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Review of Modeling of Cracks in Silicon Photovoltaic Cells Using FEM and XFEM

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Abstract

Cracks in crystalline silicon photovoltaic (PV) cells are a major reliability concern, because they reduce power output and shorten module service life. Numerical modeling has become an effective approach for understanding crack initiation and propagation under various manufacturing and operating conditions. This review presents recent advances in the application of the Finite Element Method (FEM) and the Extended Finite Element Method (XFEM) for modeling cracks in crystalline silicon photovoltaic cells. Following the PRISMA methodology, studies published between 2021 and 2026 were systematically reviewed to examine crack formation mechanisms, FEM and XFEM modeling approaches, material assumptions, loading conditions, and key findings. The review shows that FEM is widely employed to predict stress distribution, deformation, and thermo-mechanical behavior during manufacturing, transportation, installation, and service, while XFEM effectively simulates crack initiation and propagation without the need for remeshing. The reviewed studies further demonstrate that manufacturing-induced residual stresses, thermal cycling, mechanical loading, wafer thickness, and crack orientation significantly influence crack evolution and module reliability. However, several limitations remain, including simplified material assumptions, isolated treatment of loading conditions, limited consideration of electrical degradation, and insufficient experimental validation under realistic operating environments. The review highlights these challenges and identifies future research needs toward more comprehensive and experimentally validated numerical models capable of accurately predicting both crack evolution and the long-term reliability of crystalline silicon photovoltaic modules.

Keywords

Silicon Photovoltaic Cell, FEM, XFEM, Crack Initiation, Crack Propagation

1. Introduction

Photovoltaic (PV) technology has become one of the most important renewable energy solutions for addressing the growing global demand for clean and sustainable electricity. Among the various photovoltaic technologies, crystalline silicon solar cells dominate the market because of their high conversion efficiency, long service life, and low cost [1]. Continuous efforts to reduce manufacturing costs and improve module efficiency have led to the production of increasingly thinner silicon wafers [2]. However, the reduction in wafer thickness has also increased the susceptibility of silicon solar cells to mechanical damage, particularly crack formation and propagation [3].

Cracks are among the most critical reliability issues affecting crystalline silicon photovoltaic modules. They can originate during wafer cutting, soldering, lamination, transportation, installation, and long-term field operation [4]-[7]. Due to the brittle nature of crystalline silicon, even small defects can initiate microcracks that may propagate under thermo-mechanical and environmental loading conditions. These cracks can electrically isolate portions of the solar cell, resulting in inactive regions, increased series resistance, hotspot formation, reduced power output, and ultimately shortened module lifetime [8]. Therefore, understanding the mechanisms of crack initiation and propagation is essential for improving the durability and reliability of photovoltaic systems.

Experimental investigation of crack behavior in silicon solar cells is often expensive, time-consuming, and difficult, because crack evolution occurs at multiple length scales and under complex loading conditions [9] [10]. Consequently, numerical modeling techniques have become important tools for predicting crack behavior and evaluating photovoltaic module reliability [4]. Among these techniques, the Finite Element Method (FEM) has been widely used to analyze stress distribution, deformation, fracture initiation, and thermo-mechanical behavior in photovoltaic modules. FEM enables researchers to investigate the effects of manufacturing processes, material properties, thermal cycling, vibration, wind loads, and other service conditions on stress development within solar cells [11].

Although FEM is highly effective for stress analysis and crack initiation prediction, its capability for simulating crack propagation is limited, because crack growth typically requires continuous mesh modification [12]. To overcome this limitation, the Extended Finite Element Method (XFEM) was developed as an extension of conventional FEM [5]. XFEM incorporates enrichment functions into the finite element formulation, allowing cracks to initiate and propagate independently of the mesh. This capability makes XFEM particularly suitable for modeling fracture behavior in brittle materials such as crystalline silicon. Recent studies have increasingly combined FEM and XFEM to investigate crack formation, propagation, and reliability degradation in photovoltaic modules under manufacturing and operational loading conditions [4] [13]-[15].

Therefore, this review aims to provide a comprehensive overview of the application of FEM and XFEM in modeling crack initiation and propagation in crystalline silicon photovoltaic cells. The paper first discusses the mechanisms of crack formation in photovoltaic modules and the fundamental principles of FEM and XFEM. Subsequently, recent studies published between 2021 and 2026 are reviewed and compared to highlight their methodologies, key findings, and limitations. Finally, the major challenges and research gaps are identified, and future research directions are proposed to support the development of more reliable and durable photovoltaic systems.

