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Short Communication

Study of Ethylene Vinyl Acetate (EVA) Films used in Photovoltaic Modules

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Encapsulant material is an important component of the Photovoltaic (PV) modules. Generally Ethylene Vinyl Acetate (EVA) is used as the encapsulant material in PV modules due to its low lost and other properties like high adhesion to different module materials, high volume resistivity, high optical transparency and adequate mechanical strength to accommodate stresses induced by thermal expansion of glass and solar cells. The purpose of this investigation is to compare two different grades of virgin EVA films by various techniques like Fourier-transform infrared spectroscopy (FTIR), Raman spectroscopy, Thermal gravimetric analysis (TGA), UV-Vis spectroscopy and Broad band dielectric spectrometry.

Keywords: Photovolaic modules, Encapsulant, Structural, Thermal, Electrical Properties

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1. INTRODUCTION

The polymer encapsulant used in photovoltaic (PV) modules provides electrical insulation, structural support and thermal conduction for the solar cell circuit [1]. Long term stability of the encapsulant is important for PV modules deployed in the field, where a long service lifetime and reliable power output are needed [2]. Even though a wide range of different polymeric materials have been used in PV applications, EVA remains the dominating encapsulant for the PV modules due to its high volume resistivity, low processing and cross-linking temperature, very low water absorption ratio and good optical transmission. PV-grade EVA is a ethylene/vinyl acetate copolymer with a vinyl acetate content typically in the range of 28-33 % (w/w) [3]. In this work, characterization of EVA received from two different manufacturers (Company-1 & Company-2) has been done to compare their structural, thermal, optical and electrical properties. Raw material characterization is very important to check the quality of the materials and it should be done before finalizing the bill of materials (BOM) of the PV modules.

2. MATERIALS AND METHODS

The structural characterization of the EVA films has been done through FTIR and Raman spectroscopy. The FTIR spectra of EVA was measured by using Nicolet 5700 spectrometer. Thermo-gravimetric analysis of EVA was done by using SDTA 851 Metter-Toledo-Star system in the temperature range from 20 °C to 500 °C. The UV-Visible absorption spectra of EVA was recorded on a Shimadzu UV-2401 spectrophotometer. Electrical properties of EVA were measured using broadband dielectric spectrometer (Novo control technologies Germany, Concept 80) at 10 Hz in the temperature range of – 35 °C to 100 °C.

3. RESULTS AND DISCUSSION

The FTIR spectra of the EVA films (Company-1 and Company-2) was recorded in the range of 400 cm $^{-1}$ to 4000 cm $^{-1}$ as shown in Fig. 1. Raman spectra of EVA (Company-1 & Company-2) was recorded in the range of 400 cm $^{-1}$ to 4000 cm $^{-1}$, as shown in Fig. 2. The peak assignments for FTIR and Raman are given in Table I and Table II respectively [4, 5]. We have obtained the same FTIR and Raman spectra from EVA received from two companies (Company-1 & Company-2).

Thermo-gravimetric analysis (TGA) of the EVA films was done in the temperature range from 20°C to

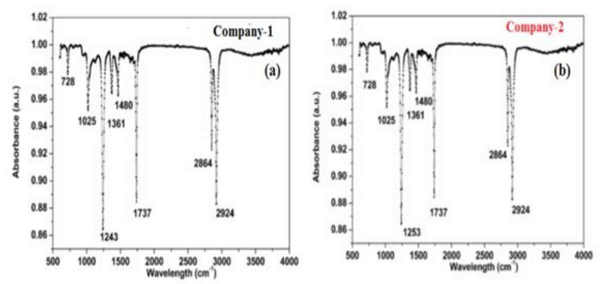

Fig. 1 – FTIR spectra of EVA films (Company-1 & Company-2)

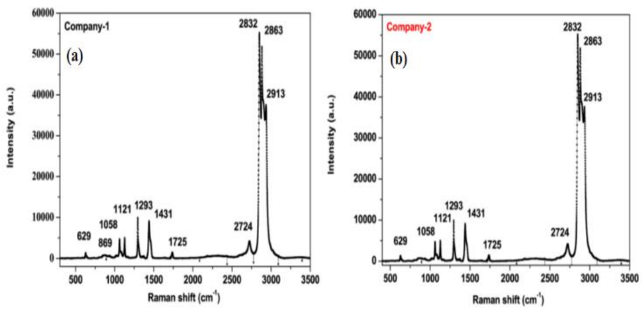

Fig. 2 – Raman spectra of EVA films (Company-1 & Company-2)

