

ENHANCEMENT OPTICAL PROPERTIES OF CARBOXYMETHYL CELLULOSE BIOPOLYMER COMPOSITE FILMS DOPED WITH CHROMIUM CHLORIDE

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ABSTRACT

Polymers are used in a wide range of manufacture applications for their low cost, light weight, mechanical and optical properties. In this paper, optical properties were studied by various experimental techniques in order to understand the impact of the chromium chloride metal salt on the biopolymer CMC properties. The chromium chloride was add to carboxymethyl Cellulose with weight percentages are (0, 1, 5, 9, 13) wt%. The absorption and transmission spectra has been recorded in the wavelength range (190-1100) nm. The experimental results showed that the absorption coefficient, optical energy gap, extinction coefficient, refractive index and real and imaginary dielectric constant effected by addition different weight percentages from chromium chloride.

CCS CONCEPTS

• Carboxymethyl cellulose, chromium chloride filler, Polymer electrolyte, Optical parameters.;

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1 INTRODUCTION

CMC (sodium carboxymethyl cellulose) is widely employed in petroleum extraction, cement modification, textile manufacture, paper production, soil improvement, and water pollution remediation [1–3]. Carboxymethyl cellulose (CMC) is a water soluble polysaccharide polyanionic polymer that is derived from plant cellulose. CMC was chosen for research because it is biodegradable,

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nontoxic, and capable of forming films [4]. While the preparation of CMCs via acid-catalyzed cellulose-chloroacetic acid reactions is relatively simple, the properties of the resulting product can vary greatly depending on the plant source as well as the cellulose separation method, which results in varying degrees of carboxyl methyl group substitution on the cellulose hydroxyls. These discrepancies have prompted investigation into alternate sources of CMC, such as plant leaf and bark [4-8]; for example, CMC produced from corn straw had a DS of 0.6 to 0.7 [4]. Pure polymeric materials can have their optical characteristics improved by adding an appropriate salt and regulating the concentration [9]. Polymers are employed in a variety of applications because of their inexpensive cost, light weight, and mechanical qualities. The doped polymers could be beneficial in integrated optics or real-time holography, for example. Understanding and controlling the electrical pathways involved in optical behavior is required in order to tailor materials with improved properties within the doped polymer class [10]. CMC has limited ionic conductivity as a pure polymer, hence it must be doped with a salt to increase its ionic conductivity for energy storage device applications [11]. In this study, chromium chloride was used as a dopant in the CMC matrix in order to create CMC/CrCl2.6H2O complex polymer electrolytes.

2 MATERIALS AND EXPERIMENTAL TECHNIQUE

Sigma-Aldrich Germany Company provided carboxymethyl cellulose and chromium chloride. A solution casting process was used to make polymer electrolyte sheets of CMC doped with chromium chloride (CrCl2.6H2O). Using distilled water as the solvent, CMC/CrCl2.6H2O of various weight ratios ((0, 1, 5, 9, 13) wt %) were made, and after hours of vigorous stirring, a homogenous mixture was achieved, which was then cast in glass Petri-dishes. At room temperature, UV-Visible spectroscopic experiments in the wavelength range of 190 – 1100 nm were carried out using a 'Shimadzu UV-1800' (Shimadzu Corp., Japan) spectrometer. The absorbance spectra were used to investigate the changes in the energy band structure caused by CrCl2.6H2O doping. The interaction of the CMC molecules with light was understood by investigating the variation of optical properties like as refractive index, absorption coefficient, and others with wavelength.

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Figure 1: UV-Visible absorption spectra of CrCl2.6H2O doped CMC Composite Films.

3 RESULTS AND DISCUSSION

3.1 Optical absorption spectra and refractive index analysis

The UV-Visible absorbance measurements of CMC film doped with CrCl2.6H2O salt in the wavelength range 190–1100 nm were recorded and are shown in (Figure 1). A single absorption peak will be shown at 200 nm, followed by an exponential drop until the absorbance spectra reached a near constant value above 350 nm, indicating a high optical transmission in the visible region. In the UV area, the absorbance increased significantly as the salt weight percentage increased, particularly for CrCl2.6H2O (13 wt%). The ability of a material to absorb light is expressed in terms of its absorption coefficient, which is determined by the Beer Lamberts law. The absorbance of a polymer increases as the concentration of chromium chloride increases, which is due to the free charge carriers absorbing the incident light [12].