2. Methodology

The methodology of this systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [16]. The data extraction and synthesis process were carried out through a structured series of steps to ensure a thorough and rigorous review. First, relevant studies were identified from databases including Google Scholar, Web of Science, PsycINFO, and Scopus, yielding 100 records. After removing duplicates and applying language criteria, 67 studies remained for screening. These were further filtered by reviewing titles and abstracts, reducing the pool to 42 records. Next, 28 full-text articles were assessed for eligibility based on relevance and quality considerations. Following detailed evaluation, 11 studies were excluded according to predefined criteria, resulting in a final inclusion of 17 studies. Each stage of the process systematically eliminated irrelevant publications, ensuring that the final synthesis was based on the most relevant and high-quality evidence available.

3. Crack Formation in Silicon Solar Cells

Crack formation is one of the major mechanical reliability problems affecting crystalline silicon cell based in photovoltaic modules [17]. The silicon cell is sandwiched between different material polymer to form the PV module, as shown in **Figure 1**.

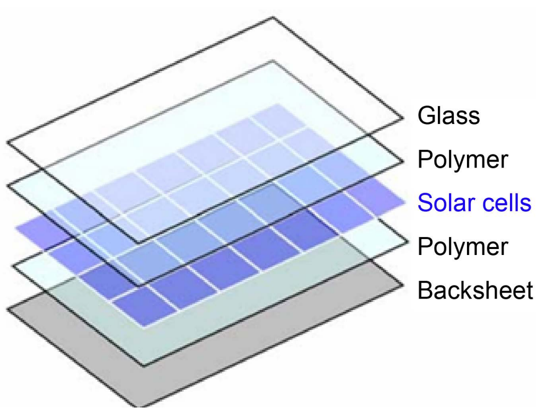

Figure 1. Layers of Silicon solar cell PV module [18].

This configuration is widely used in photovoltaic (PV) technology because of its excellent electrical properties and high conversion efficiency. However, crystalline silicon is inherently brittle and possesses low fracture toughness, making solar cells highly susceptible to cracking under mechanical and thermal loading conditions [17] [19]. Since modern silicon wafers are manufactured with very small thicknesses to reduce material costs and improve efficiency, their resistance to mechanical damage becomes even lower. As a result, cracks can easily initiate and propagate during the manufacturing process, transportation, installation, and long-term field operation of photovoltaic modules [2].

Cracks in silicon solar cells can be classified according to their size, shape, position, orientation, and severity. Based on size, cracks are categorized as microcracks (width less than 30 μm) and macrocracks [20]. According to their position, they may be surface (facial) cracks, which are visible on the wafer surface, or subsurface (subfacial) cracks, which propagate beneath the surface. In terms of orientation, cracks can be diagonal, parallel or perpendicular to busbars, ±45°, dendritic, or multidirectional [21]. Cracks are also classified by severity into Mode A, Mode B, and Mode C. Mode A cracks do not electrically isolate cell regions and have little effect on performance, whereas Modes B and C progressively disconnect parts of the cell, leading to power loss and, in severe cases, hotspot formation [2]. Additionally, in multicrystalline silicon, cracks may propagate as transgranular cracks (through crystal grains) or intergranular cracks (along grain boundaries) [18]. Those cracks can be formed during manufacturing transportation, and environmental conditions, as depicted in **Figure 2**.

