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Synthesis and Characterization of Polyvinyl Alcohol-Gum Arabic Polymer Blend Membranes

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Membranes of poly(vinyl alcohol) (PVA), gum arabic (GA) homopolymer and their blends of six different compositions (w/w) were prepared using solution casting method. Mixing of synthetic polymer *e.g.*, PVA and natural polymer *e.g.*, gum arabic can give a new class of polymer blend with better mechanical properties and biocompatibility than those of single components. The structural, optical and conductivity studies of these prepared membranes were examined by XRD, FTIR, UV and EIS. The XRD diffraction patterns for the polymer blend samples showed that they are more amorphous in nature as compared to pure PVA and pure gum arabic. The FTIR analysis of the samples gave information about various functional groups present in the samples. The energy band gap of various samples were obtained from UV-visible analysis. The conductivity of polymer membrane was analyzed by electronics impedance spectroscopy (EIS). Addition of natural polymer gum arabic has resulted slight increase in the conductivity of blend polymer.

Keywords: Blends, Gum arabic, Polyvinyl alcohol, Ipedance spectroscopy, Electrolyte.

INTRODUCTION

A polymer blend or a blended polymer is a new class of materials equivalent to metal alloys, in which two or more polymers are melded together to form a new material with different physical, chemical and mechanical properties [1]. Blended membranes do not generally improve all of the target properties to any significant extent [2,3]. But the properties of blended membranes are tuneable according to the category or content, of the blended polymers and can thus be formulated with the desired properties for different applications. Polymer blends are used in the area of pharmaceutical fields, food industry, research lab, chemical labs, fuel cell applications, *etc*.

Acacia gum, also known as gum arabic (GA), is a natural gum consisting of the hard-edged sap of various classes of the acacia tree [4,5]. Gum arabic is classed in a group of substances called arabinogalactan proteins. It is essentially a very complex polysaccharide, comprised mostly of galactose, arabinose, rhamnose and glucuronic acid. Gum arabic readily dissolves in water to form highly concentrated solutions of relativity low viscosity, which is the consequence of gum′s highly branched large and estimated weight is suggested to be about 20,000-60,000 daltons. The property of gum arabic is that of brittle, odourless and generally tasteless material that contains a number of neutral sugars, calcium, acids and other electrolytes [6]. The main component of gum is arabin, which is calcium salt of polysaccharide arabic acid. Gum arabic has unique physio-chemical properties [7,8] that makes it desired as a thicker, a stabilizer, and as a packing material in pharmaceuticals and food industries [9]. The wide use of gum arabic is due to its high solubility and low viscosity compared to other polysaccharides, its good emulsifying characteristics and non-toxic nature [10].

Poly(vinyl alcohol) (PVA), a polyhydroxy polymer, is the largest volume, synthetic water soluble polymer produced in the world that has been used globally from the first half of the 20th century [11]. As a chemically resistant emulsifier with good adhesion properties [12,13], PVA has the ability to produce high class films with good mechanical properties [14]. PVA is usually designated as a cross-linker because of its membrane-forming capacities and hydrophilic properties [15].

Hindi *et al*. [15] studied the biodegradation of PVA-GA blend by bacteria and fungi. Several researches [16-19] have been carried out in the structural and electrical conductivity properties of gum arabic . Being a natural polymer, a stabilizer and a thicker gum arabic may change the physical and electrical properties of a synthetic polymer like PVA. The main goal of the present work is to check the electrical conductivity of PVA blended with gum arabic in different weight ratio which may lead to obtain some new and interesting results. Blending of a synthetic polymer PVA with another flexible, natural polymer such as gum arabic seems to be an attractive way for improving properties of film. Gum arabic acts as a supporting layer to the mixture by providing flexibility and it also improves the conductivity of poly(vinyl alcohol).

EXPERIMENTAL

In this work, solution casting method is adopted due to its simplicity, cost effective and the easiest one to prepare the polymer blend films in a wider perspective.

The sample prepared is a polymer blend consisting of an artificial polymer like PVA and a natural polymer *i.e.*, gum arabic. Various samples were prepared using casting method, in which different ratios of both PVA and gum arabic were taken, but their total mass was kept constant as 1 g. These polymers were allowed to dissolve in distilled water and stirred magnetically under room temperature for 24 h. The rotation per minute (rpm) was kept around 300 rpm. The properly mixed sample solution was transferred to a petri-dish (70 mm) for casting. A membrane was obtained which was transparent and flexible in nature.

Preparation of the samples started with sample A wherein 0.9 g of PVA and 0.1 g of gum arabic were added in a 40 mL of distilled water. It was then stirred for 24 h, which resulted in a a clear solution. This solution was then transferred to a 100 mm petri-dish and kept in an oven for 20-24 h at 35- 40 ºC. At the end of process, a transparent and flexible membrane was obtained. Similarly, various membranes were prepared in a same manner using different ratios of PVA and gum arabic as shown in Table-1. A pure PVA membrane (sample G) and pure gum arabic membrane (sample H) were also prepared.

