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# Degradation Influence of Ethylene Vinyl Acetate Copolymer (EVA) in Photo-Voltaic Modules: The Reason and Effect. A Review

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***Abstract**: The photovoltaic modules prone to many environmental and weather aging factors promote induced degradation as a significant reason in shortening their lifetime. The mechanisms of the natural deterioration have been addressed for the ethylene-vinyl acetate to determine its stability and consequently to support the reliability of the silicon photovoltaic modules. This requires knowing in detail the operation conditions of these modules and their relationship with the degradation factors like moisture, UV radiation, and heat at the conditions of the PV module's functions. The main target of this study is to review the written literature about the degradation of EVA encapsulation which promotes the performance loss of the PV units. The deleterious effects on the EVA like photo-degradation, delamination, moisture, bubble formation, their link with the polymer properties are discussed approaches in this review.*

***Keywords**: ageing characterization, solid state luminescence, polymer thermal degradation, Ethylene Vinyl Acetate***.**

## 1. Introduction

Recently, worldwide energy demands have expanded, essentially, the anticipated essential utilization of energy will increase half over the duration in between 2016– 2030. This point of view is basically because of quick industrialization and populace development, particularly connected with the necessities of creating nations [1].

At this moment, The world's primary energy is generally given through non-sustainable power sources (coal, oil, and gas) which had their stores ceaselessly diminished. The broad-scale use of oil subsidiaries, is unfriendly to the earth and is identified by the overall natural change, demonstrating the essential for changes from non-interminable to helpful energy sources. Notwithstanding the way that at present practical power sources (sun-based, biomass, wind, marine, geothermal, hydroelectric) addresses a minority part of the energy (addressed for the power division in Fig. 1), their arrangement plan and use are growing rapidly [2]. Sunlight based energy is the most-rich earthly sustainable power source asset and among the sunlight based methodologies, photovoltaics (PV) are right now the quickest developing innovation with the most reduced purchaser costs. Nonetheless, to be financially fit and bankable, PV modules are required to work dependably for about 25– 30 years under the conditions of their function [3,4]. Writings contain various reports recording the need and trouble to contemplate and distinguish the deterioration of PV modules under genuine working conditions [1,4– 8]. The execution of a PV framework is straightforwardly connected to explicit natural furthermore, atmospheric conditions, for example, sunlight based irradiance, wind, temperature, dampness, precipitation, and sun based unearthly qualities (involving UV forces). It is suggested that introduced PV modules between 10 - 12 years keep up the degradation rate lower than 10% of its hidden apparent power and up to 20% for PV modules with 20–25 years of action [7].

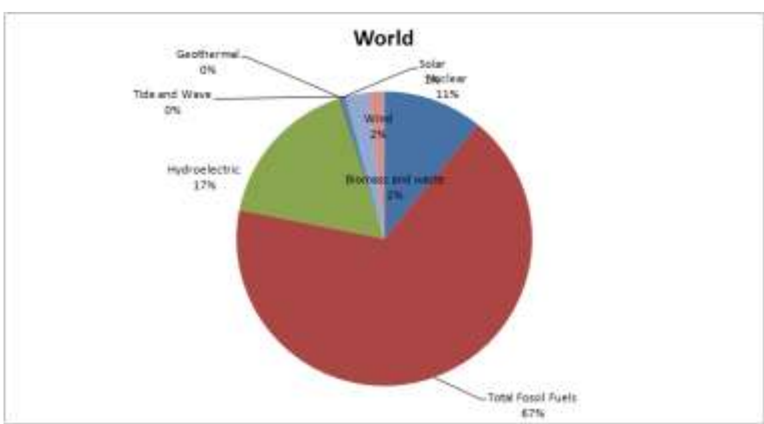


Fig. 1. Assessed Renewable Strength Share of Global Electrical Power Production, End- 2015 [2].

The uncensored field conditions, everywhere the PV module is introduced, expect basic employment on the constancy and the capability of its energy change. taking into account this one of a unique circumstance, it is imperative to analyze parameters, their association with the portions, and the ability to progressive effection upon the PV module under outside conditions. Among the segments, which involve the Si-based PV modules, the encapsulant film contained ethylene-vinyl acetate copolymer (EVA) has focal points as high transmittance, protection from UV radiation, a great attachment to glass and relative climate protection [8–10]. The thermoplastic EVA is the segment that is all the more regularly exposed to the phenomena of degradation [9– 12].

