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Thermal Lifetime Estimation of EVA Encapsulants from Activation Energy based Method

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Abstract

A rapid test method based on a logarithmic degradation model for the lifetime assessment of ethylene-vinyl acetate (EVA) used as encapsulants in Photovoltaic (PV) module is proposed. In general, encapsulants are used in widely varied conditions. However, factors such as voltage stress, irradiation, mechanical shock and vibration, environmental conditioning and chemical contamination should be evaluated. In the present study evaluation is carried on the dumbbell specimens of encapsulating material itself and is based on the percentage of reduction in the property i.e elongation percentage, which is a destructive test. Dumb-bell specimens as per ISO 37:2011(E) standard are employed. Adequate number of test specimens were subjected to thermal aging at three different temperatures 35 ºC, 45 ºC and 55 ºC. The conditioned specimens after removing from oven were stored in decicator prior to testing i.e. while the specimens were attaining room temperature. The constant factors of the life time line a and b were calculated, and finally, the lifetime values were estimated.

Keywords: Elongation Percentage, Ethylene-Vinyl Acetate (EVA), Lifetime Estimation, Photovoltaic Solar Cell

1. Introduction

One of the most encouraging and eco-friendly renewable energy sources to meet the ever-increasing energy demand is Photovoltaic. Thin solar cell films (organic and perovskite) based photovoltaic technology is evoking scientific and industrial interest due to low manufacturing cost and its light weight. But the solar cells are delicate in nature. The direct exposure of the solar cell to the atmosphere will cause damage of the internal circuit. Therefore, solar cells are needs to be encapsulated to safeguard from external stress factors. Encapsulation also provides electrical isolation and structural support to the cells. The PV modules are primarily damaged due to delamination or decomposition of the encapsulation materials[1]. Different polymeric materials, Ethylene-Vinyl Acetate (EVA), Polyvinyl Butyral (PVB), silicone, Thermoplastic Polyolefin (TPO), Polyurethane (TPU) etc. are being been used as encapsulant in the PV industry. Among them EVA is the most commonly employed material. But, EVA degrades in presence of temperature, Ultraviolet (UV) irradiation and moisture which leads to efficiency loss and permanent damage of the cell[2, 3].

The EVA degradation involves a physico-chemical mechanism. The inclusion of thermal conductive nano particles in the EVA matrix can provide good thermal resistance. Decomposition of EVA encapsulating material is a severe issue for the photovoltaic industry which affects its service life[4]. Accelerated ageing test procedure is generally used to check thermal capabilities of encalsulant materials as per IEC 60216 to estimate the life time. In this procedure, physico-chemical models hypothesized for the degradation processes based on the Arrhenius equations is used to describe the rate of ageing[5,6]. In this method, evaluation of Thermal Index (TI) is intended on basis of thermal decomposition as the main cause of performance loss. This is temperature in °C at which the encapsulant deteriorates its property to reach an accepted end-point after 20000 hours.

It was believed that incorporation of very little amount of thermal conducting nano filler nano Zinc Oxide (n-ZnO) in EVA matrix can significantly improve thermal

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ageing properties. For a long-term efficient operation, high performance thermal conductive encapsulants is highly in demand.

For this study, 0.1 wt% n-ZnO incorporated in EVA matrix during compounding process and the prepared EVA/ ZnO nano composite was thermally aged along with commercial EVA encapsulant. The deterioration in the property of percentage elongation after thermal ageing as per IEC 60216-1-2013 is employed. The test chosen is anticipated to relate to a property which is likely to be of significance in practice. The end point criterion is a decrease in % elongation below 200% of the actual value. In this work, TI of EVA and prepared nano composite were checked and compare for better suitability.

2. Experimental Procedure

2.1 Sample Preparation

28% Vinyl acetate content EVA polymer was taken as base polymer. 100- 200 nm particle size ZnO nano was modified with silane coupling agent and taken for nano composite preparation. Ethylene Vinyl Acetate/ Zinc oxide nano-composites were prepared by solvent casting method using toluene as solvent and finally 0.5 mm thick film has been casted by hot press moulding at 130°C.