TABLE-1
CONDUCTIVITY AND ENERGY BAND VALUES OF POLYVINYL ALCOHOL-GUM ARABIC POLYMER BLEND MEMBRANES PREPARED IN DIFFERENT RATIO

Sample	Ratio (wt:wt) g PVA:GA	Conductivity (S/cm)	Energy band gap (eV)
A	0.9:0.1	1.710×10^{-8}	5.27
B	0.8:0.2	3.210×10^{-8}	5.23
C	0.7:0.3	8.010×10^{-8}	5.21
D	0.6:0.4	5.477×10^{-8}	5.06
E	0.5:0.5	4.490×10^{-8}	5.08
F	0.3:0.7	2.990×10^{-8}	4.93
G (pure PVA)	1.0:0	–	–
H (pure GA)	0:1.0	–	–

RESULTS AND DISCUSSION

XRD analysis: The stacked X-ray diffractograms for polymer blend samples A-F are shown in Fig. 1. The XRD patterns of polymer blends obtained by mixing of gum arabic and PVA showed that blends are highly amorphous in nature. There is no significant peak observed in the XRD spectra of blended samples.

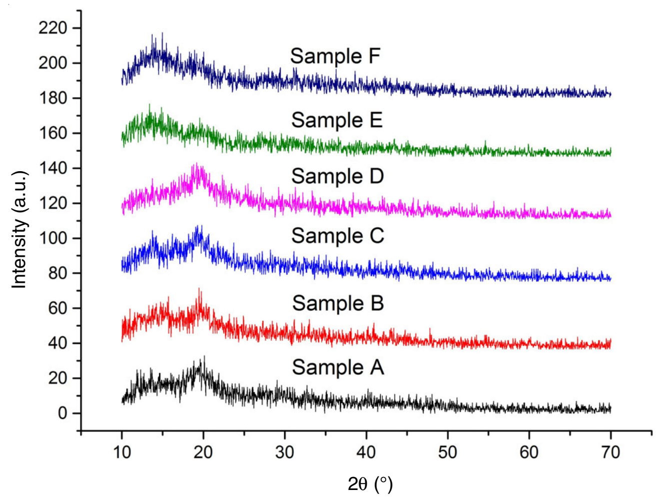

Fig. 1. XRD diffractogram of the six polymer blend membranes

Also, it can be seen that as the gum arabic concentration increases, amorphous nature also increases as no sharp peaks can be visible in samples E and F [19].

Ionic conductivity: Conductivity studies for different polymer blend samples were done at room temperature using a Hioki IM 3536 LCR Meter. For different frequencies, variation in impedance values (Z) and phase were measured. The phase values were converted to radian (θ) and a graph was plotted using Origin software with Zcos θ in the x-axis and Zsin θ in the y-axis. From the graph, bulk resistance (x-intercept) value was obtained and the conductivity of the samples were calculated [18,20] using the following formula:

$$\sigma = \frac{l}{AR_b}$$

where, l is the thickness of sample, A is the area of probe and R_b is the bulk resistance obtained from graph.

The complex impedance plot (Nyquist plot) of six polymer blend samples (A-F) with different wt. % at room temperature are shown in Fig. 2. The intercept of semi-circle (using curve fitting) on the x-axis gives the value of bulk resistance (R_b). The calculated values of ionic conductivity of the blended polymers are gvien in Table-1. It was observed that the addition of gum arabic increases the conductivity and mechanical stability of PVA. It can be seen (Table-1) that ionic conductivity increases on increasing the wt. % of gum arabic. The highest value of conductivity ($\sigma = 8.01 \times 10^{-8}$ S/cm) is attained for sample C (0.7PVA:0.3GA). On further increase in gum arabic wt. %, a drop in ionic conductivity was observed. The increase in conductivity could be due to the presence of gum arabic expediting the path for ionic transport and polymer segmental motion. The decreased conductivity at higher concentration of gum arabic signposts the reduced conducting pathways for the mobility of charge carriers [20].