EVA deterioration includes a physical-chemistry process which is topic to temperature, dampness, and bright light. For a long term proficient task, an examination of these limitations is important to gain technical methods conceivable to control or alleviate the EVA disintegration. Some advancement has been made to identify with the maturing opposition execution of EVA diaphragms which change the expansion in the system of the polymer, by utilizing sorts as cancer prevention agents, absorbers of UV radiation and light stabilizers to enhance its photograph and its thermal-stability [9,12]. Along these lines, the condition of workmanship must be appeared and is essential to make a deep knowledge about the components of EVA degradation with the goal that more researchers can dedicate their endeavors through the structure of new encapsulant materials which utilized in the solar cells with the higher solidness. The key goal of the paper is to review the literature of degradation, fail mechanisms, and shelf-life of the EVA wrapper, frequently applied in Si-based photovoltaic units. The physics and chemistry of the EVA, influences of external environmental settings on the polymer, its potential and application constraints of the encapsulant, and its protecting and precision function was managed. In conclusion, a review of the collected works is offered in the latter section illustrating the growth of the assemblage characteristics by integrating constituents into the EVA.

## 2. Attributes of the Si photovoltaic unit

Encapsulant is the physical system of security for sun powered-cells against ecological/climate impacts, for example, dampness, downpour, ultraviolet radiation (UV), low mechanical burdens, e.g. bending or twisting, and low-energy impacts (hail, shots, and so forth.). In this way, PV units are fixed and ensured by encapsulant substances (thermoplastics or then again silicones with amazing optical straightforwardness), intro pages (glass with low iron substance, plastic pitches or thermoplastic designing with great optical straightforwardness and mechanical quality) [10].

The substrates (back sheets) refer to polymer foils, pane metal, and glass. These materials need steady and strong synthetic and physical features that don't degrade by the activity of bright radiation and/or temperature, show great dimensional security, low water or gas porousness, simple preparing, minimal effort, and similarity/soundness /quality at the interfaces among them [14,15].

For almost the last three decades, the selected material used as an envelope was ethylene vinyl acetate (EVA) co-polymer and approximately 80% of photovoltaic PV units were encapsulated by EVA substances [10,16,17]. With a view to offer mechanical strength, moderated glass (woven and / or with anti-reflective varnish) with a thickness of about 3.2 mm is utilized as the front shield. This glass screen has a permeability greater than 90% for most of the solar radiation spectrum, and has numerous commitments for the unit such as mechanical strength, impact resistance, and electrical insulation of the solar cell loop [1,10].

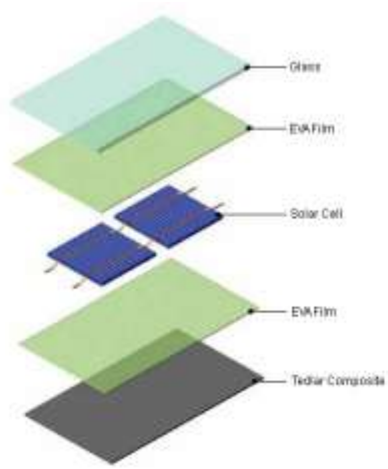


Fig. 2. Segments of a photovoltaic module [6].

It does not have to be pellucid. The protection module was accomplished with a multilayered foil structure made up of sheets of polyester (PET) encapsulated between polyvinyl (PVF) and fluoride, named EVA, and Tedlar (TPT) [1,9]. $TiO_2$ is a polymerized polymer that is a surface sheet used to protect the back layer of ultraviolet radiation. Figure 3 shows the construction of the manifold sheets that make up the PV unit. Glass is a "back cover" alternative to the photoelectric module, and this approach provides reliable packaging; however, employing a second sheet of glass adds considerable weight and cost to the unit.

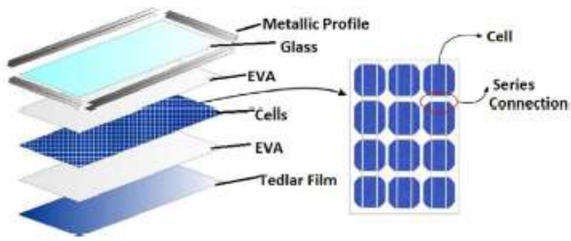


Figure 3. Multilayer construction of the photovoltaic unit [18].

The sealing layer is utilized between the top layer face and glass, and the back layer is achieved using an encapsulation device, which sets the appropriate temperature and pressure on the 5-component constituents (EVA / EVA, PV / EVA, paper / To close the lamination). Initially, the air is removed inside the structure employ a rolling mill, then the pressure is engaged from the upper of the packaging hall to eliminate residual moisture and air inside the laminate.