2.2 Characterization

2.2.1 Thermal Ageing

Adequate number of dumbbell specimens of EVA encapsulating materials as per Type 2 of ISO 37:2011(E) are subjected to hot air oven for accelerated thermal ageing test at 35°C, 45°C and 55°C.

2.2.2 Elongation at Break test as per As per ISO 37:2011(E))

Elongation percentage at break for test specimen were measured on dumb bell specimens as per Type 2 of ISO 37:2011(E) and gauge length 20 mm by using Universal Testing Machine, with load cell of 5kN at 500 mm/min rate of separation.

3. Results and Discussion

The temperatures 35 °C, 45 °C and 55 °C were considered as the exposure temperatures for continuous ageing. Only the specimens to be tested at each time were taken out of the oven and allowed to cool to test temperature i.e. prevailing ambient room temperature in the present case. The test being destructive, the specimens were discarded after the test.

Table 1. Test data of Elongation at Break at 3 different temperatures for commercial EVA encapsulant

	Elongation at Break (%)		
Time (hours)	35 °C	45 °C	55 °C
120	723.4	621.6	450.0
240	689.9	550.2	329.6
360	660.2	493.3	159.3
480	530.5	410.2	
600	498	360.3	
720	470.1		
840	403.2		

The total ageing duration at temperatures 35 °C, 45 °C and 55 °C resulted as 840 hrs, 600 hrs and 360 hrs respectively and the elongation percentage results are tabulated in Tables 1 and 2 for commercial EVA encapsulant and prepared EVA/ 0.1 wt% n-ZnO nano composite respectively.

Table 2. Test data of Elongation at Break at 3 different temperatures for prepared EVA/ 0.1 wt% n-ZnO nano composite

	Elongation at Break (%)		
Time (hours)	35 °C	45 °C	55 °C
120	1048.3	802.2	750.0
240	921.2	707.5	439.0
360	940.7	680.1	201.3
480	839.5	540.3	
600	805.6	430.4	
720	669.8		
840	591.4		

Property - time graph at 35 °C, 45 °C and 55 °C for commercial EVA encapsulant are depicted in Figures 1 to 3. As per Arrhenius equation time values were plotted against the reciprocal of the temperature in Kelvin and then thermal index or Thermal Endurance calculated by using Arrhenius equation. An end-point criterion was chosen as 200% Elongation at break. Figure 4 provides the Thermal Endurance graph for commercial EVA

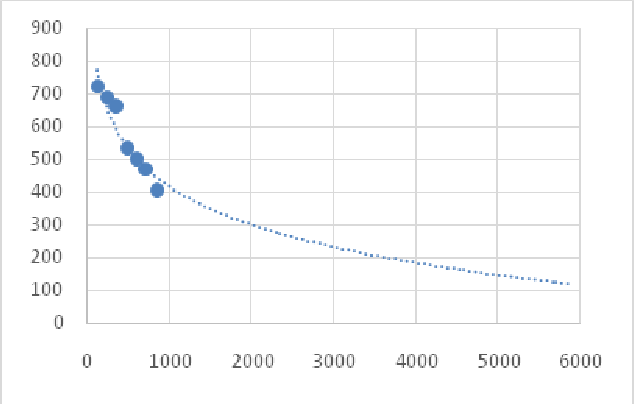

Figure 1. Property - time graph at 35 °C for commercial EVA encapsulant.

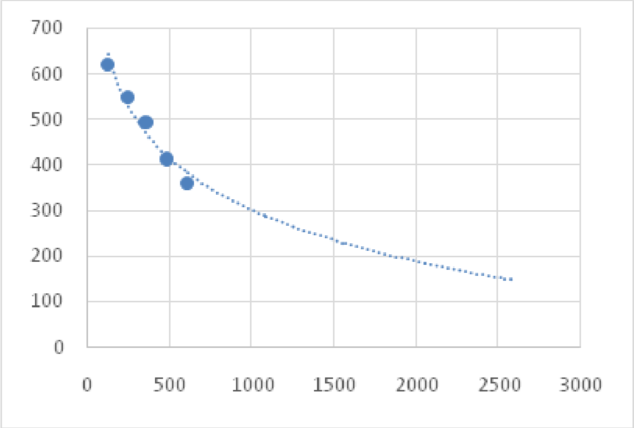

Figure 2. Property - time graph at 45 °C for commercial EVA encapsulant.