Table 1 – Peak assignment for FTIR data

Peak Wave number (cm^{-1})	**Associated Bond**
728, 1361, 1480, 2864, 2924	C-H
1025	C-O
1243	C-O-C
1737	C=O

Table 2 – Bonds associated with raman shift of EVA films

Raman Shift (cm^{-1})	**Associated Bond Vibration**
629	δ(O-C-O)
1068	υ(C-C)
1126	υ(C-C)
1293	t(C-H)
1431	d(C-H)
1724	υ(C=O)
2832, 2863, 2880, 2895, 2913	$\upsilon(CH_2)$ and v(CH_3)

550 °C as shown in Fig. 3. The heating rate was 10 °C/min during the experiment. EVA received from company-1 shows thermal stability up to 330 °C while EVA while EVA received from company-2 shows that stability up to 310 °C. Acetic acid formation takes place in both the EVAs after 300 °C. TGA results show that EVA received from company-1 is relatively stable than EVA received from company-2.

Thermo-gravimetric analysis (TGA) of the EVA films was done in the temperature range from 20 °C to 550 °C as shown in Fig. 3. The heating rate was 10°C/min during the experiment. EVA received from company-1 shows thermal stability up to 330 °C while EVA while EVA received from company-2 shows stability up to 310 °C. Acetic acid formation takes place in both the films after 300 °C. TGA results show that EVA received from company-1 is relatively more stable than EVA received from company-2.

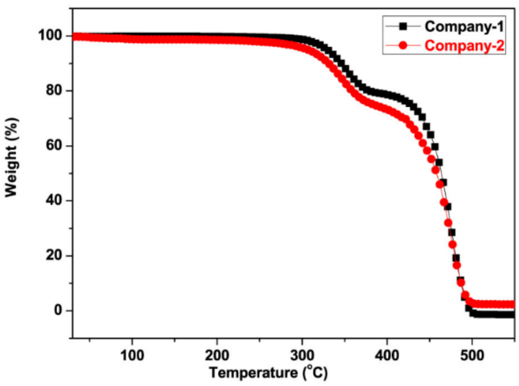

Fig. 3 – Thermal-gravimetric analysis (TGA) of the EVA films (Company-1 & Company-2)

Optical transmittance of the EVA films was measured by UV spectroscopy in the wavelength range of 250 nm to 2500 nm as shown in Fig. 4. EVA received from company-1 shows transmittance of 94 % while EVA received from company-2 shows transmittance of 92 %. It should be noted that the transmittance of the EVA film in the PV module is related to the cured film,

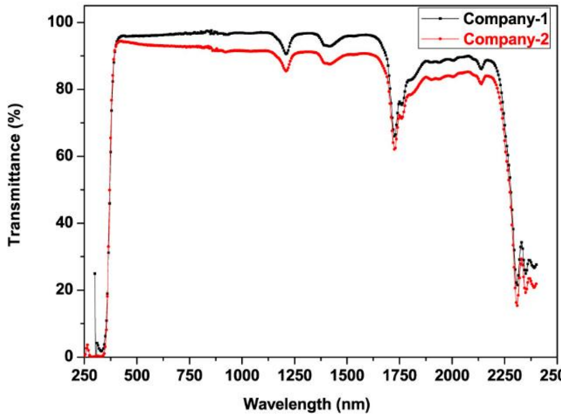

Fig. 4 – Transmittance of EVA films (Company-1& Company-2)

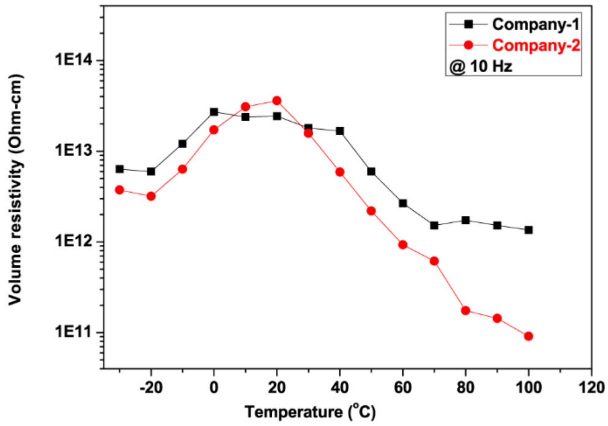

Fig. 5 – Volume resistivity of EVA films vs Temperature (Company-1& Company-2)

and not the raw film which has been measured in this study.