Throughout this procedure, the unit temperature is kept between 80 °C and 100 °C so that the EVA dissolves and doings as an adhesive after cool it down, by forming the links between the front cover glass and the Tedlar paper. The laminate unit is heated from 150 to 200 °C in the processing process. In this polymerization, EVA evaporation and processing time are important for the creation of the chemical bonding, thus providing longer shelf life and resistance to plate [1] EVA. An important measure of EVA quality of laminated glass material is "gel content", which is an insoluble product in. EVA Gel content is generally considered to be over 70% acceptable. The contented gel is usually measured using chemical analyses or plain peeling tests, but not as much by accurate [19]. This lamination procedure is the most important industrial step to ensure a higher durability for packaging material under specific environmental circumstances.

The another step in this process comprises the oxidation of aluminum of the PV module frame which produces an additional electrical conductivity in the same module box [20].

### 3. Properties and functions of the encapsulant

The encapsulant Si-module is an adhesive polymer employed to bind the solar cells with the back sheet, glass, and any regions between the glass and the back cover.

Encapsulant presents a mechanical help of the cell creation and structure whilst giving sufficient optical coupling, securing photovoltaic cells versus an outer factor activity, and electrical segregation [14,21]. The most significant attribute of the packaging components are compound, mechanical, optical and electrical [22].

The principle fundamental elements of bundling materials can be listed as follows [23]:

• Offer structural backing and evolution of solar cells in modular design during industrialization, curing, store, synthesis, and running;

• The condition of coupling the optical properties between that of the solar cells and that of the glass should be kept while preserving a solar radiation permeability ratio of at least ninety percentage and maximum loss of five percentage over twenty to thirty years or perhaps more than that throughout the operating duration;

• Presence of insulator between the solar models and their elements is an essential matter, in addition, to save the circuit during its running against the potential environmental attacker.

• The operation of the PV modules demands, offering a dielectric separates the solar cells from the circuit constituents.

• Maintain the safety of the circuit, which produces current and voltage desired during exposure to light. The lifetime of the photovoltaic modules requires an encapsulant that has minimum transparency of 90% of the solar light permeability.

Polymer Joint Ethylene Vinyl Acetate (EVA) acts as thermoplastic and flexible plastics relying on the amount of acetate vinyl (VA) present.Polymer Joint Ethylene Vinyl Acetate acts as thermoplastic and flexible plastics relying on the amount of acetate vinyl present.

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For its physical and mechanical properties, simple processing, as well as premium electrical and chemical resistance, EVA is widely used in many applications of materials, like biomedical devices, hot melt adhesives, and insulators. The photovoltaic applications demand EVA contains ca. 28-33% by weight of acetate vinyl, enhanced with additives such as processing agents, optical antioxidants, ultraviolet absorption, thermal antioxidants [25]. To prohibit degradation reactions, a few amounts of additives must be added to the usual EVA. It is fascinating to take note of that the HALS works by breaking down the peroxides that might be shaped by heat presentation or ultraviolet radiation. Phenolic antioxidants are oxidized to create phenols and phosphates and don't devour HALS [30]. EVA offers low cost, low coefficient of water absorption, and wet steam resistance. The EVA offers a low absorption coefficient of water, low cost, and wet steam impedance. The EVA has many utilities for use in lamination/packaging materials in the units of photovoltaic and should have the following characteristics [28,15,10]: high electrical and volume resistivity ($0.2\text{-}1.4 \times 10^{16}\ \Omega\ cm^{-1}$), low temperature toughness, UV resistance, low water absorption / compression, gel content above 70% after treatment, high optical transmission (above 91%), adhesion strength of glass (90 ° peeling strength 9- 12 $mm^{-1}$), and high transparency, with glass-like transition properties within the bounds of 400-1100 nm. [10]. Alongside every one of these properties, EVA experiences complex deterioration when exposed to ecological conditions, for example, dampness, warmth, and UV illumination, which lead to the aging of EVA [25]. The color transformation from yellowing to dark-colored is because of the impact of bright radiation and this declines its permeability [29]. Different polymers have additionally been utilized for photoelectric encapsulation, comprise polyvinyl butyl (PVB), polyacetylene (ION), polyolefin thermoplastic (TPO), thermoplastic polyurethane (TPU), polydimethylsiloxane (PDMS), or different polysiloxanes (Silicone)[12,14,30]. Throughout the two decades of the sixties and the seventies of the twentieth century, when the photovoltaic boards were created just because, prevailing inclinations depended on PDMS [29,30]. The PDMS was selected due to its remarkable natural dependability to resist the thermal and ultraviolet (UV) stress. The PDMS tests were better permeable, About 0.6% superior to anything the best hydrocarbon-based materials, by depending on the Kempie considers (2011). The absence of UV absorption was one of the reasons appears PDMS as a characteristic option [30]. Kempe reported (2010) a short summary of particular polymers that are suitable to be used in the PV modules, with certain focal points and impediments. After arriving at the resolution, the EVA is the valuable encapsulant picked for photovoltaic use since it contains the best blend of features, basically, it is less expensive, and displays satisfactory strength [10].