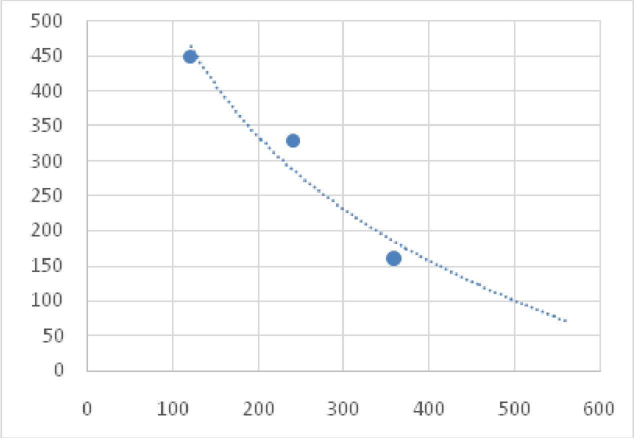

Figure 3. Property - time graph at 55 °C for commercial EVA encapsulant.

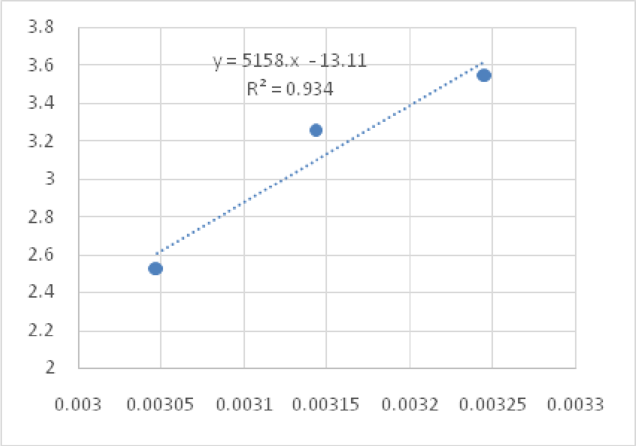

Figure 4. Thermal Endurance graph for commercial EVA encapsulant.

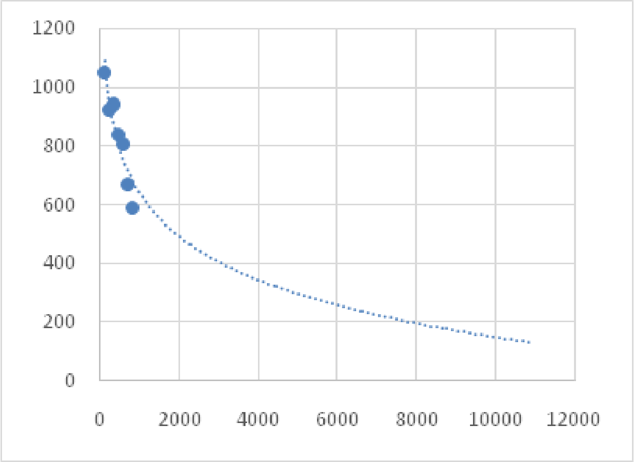

Figure 5. Property - time graph at 35 °C for prepared EVA/ 0.1 wt% n-ZnO nano composite.