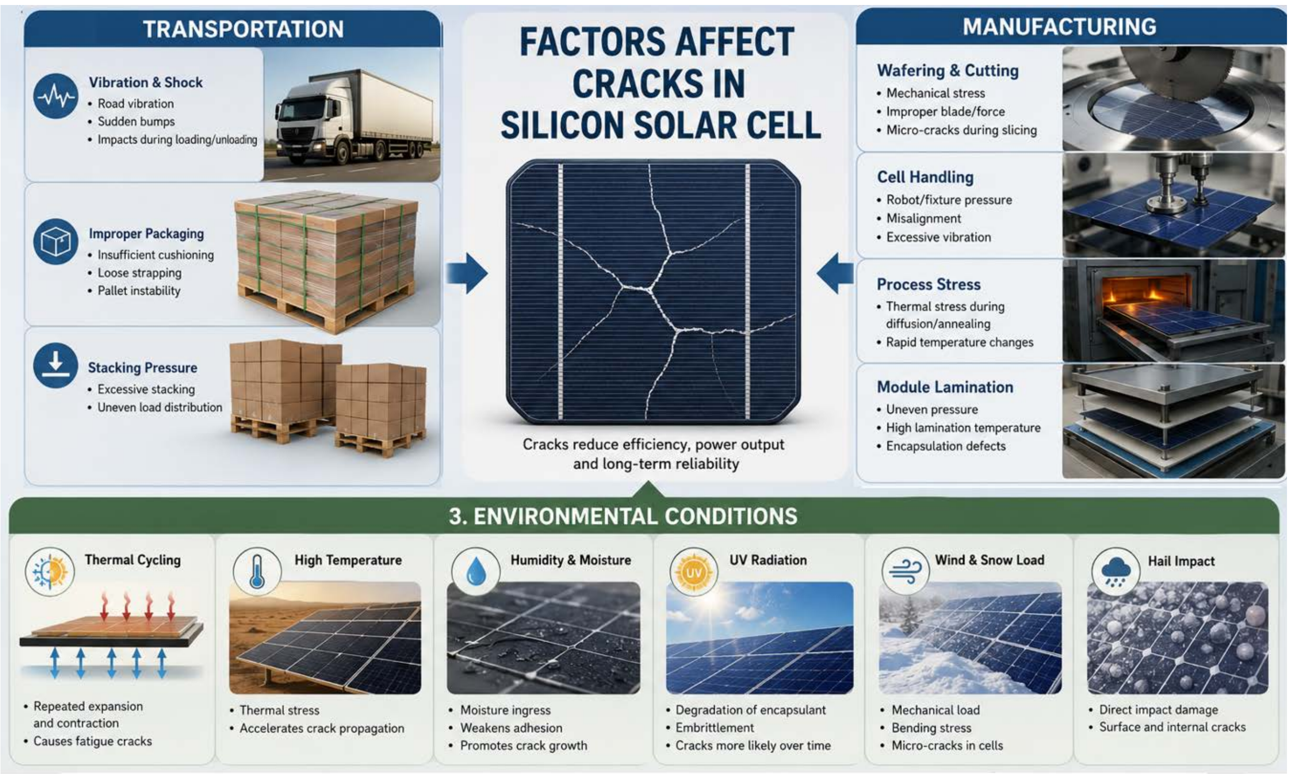

Figure 2. Factors induced cracks in PV module.

The manufacturing stage is one of the primary sources of crack initiation in silicon solar cells. During wafer slicing, handling, screen printing, soldering, and lamination processes, the silicon wafers are subjected to mechanical contact forces and thermal stresses that may generate small defects or residual stresses [5]. Wafer cutting can produce microscopic flaws on the wafer surface, which later act as crack initiation sites [12]. Similarly, soldering of interconnect ribbons onto solar cells introduces localized heating and thermal expansion mismatch between materials, resulting in thermo-mechanical stresses within the cell structure [22]. Lamination and encapsulation processes may also contribute to stress accumulation because different module layers possess different coefficients of thermal expansion [23].

Transportation and installation conditions further increase the risk of crack formation [4] [7]. Photovoltaic modules are exposed to vibration [24], bending, impact loads, and handling stresses during packaging, shipping, and installation. This means that improper handling or accidental dropping of modules can generate significant stress concentrations that initiate cracks within the brittle silicon wafers. In large-scale solar installations, mechanical loading due to mounting pressure, wind loads, and snow accumulation can also induce bending stresses in PV modules [20]. These stresses are transferred to the silicon cells and may accelerate crack propagation over time.

Environmental and operational conditions play an important role in long-term crack development [6]. Solar modules experience repeated thermal cycling due to continuous day-to-night temperature variations and seasonal weather changes. The repeated expansion and contraction of module materials generate cyclic thermo-mechanical stresses that promote fatigue crack growth in silicon cells [25]. High humidity and moisture penetration may weaken adhesive interfaces and encapsulation materials, indirectly contributing to crack propagation [1]. The presence of cracks significantly affects the electrical and mechanical performance of photovoltaic modules. Cracks interrupt conductive pathways inside the silicon cell, causing electrically inactive regions that reduce power generation efficiency. Severe crack propagation may lead to complete electrical isolation of parts of the cell, increased series resistance, and hotspot formation. Over time, crack growth reduces the structural reliability and operational lifespan of photovoltaic systems. Therefore, understanding the mechanisms of crack initiation and propagation is essential to improve the durability of the PV module and develop accurate finite element models capable of predicting crack behaviour under different loading conditions.