Kim et al in (2016) expressed that EVA of the minimal expense accounted for as a bit of disadvantage and advantage in UV vulnerability [21]. Polymers, for example, PVB, PDMS, TPU, and Ionomer have risen as great substitutes for EVA and have been tried by Afif and Hassan (2014) to improve the packing of photovoltaic modules. Afif and Hassan (2014) presumed that the proficiency of the photovoltaic unit isn't influenced by the adjustment in its envelope [29]. In any case, Ionomer as an encapsulant gives a most extreme lifetime to the PV module at a sensible expense [29]. However, the writings and reports, detailed that the silicon and Ionomer envelope didn't perform better contrasted with customary EVaps encapsulant within dusty conditions [12,30,31].

## 4 . General conditions for PV

To give unwavering quality and significance to EVA conditions in photovoltaic modules and their life expectancy, the significant corruption issues identified with the exemplification may emerge from the overlay, splitting or discontinuity of the foundation sheet for the accompanying potential reasons:

- Because of dampness

• Moisture ingestion of the top covered encapsulant.

• Metal (compound) touchy to wet.

• Connect dampness delicate under the inter-cell light and the cell framing where it continuously starts, including/separating/splitting/disintegrating

• Poor bond between the encapsulant and back sheet

• Humidity entering through the back edges as well as the edges of the layer.

• Polymer deterioration after some time.

Degradation can happen with the impact of the environment, the collection of soil and garbage on the outside of the glass, photovoltaic systems, oxidation and corruption of cement, trade of particles and associations at the polymer interface, causing the separation of overlay plating, delamination. A considerable lot of these issues happen in view of the high ionic fixations coming about because of exhaustion and gases, just as off base utilization of materials/items during the assembling of the photovoltaic unit. Physical deformities, (for example, broken cells and little breaks prompting "winding ways") can happen during the production, transportation, or establishment of PV modules. In short, the failure of EVA by the environmental effects can be outlined by the following impacts which are: discoloration, corrosion, and delamination for the layers. [31].

It is fascinating to take note of that a 20% decrease is typically a failure, yet there is no accord on the meaning of failing in light of the fact that the high-proficiency unit that has crumbled by half may even now have the productivity of an undeveloped unit of less effective innovation.

Deciding the system of essential degradation through the workout and displaying can straightforwardly prompt upgrades over the length of serving [32].

## 5. Summary and conclusions

The reduction of the solar cells cost related to their shelf life. This fact is linked to the quality of the used encapsulant material and how would be after the installation as well as its affected climatic and environmental conditions. In this work, literature surveys have been done to the results and reasons originated the EVA degradation problems in PV modules.
The main conclusions are:

- In photovoltaic aging, the optical coupling should be available between PV modules and the EVA encapsulation. Where the EVA is the protector from the climatic stress. The environmental factors affecting the chemical structure of the EVA are UV and the temperature of the sun. The two latter factors attack the EVA in PV units to cause the deterioration in them and one trace of that is the discoloration and consequently decreasing its efficiency.
- The most important indicator refers to the degradation in EVA is the originated luminophores and chromophores which represent a direct result from the deterioration of the additives in the encapsulant material. That is why appearing of the yellowing and browning in EVA.
- Production of multiple interfaces due to the photolysis inside the EVA encapsulant as a result of the discoloration and corrosion which occur in the PV module. The interfaces come from the existence of molecular oxygen and high temperatures which produce acetate acid and other volatile gases. Trapping of these degradation products is the source of the interfaces. Thus formed bubbles and delamination reduce the performance of PV cells. Moreover, PV modules suffer the corrosion for presence of acetate acid.

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