulfonic acid doped polyaniline-sodium alginate composites", Cellulose Chemistry and technology, Vol. 49, no. 1, pp. 24-28, 2015.

[3] T. Sheela, R.F. Bhajantri, V. Ravindrachary, Sunil
G. Rathod, P.K. Pujari, Boja Poojary and R. Somashekar, "Eect of UV irradiation on opti-cal, mechanical and microstructural properties of PVA/NaAlg blends", Radiation Physics and Chem-istry, Vol. 103, pp. 45-52, 2014.

[4] Y.T. Ravikiran, S. Kotresh, S.C. Vijayakumari and S. Thomas, "Liquid petroleum gas sensing performance of polyaniline-carboxymethyl cellulose composite at room temperature", Current Applied Physics, Vol. 14, pp. 960-964, 2014.

[5] L. G. Allgen and Siw Roswall, "A dielectric study of sodium alginate in aqueous solution", Journal of Poly-mer Science, Vol. 23, no. 104, pp. 635-650, 1957.

[6] L. G. Allgen and Siw Roswall, "A dielectric study of a carboxymethylcellulose in aqueous solution", Journal of Polymer Science, Vol. 12, pp. 229-236, 1954.

[7] S. G. Rathod, R. F. Bhajantri, V. Ravindrachary,
P. K. Pujari and T. Sheela, "Ionic conductivity and
dielectric studies of $LiClO_4$ doped poly (vinylalco-
hol)(PVA)/chitosan (CS) composites", Journal of Ad-vanced Dielectrics, Vol. 4, no. 4, pp. 1450033(1-7), 2014.

[8] I. Jungner, "Dielectric Determination of Molecular Weight and Dipole Moment of Sodium Thymonucle-ate", Acta Physiol. Scand. 20, Supp. 69, 1950.

[9] L. G. Allgen, "A Dielectric Study of Nucleohistone from Calf Thymus", ibid. 22, Suppl. 76, 1950.

Shinya Ikeda and Hitoshi Kumagai, "Scaling Be-havior of Physical Properties of Food Polysaccharide Solutions:â‰ Dielectric Properties and Viscosity of Sodium Alginate Aqueous Solutions", J. Agric. Food