4. Fundamentals of Modeling in Silicon Photovoltaic Cells

This section focuses on the application of both finite element method and the extended finite element method on silicon photovoltaic cells.

4.1. Basic Concept of Finite Element Method

The Finite Element Method (FEM) is a numerical computational technique used to analyze the behavior of engineering structures and materials under different physical conditions [9]. FEM is particularly useful for solving problems with complex geometries, heterogeneous materials, and irregular loading conditions that cannot easily be solved analytically. The FEM process generally involves several stages, including geometry creation, material property assignment, mesh generation, application of boundary and loading conditions, numerical solution of governing equations, and post-processing of results [10].

The mesh generation is one of the very important steps in FEM. The method usually works by dividing a complex structure into many smaller interconnected parts called finite elements, which are connected through nodes to form a mesh [26]. In structure analysis for instance, each element is represented by mathematical equations that describe its mechanical behaviour. By solving these equations simultaneously, FEM determines important parameters such as stress, strain, displacement, deformation, and temperature distribution within the structure. The quality of the mesh strongly affects the simulation accuracy because finer meshes near crack tips and stress concentration regions improve the prediction of crack behaviour.

Cracks may form during wafer manufacturing, soldering, lamination, transportation, installation, or long-term environmental exposure. FEM enables researchers to simulate these different loading conditions and study their influence on crack formation [4]. For example, thermal cycling caused by daily temperature variation produces thermo-mechanical stresses due to differences in thermal expansion coefficients between silicon, glass, encapsulants, and metallic interconnects [27]. FEM can calculate the resulting stress distribution and identify regions susceptible to crack propagation.

As FEM may not predict crack-propagation, it has the ability to combine with crack propagation modelling approaches, such as the extended finite element method (XFEM), Cohesive Zone Modelling (CZM), and phase-field fracture modelling. XFEM is particularly important because it allows crack growth simulation without continuous remeshing of the structure [6].

FEM is also important because experimental crack testing in solar cells is often expensive, time-consuming, and difficult to control precisely. Numerical simulations therefore provide a cost-effective approach for evaluating photovoltaic reliability and optimizing solar cell design before fabrication and deployment.

4.1.1. Modeling Assumptions

Several assumptions are commonly adopted in finite element analysis of silicon solar cells to simplify the numerical model and reduce computational cost. One of the most common assumptions is linear elastic material behavior for crystalline silicon [6] [28]. Silicon is considered brittle; therefore, the linear assumption was considered because silicon maintains the linear property until the fracture occurs [29].

Most FEM studies assume isotropic material behavior for silicon, meaning that material properties are identical in all directions [6]. However, crystalline silicon may exhibit anisotropic mechanical behavior depending on crystal orientation, and some advanced models incorporate anisotropic fracture properties for improved accuracy [30]. However, it was found that in term of stress distribution and deformation, the result from anisotropic assumption is very similar with isotropic assumption [31]. Similarly, the simplified, isotropic model seems to provide accurate values compared to the anisotropic model for deflection due to the mechanical load (error: 2.8%) [12].

Another common assumption is perfect bonding between different layers of the photovoltaic module, including silicon cells, encapsulants, glass, and backsheets [11] [17]. This means that no slipping or separation occurs between layers except at predefined crack or interface regions. In crack propagation studies, interface elements or decohesion elements may be introduced to simulate delamination and interfacial fracture [32].

To reduce computational requirements, two-dimensional models are often used instead of full three-dimensional geometries. Although three-dimensional simulations provide more realistic results, they require significantly higher computational resources [33]. The use of two-dimensional simplifications may neglect out-of-plane deformation, thickness-wise stress gradients, and three-dimensional crack-front effects [9]. Therefore, the predicted stress fields and crack paths may differ from those obtained using full three-dimensional models.

4.1.2. Material Properties Used for Silicon PV Cell

The accuracy of finite element simulations strongly depends on the material properties assigned to the solar cell components. Crystalline silicon is the primary material in most photovoltaic cells, and several mechanical and thermal properties are required for FEM analysis. The most important property are Young's modulus, Poisson's ratio, density, tensile strength, and thermal expansion coefficient [14] [34] [35].