FTIR analysis: The FTIR spectra (Fig. 3) of six polymer blends are dominated by sturdy and broad O-H stretching vibration at 3300 cm^{-1}. The peak in the range 2940-2853 cm^{-1} is due to stretching vibrations of alkanes (C-H) bond. The absorption peak arising in the range 2114-2092 cm^{-1} is due to stretching vibrations of alkyne (C-C) bond. The characteristic absorption peak around 1730 cm^{-1} shows the stretching vibra-

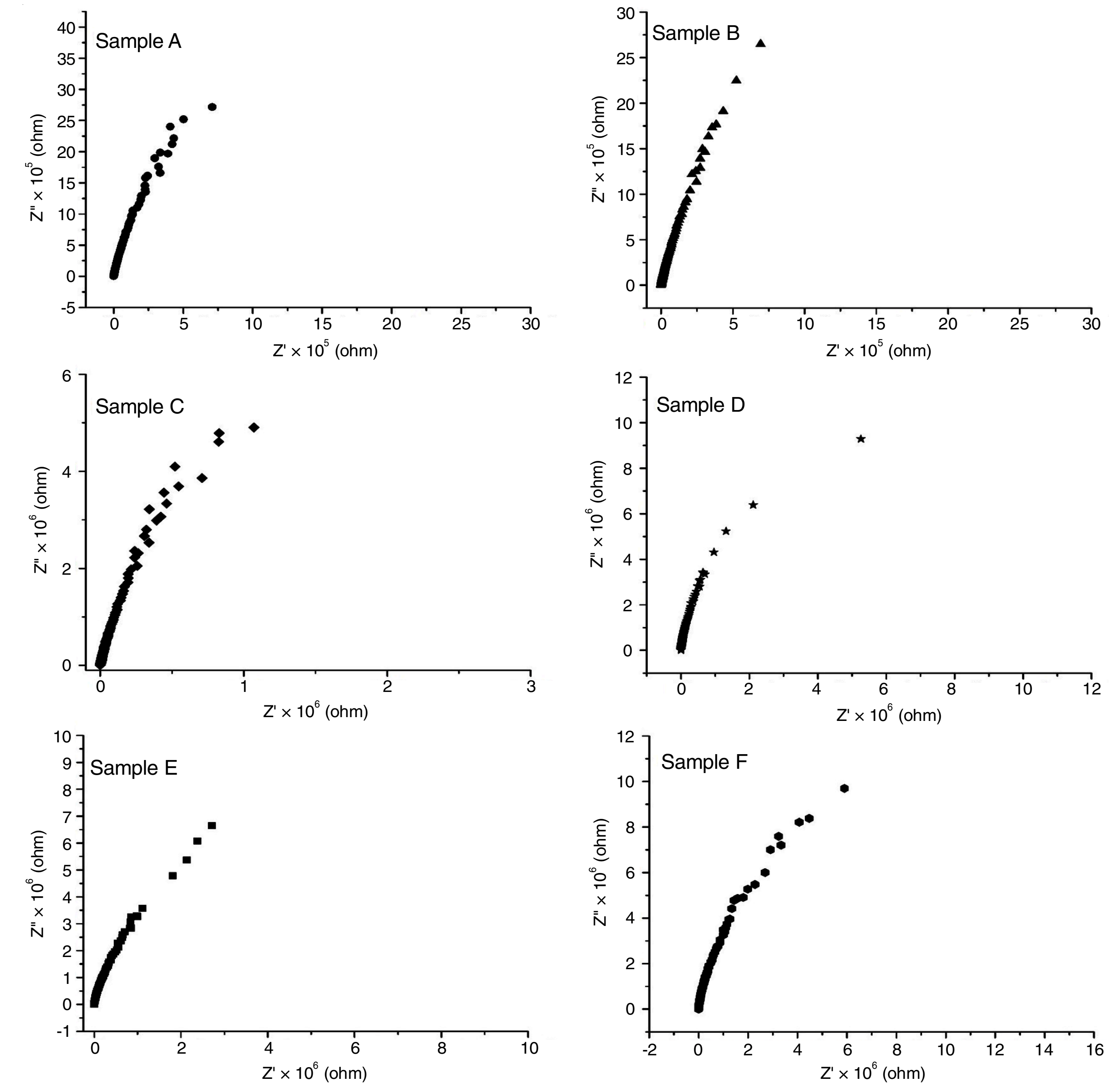

Fig. 2. Conductivity graph of polymer blend samples A to F

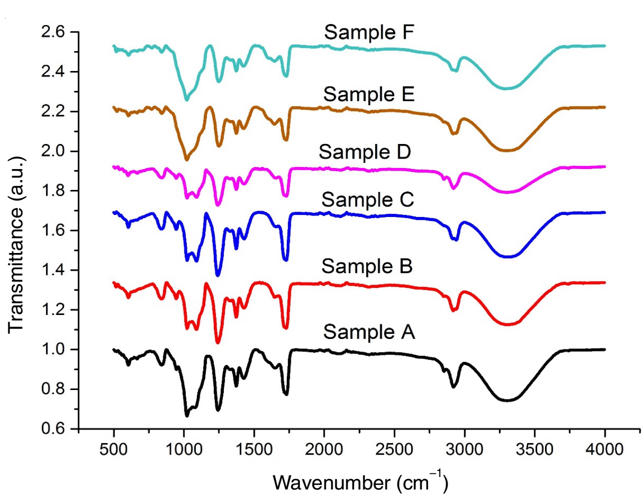

Fig. 3. FTIR spectra of six polymer blend membranes

tions due to the presence of functional groups such as aldehydes and ketones [17]. The absorption peak prominent around 1420 cm^{-1} shows the stretching vibrations of the aromatic group (C=C) present in the blend. In the fingerprint region, the peak arising in the range 1374-1373 cm^{-1} is due to bending vibrations of O-H bond present in either carboxylic acid, alcohol or phenol [16,21,22]. The peak arising in the range 1248-1240 cm^{-1} is due to the stretching vibrations of alkyl aryl ether (C-O) bond. The peak arising in the range 1089-1020 cm^{-1} is due to the stretching vibrations of (C-O) bond present in either alcohol, carboxylic acid, ester or ether. The peak appearing in the range 771-843 cm^{-1} is due to the stretching vibrations of alkyl halides (C-Cl) bond. The peak present in the range 666-516 cm^{-1} is due to the stretching vibrations of alkyl halides (C-Br) bond. The characteristic peaks due to stretching vibrations and those due to bending vibrations *i.e.* in fingerprint region are found to be slightly shifted due to the interaction between molecules in the mixture.