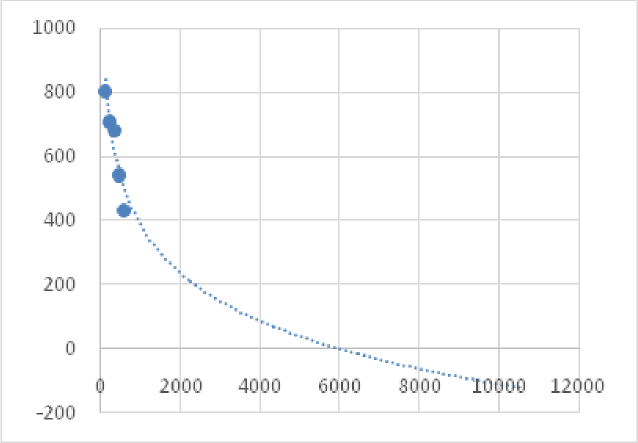

Figure 6. Property - time graph at 45 °C for prepared EVA/ 0.1 wt% n-ZnO nano composite.

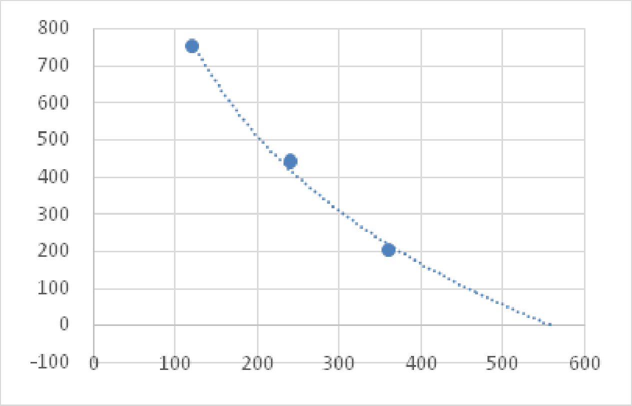

Figure 7. Property - time graph at 55 °C for prepared EVA/ 0.1 wt% n-ZnO nano composite.

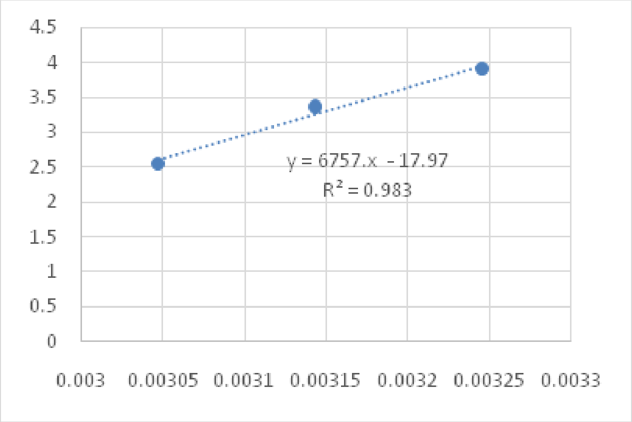

Figure 8. Thermal Endurance graph for prepared EVA/ 0.1 wt% n-ZnO nano composite.

encapsulant. Property - time graph at 35 °C, 45 °C and 55 °C for prepared EVA/ 0.1 wt% n-ZnO nano composite are depicted in Figures 5 to 7. Figure 8 provides the Thermal Endurance graph for prepared EVA/ 0.1 wt% n-ZnO nano composite.

From property time graph and thermal Endurance graph Thermal Index (TI) calculated for commercial EVA encapsulant is 23 °C and for EVA/0.1 wt% n-ZnO nano composite is 30 °C. From the reference life curve, Figure 4 for commercial EVA encapsulant, it is observed that commercial EVA encapsulant can sustain 20000 hours when continuously facing 23 °C. Whereas, EVA/0.1 wt% n-ZnO nano composite is withstanding 30°C temperature for 20000 hours. Addition of very less (0.1 wt%) amount of n-ZnO heat dissipation of EVA encapsulant increased and it can sustain more temperature during its service life.

4. Conclusion

The encapsulant materials shall have a minimum thermal index which provides the information of maximum operating temperature of said material in application. It is a useful tool for selecting materials on basis of its thermal grading. Under this study, the prepared EVA/0.1 wt% n-ZnO nano composite is showing better thermal property than the commercial one. Degradation of encapsulating materials is not only caused by temperature alone. UV radiation, humidity and other environmental factor can significantly contribute to the degradation of encapsulating materials. But this is a magic number on basis of which encapsulating materials can be selected.

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6. References

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