Young's modulus describes the stiffness of the material and its resistance to elastic deformation. While, Poisson's ratio describes the lateral deformation behavior of a material when subjected to loading and is commonly incorporated into finite element models to predict elastic deformation, strain distribution, and thermo-mechanical responses in photovoltaic cells [14].

The thermal expansion coefficient (CTE) is an important material property in finite element modeling (FEM) of photovoltaic (PV) cells because it governs how much a material expands or contracts when subjected to temperature changes. In crystalline silicon solar cells, temperature variations occur during manufacturing processes such as soldering and lamination [3].

Since photovoltaic modules are multilayer structures, material properties of other components must also be included in the FEM model. These materials include glass covers, polymer encapsulants such as EVA, backsheets, metallic ribbons, and adhesives. Each layer contributes differently to the overall thermo-mechanical behavior of the module.

For thermo-mechanical simulations, temperature-dependent properties may be included to account for material behavior changes under varying environmental conditions. Some advanced studies also incorporate viscoelastic properties for polymeric materials because encapsulants and backsheets may exhibit time-dependent deformation behavior under long-term thermal exposure.

4.2. Extended Finite Element Method

Due to mesh dependence, the finite element method may not accurately predict the propagation of the crack. Therefore, the researchers have used XFEM. They have incorporated XFEM into the conventional FEM framework after the thermomechanical stress analysis of the photovoltaic (PV) module [12]. In conventional FEM, the mesh would need to be remeshed as the crack grows, but XFEM overcomes this limitation by enriching the displacement field at selected nodes.

This **Figure 3** illustrates the Extended Finite Element Method (XFEM) representation of a crack within a finite element mesh. The black diagonal line represents the crack passing through the elements without requiring the mesh to conform to the crack geometry. The nodes marked with blue dots (K_T) are Heaviside enrichment nodes, which are associated with elements cut by the crack faces. These nodes use the Heaviside function to model the displacement discontinuity across the crack surfaces. The nodes marked with red dots (K_A) are crack-tip enrichment nodes, located around the crack tip region. These nodes employ special asymptotic crack-tip functions to accurately capture the stress singularity and high stress gradients near the crack tip. The shaded yellow elements indicate the enriched region where additional XFEM functions are applied. By using these enrichment functions, XFEM can represent crack initiation and propagation independently of the mesh, improving the accuracy and efficiency of fracture mechanics simulations [6].

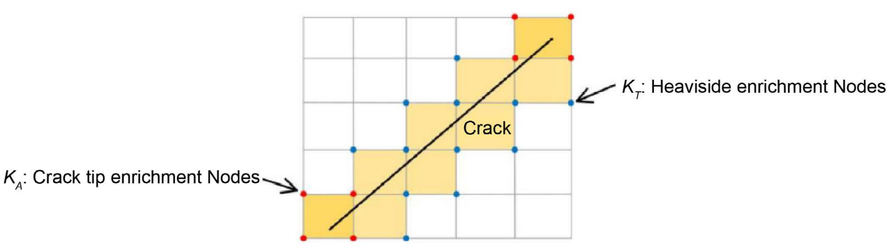

Figure 3. XFEM Scheme to model a crack with Heaviside enrichment function for the discontinuity and asymptotic enrichment functions for the singularity at the crack tip [6].

First, FEM is used to simulate sequential manufacturing and operating stages, including laser cutting, soldering, lamination, mechanical loading, and thermal cycling, while transferring residual stresses from one step to the next. Once the stress field is obtained, XFEM is applied to the silicon cells to model crack initiation and propagation without requiring remeshing [4]. The initiation of cracks is governed by the maximum principal stress criterion (MAXPS), which assumes that a crack nucleates when the maximum tensile principal stress (σ_m) in the silicon cell reaches or exceeds the tensile strength of silicon (σ_t) [36]. Therefore, the quantity controlling crack initiation is the maximum principal stress. After crack initiation, crack propagation is modeled using a cohesive traction-separation law, where the evolution of damage is governed by the critical energy release rate (G_c), defined as the energy required to create a unit area of new crack surface. A crack is considered to be growing when the energy available for crack extension, known as the energy release rate (G), reaches or exceeds the critical value (G_c) [5]. Thus, FEM provides the stress distribution, while XFEM enriches the finite element solution with additional degrees of freedom to capture crack formation and propagation within the silicon cells.