The absorbance coefficient of composite varies with wavelength (Figure 2). When the absorption coefficient values are high ($\alpha > 104 \text{ cm-1}$) at high energies, we expect direct electronic transitions, and the energy and momentum of the electron and photon are preserved; when the absorption coefficient values are low (104 cm-1) at low energies, we expect indirect electronic transitions, and the energy and momentum of the electron and photon are preserved by phonon. The results demonstrate that the composites' absorption coefficients are less than (104 cm-1), indicating that the electronic transition is indirect. The indirect transition's forbidden energy gap [7].

The fraction of electromagnetic energy lost owing to scattering or absorption of photons in the sample is expressed by the extinction coefficient, k (λ). The extinction coefficient declined exponentially with increasing wavelength above ca. (210 nm), as shown in (Figure 3), and its low value in the visible area suggested that photon absorption or scattering was low. In the visible region, the CrCl2.6H2O doped CMC polymer samples demonstrated somewhat higher transparency than the pure CMC polymer film. The refractive index, n, and the extinction coefficient are linked [13].



Figure 2: The absorption coefficient for (CMC/CrCl₂.6H₂O) composite with various wavelength.



Figure 3: Extinction coefficient as the function of wavelength for different weight percentage of CrCl₂.6H₂O in CMC matrix.

Figure 4 shows how the refractive index of composites changes as a function of wavelength. According to the Lorentz - Lorentz formula [14], the value of refractive index increases as the concentration of CrCl2.6H2O increases, which is related to an increase in the number of atomic refractions due to an increase in linear polarizability. Because we know that the refractive index is mostly determined by reflectance, we note that raising the concentration of CrCl2.6H2O increases the refractive index because the reflectance increases. This behavior is attributed to an increase in density as the concentration increases [15, 16].

The loss factor can be determined by calculating the real and imaginary parts of the dielectric constant. The fluctuation of real and imaginary parts of dielectric constants ($\epsilon 1 = n2 - k2$ and $\epsilon 2 = 2nk$) of composites is shown in (Figures 5 and 6). The fluctuation of 1 is shown to be mostly dependent on (n2) due to small values of

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Figure 4: Refractive index as the function of wavelength for different weight percentage of CrCl₂.6H₂O in CMC matrix.



Figure 5: Variation of real part of dielectric constant (CrCl2.6H2O/CMC) composite with energy photon.

(k2), whereas the variation of (ϵ 2) is primarily dependent on (k) values, which are related to the variation of absorption coefficients [17]. The real component of the dielectric constant is linked to the term that describes how much it slows down the speed of light in the material, while the imaginary part describes how a dielectric absorbs energy from an electric field owing to dipole motion [18]. Because the dependence of (ϵ r) on refractive index an (ϵ i) on the value of extinction coefficient and the value of real part are higher than the imaginary parts, the real and imaginary parts of dielectric constant follow the same pattern as the refractive index and extinction coefficient, respectively [19].



Figure 6: Variation of imaginary part of dielectric constant (CrCl₂.6H₂O/CMC) composite with energy photon.



Figure 7: Variation of $(\alpha hv)1/2$ for (CMC/CrCl2.6H2O) composites with photon energy.

3.2 Optical band gap energy

The relationship between the optical band gap energy and the absorption coefficient [20] is given by the equation

$$\alpha hv = B(hv - Eq)^m \tag{1}$$

When E_g is the optical band gap energy, B is an energy independent constant, is the photon frequency, and m is an index whose value is defined by the type of transition; m=2 for an indirect allowed transition. The plot of $(hv)^{1/2}$ versus hv at room temperature for our samples revealed a linear tendency, which can be used as evidence for the indirect allowed transition. The optical band gap

energy is obtained by extrapolating the linear component of this curve to a point $(hv)^{1/2} = 0$. For instance, consider polymer sheets. The fluctuation in optical band gap energy with salt content (7) suggests that there was structural variation due to doping. The salt content is thought to impact the polymer's microstructure, resulting in a shift in optical band gap energy. The optical band gap energy of CMC was 5.2 eV, while it was 4.5, 4.02, 3.9, and 3.8 eV for 1, 5, 9, and 13 wt% CrCl₂.6H₂O, respectively, as shown in (7). As a result of the CrCl₂.6H₂O doping, the optical energy band gap values changed somewhat to lower energies. The Cr⁺ and OH⁻ groups of CMC may create a complex, resulting in microstructural heterogeneity in the polymer matrix. The microstructural alteration occurred as the dopant concentration was increased, and this was represented in a drop in the optical band gap energy, E_g [21].

4 CONCLUSION

A solution casting process was used to make biopolymer electrolyte films of CMC/CrCl2.6H2O. The optical properties of the doped polymer electrolytes differed significantly from those of the pure film, indicating a considerable change in microstructure due to doping.

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