Resistivity studies are very important for insulating materials, because the most desirable characteristic of an insulator is its ability to resist the leakage of electrical current. Volume resistivity is an intrinsic property of the insulating material [6]. Volume resistivity and dielectric constant of EVA (Company-1 & Company-2) were measured by Broad-band dielectric spectrometer. The volume resistivity was measured at frequency of 10 Hz in the temperature range of – 35 °C to 100 °C as shown in Fig. 5. Fig. 5 compares the volume resistivity as a function of temperature. It was observed that initially volume resistivity of EVA received from both companies (Company-1& Company-2) increases with the temperature. Volume resistivity of EVA received from company-1 increases in the temperature range of -20 °C to 0 °C, after which it is almost constant from 0 °C to 40 °C and then drastically decreases with increasing temperature up to 85 °C. Volume resistivity is almost constant in the temperature of 85 °C to 100 °C. Volume resistivity of EVA received from company-2 increases in the temperature range of -20 °C to 20 °C and then drastically decreases with increasing temperature. Volume resistivity of encapsulant should be high (> = 10^{14} Ohm·cm ideally) for PV application [2]. If the

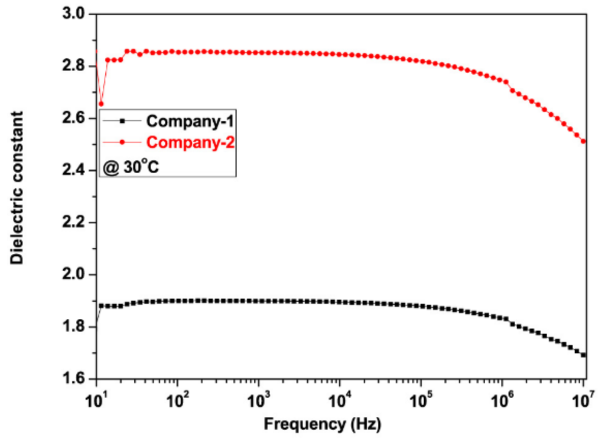

Fig. 6 – Dielectric constant of EVA films vs Frequency (Company-1 & Company-2)

volume resistivity is very low, the module may suffer from Potential Induced Degradation (PID) which would reduce the power output drastically. The Volume resistivity measurements suggest that EVA received from company-1 is relatively better than EVA received from company-2. The volume resistivity depends on the charge carrier concentration and on the mobility of charge carriers. Vinyl acetate content can increase carrier mobility in EVA, which may cause the increment of the electrical conductivity and consequently the decrease in volume resistivity [7].

Dielectric constant refers to the ability of any material to store electric charge. The dielectric constant of materials arises due to polarization of molecules and usually the dielectric constant increases with increase in polarizability [7]. Dielectric constant of EVA was measured at temperature of 30°C in the frequency range of 10 Hz to 10^7 Hz as shown in Fig. 6. It was observed that that dielectric constant of EVA received from both manufacturers (Company-1 & Company-2) is almost constant in the frequency range of 10^1 to 10^4 Hz. The dielectric constant consists of orientation, atomic and electronic polarization, respectively. Here, the dispersion region spreads over a wide range of frequencies. Dielectric constant of EVA (Company-1 & Company-2) decreases at high frequency in the range of 10^5 to 10^7 Hz. Above ~10^5 Hz, the decrease in dielectric constant of EVA (Company-1 & Company-2) with increasing frequency is assumed due to the drop in orientation polarization [8]. EVA received from company-1 has lower dielectric constant ~ 1.87 than EVA received from company-2 (dielectric constant ~ 2.82). Hence, EVA received from company-1 is relatively better than EVA received from company-2.

4. CONCLUSIONS

Virgin EVA films received from two companies (Company-1 & Company-2) was characterized by various techniques like Fourier-transform infrared spectroscopy (FTIR), Raman spectroscopy, Thermal gravimetric analysis (TGA), UV-Vis spectroscopy and Broad band dielectric spectrometer to compare their structural, thermal, optical and electrical properties. Thermal, optical and electrical characterization show that EVA films received from company-1 is relatively better than EVA films received from company-2. FTIR, Raman Spectroscopy and thermal (TGA) analysis are good tools to characterize the EVA films but Broad band dielectric spectrometer is sufficient tool to distinguish the quality of the EVA films.

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