5. Application of FEM and XFEM for Crack in Slicon Photovoltaic Cells

Recent studies have employed different loading conditions to investigate the mechanical reliability of photovoltaic (PV) cells and modules. Under mechanical loading conditions, Zhang *et al.* [34] developed a three-dimensional finite element model in ABAQUS to investigate micro-crack initiation in polycrystalline silicon wafers subjected to tensile loading. The model predicted stress distributions and identified the maximum principal stress as the dominant parameter governing crack initiation. It also revealed the influence of dislocations and impurities on the critical stress required for crack formation. Similarly, Tariq *et al.* [15] investigated the effects of pre-existing microcracks under tensile loading using a FEM-based numerical homogenization approach. By incorporating Voronoi-generated polycrystalline silicon microstructures, the model predicted effective material properties and stiffness degradation caused by crack propagation. The homogenized approach efficiently captured the mechanical degradation of PV cells while reducing computational costs. Likewise, Raj *et al.* [37] examined the mechanical strength of silicon solar cells subjected to four-point bending tests using an ANSYS-based finite element model. The model predicted stress distributions, deformation, fracture stress, and the influence of busbar orientation on cell strength. Residual stresses generated during manufacturing and local stress concentrations at metallization-silicon interfaces were not considered. Furthermore, Nikitin *et al.* [38] employed a finite element model combined with ring-on-ring testing under biaxial bending loads to evaluate the fracture strength of silicon wafers with different surface textures. The model successfully predicted stress distributions, fracture strength.

In addition to purely mechanical loading, several studies have investigated the thermal response of photovoltaic modules. Roy *et al.* [14] developed an FEM model in ANSYS to evaluate the thermo-mechanical behavior of thin-film solar cells under thermal loading. The model predicted thermal heat flux, deformation, thermal stress, and elastic strain for different photovoltaic materials. However, it did not consider crack initiation or propagation and was limited to simplified thin-film geometries under uniform temperature conditions. Similarly, Laha *et al.* [39] used a three-dimensional thermal finite element model in ANSYS to investigate temperature distribution and hotspot formation in photovoltaic panels. Their findings demonstrated that implementing cooling systems effectively reduced operating temperatures and improved panel efficiency. Wang *et al.* [11] focused on thermo-mechanical loading generated during soldering and lamination in multi-busbar photovoltaic modules. Their finite element model successfully characterized stress evolution around solder joints and overlapping regions while evaluating the effects of different solder materials and cell configurations on stress concentrations. Similarly, Mathusuthanan *et al.* [4] developed a two-dimensional FEM model incorporating XFEM and Linear Elastic Fracture Mechanics (LEFM) to investigate inherent microcracks during soldering and lamination. The study predicted stress intensity factors, residual stress distributions, and crack propagation behavior, demonstrating that crack growth strongly depended on crack location and manufacturing-induced residual stresses. Furthermore, Du *et al.* [3] examined ultra-thin silicon PV modules subjected to soldering, lamination, and dynamic mechanical loading using both two-dimensional and three-dimensional finite element models. Their results revealed that thinner wafers experienced greater stresses, higher fracture risks, and larger power losses while identifying an optimal super multi-busbar configuration that enhanced module reliability.

Moreover, thermal cycling has received considerable attention because of its influence on long-term structural reliability. Klasen *et al.* [40] recent study developed three-dimensional and pseudo-two-dimensional thermo-mechanical FEM models in COMSOL Multiphysics to investigate crack formation in shingled photovoltaic modules subjected to repeated thermal cycles between −40˚C and 85˚C. The simulations successfully predicted tensile stress distributions, deformation fields, and crack-prone regions around electrically conductive adhesive joints while explaining experimentally observed crack patterns. Likewise, Tao *et al.* [23] another study employed a three-dimensional FEM implemented in COMSOL Multiphysics, together with experimental validation, to analyze photovoltaic modules exposed to thermal loading during lamination as well as static and dynamic service loads representing wind and snow conditions. The model successfully predicted thermo-mechanical stress distributions and micro-crack formation. In contrast to manufacturing-related loading, several researchers have focused on dynamic loading encountered during transportation and service. Desai *et al.* [8] investigated vibration-induced damage during road transportation using a three-dimensional finite element model capable of predicting natural frequencies and mode shapes. The study successfully identified regions most susceptible to cracking. Similarly, Bhore *et al.* [28] analyzed photovoltaic modules subjected to metro-train-induced vibrations through modal and harmonic response analyses. Their findings demonstrated that mounting configurations significantly influence vibration behavior and structural degradation. Nevertheless, crack propagation and electrical performance losses were not explicitly considered.