UV-visible analysis: The UV-visible spectra of polymer blend samples (samples A-F) are shown in Fig. 4. Using Tauc plot method (Fig. 5), the energy band gaps for each sample was determined [21] and the values are shown in Table-1. It is clear that no absorption band in the visible region for all the investigated samples was found since the films are transparent. The absorption peak for samples A, B, C, D, E and F are centred at 219.85, 219.65, 222.50, 225.65, 224.60 and 228.80 nm, respectively.

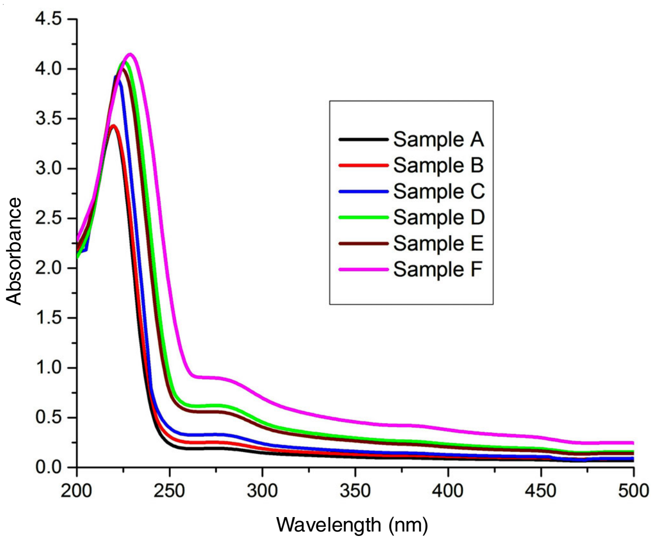

Fig. 4. UV spectra of polymer blend membranes

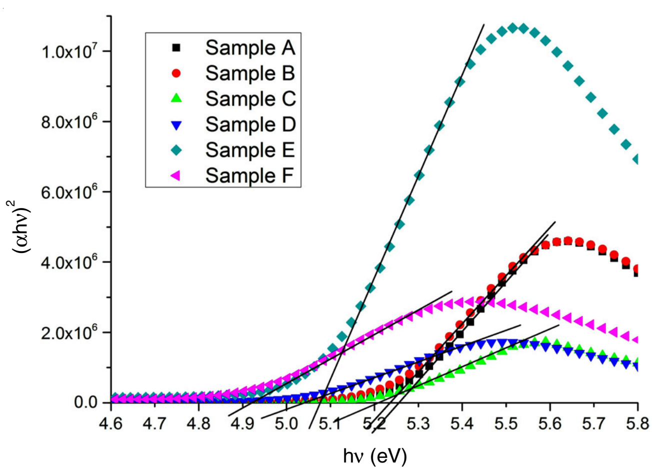

Fig. 5. Tauc plot from the absorbance spectrum of polymer blend membranes

Since the energy band gap values are above 3 eV, the samples are insulators with respect to electronic conduction. This shows that ions are only involved in conduction process.

Conclusion

The structural, optical and electrical characterizations of PVA-GA polymer blend membranes are reported. The conductivities values are found in the order of 10^{-8} Siemen/cm. Addition of a natural polymer gum arabic (GA) could increase the conductivity value of PVA to two to three-folds. The XRD patterns showed that all the prepared polymer blend membranes were highly amorphous in nature. The absence of absorption peaks in the visible region proved the transparency of polymer blend membranes. The energy band gap was calculated for each membrane and it was found that membranes were insulators with respect to electronic conduction. Further studies can be done by doping the blend membrane with diverse salts to develop different types of highly conducting polymeric electrolyte membrane.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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