To overcome the limitations of conventional FEM, recent studies have increasingly adopted the Extended Finite Element Method (XFEM) to explicitly simulate crack initiation and propagation. Papargyri *et al.* [12] one study developed a combined three-dimensional FEM-XFEM model to investigate crack initiation and propagation under uniform snow-load conditions. The model accurately predicted stress distributions, crack growth paths, and failure loads while demonstrating that thinner silicon wafers reduced fracture resistance and half-cell configurations delayed crack initiation. Similarly, Jiao *et al.* [6] employed a three-dimensional XFEM model to simulate crack propagation in photovoltaic modules containing pre-existing microcracks under static mechanical loading. The findings highlighted the significant influence of support configuration and crack orientation on structural integrity. Furthermore, Fang *et al.* [41] extended XFEM by coupling it with Paris' law to investigate fatigue crack propagation under cyclic wind- and snow-induced loading. The model successfully predicted crack growth rates and the influence of loading characteristics but excluded temperature-dependent degradation mechanisms. Finally, Papargyri *et al.* [5] a more comprehensive modeling strategy was proposed through a sequential FEM-XFEM framework covering the entire photovoltaic module lifecycle, including laser cutting, soldering, lamination, mechanical loading, and thermal cycling. The results demonstrated that manufacturing-induced residual stresses play a crucial role in crack formation and that half-cut cell modules exhibit greater resistance to crack propagation than conventional full-cell designs.

6. Challenges and Research Gaps

Despite substantial progress in FEM and XFEM-based modeling of photovoltaic module reliability, several key challenges and research gaps remain. Many models treat mechanical, thermal, and dynamic loads separately, even though PV modules in real environments experience coupled thermo-mechanical, vibrational, and cyclic loading that interact to accelerate fatigue damage. Although XFEM approaches improve crack simulation, they are often limited by predefined crack locations, neglect of complex fatigue-thermal coupling, and simplified fracture mechanics formulations. Furthermore, there is still weak integration between mechanical damage and electrical performance degradation, with only limited studies quantifying how cracks affect power output, fill factor, or interconnection resistance. Many simulations also use idealized service conditions, failing to represent fluctuating environmental loads such as wind turbulence, thermal gradients, transport shocks, and long-term aging effects. Manufacturing-induced residual stresses from processes such as soldering, lamination, and laser cutting are frequently simplified or ignored, despite their strong influence on later failure. Finally, validation remains limited, as most models are calibrated against short-term experiments rather than long-term field data, reducing confidence in lifetime reliability predictions. Overall, there is a clear need for fully coupled thermo-mechanical-electrical FEM-XFEM frameworks, improved material constitutive models, and more realistic lifecycle and experimental validation approaches.

7. Conclusion

This review examined recent applications of the Finite Element Method (FEM) and Extended Finite Element Method (XFEM) for modeling crack initiation and propagation in crystalline silicon photovoltaic cells. The reviewed studies demonstrate that FEM is widely used to evaluate stress distribution, deformation, and thermo-mechanical behavior under manufacturing processes, mechanical loading, thermal cycling, vibration, and transportation conditions, whereas XFEM overcomes the mesh dependency of conventional FEM by enabling accurate simulation of crack initiation and propagation. The literature further shows that manufacturing-induced residual stresses, wafer thickness, crack location, support configuration, and loading conditions significantly influence crack development and module reliability. Although recent FEM-XFEM models have improved the prediction of fracture behavior, most studies remain limited by simplified material assumptions, incomplete coupling of different loading conditions, and limited consideration of electrical degradation associated with crack growth. Therefore, further research should focus on developing more realistic and experimentally validated models that integrate manufacturing and operational loading conditions while simultaneously evaluating both structural integrity and photovoltaic performance throughout the service life of the module.

8. Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this study, the author used Grammarly to check and improve English. After using this tool/service, the author reviewed and edited the content as needed.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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