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# Comprehensive Review and Future Prospects of Encapsulation Technologies for Building-Integrated Photovoltaic (BIPV) Systems

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**Abstract:**The incorporation of building-integrated photovoltaics (BIPV) presents a viable solution to the challenge of balancing the reduction in building energy consumption with the growing demand for energy in buildings. This approach represents a significant future trend in the photovoltaic market. This paper provides a thorough review of the current state of encapsulation techniques for solar modules used in BIPV systems, both domestically and internationally. Additionally, it offers insights into the prospective developments in encapsulation technologies for solar cell modules within BIPV applications.

**Keywords:**Building-integrated photovoltaic; solar modules; encapsulation; status analysis.

## 1. Introduction

Building-integrated photovoltaic technology (BIPV) is a new building technology which combines solar cell module with glass curtain wall. It is an effective way to solve the contradiction between reducing building energy consumption and increasing building energy demand [1], which helps to digest the production capacity of photovoltaic industry. Solar cell module is the key component of photovoltaic power generation system, and the process packaging technology applied in the packaging operation of solar cell module is the key technology of solar cell module production. In this paper, the research status of solar cell module packaging technology for photovoltaic building integration at home and abroad is comprehensively reviewed, and the development trend of solar cell module packaging technology suitable for BIPV is prospected.

## 2. Research Status of Encapsulation Technique of Abroad Solar Cell Module for BIPV

In view of the unique advantages of BIPV, foreign countries began to apply solar cell modules to buildings as early as the 1970s, and gradually realized the commercialization of solar cell module products for BIPV [2-3], and developed countries have issued incentive policies to promote the application of BIPV products technology [4]. Driven by economic development, Japan, Europe, the United States and other energy consuming countries have started the development and utilization of BIPV technology earlier. They are in a leading position in the packaging technology of solar cell modules. Representative component packaging equipment manufacturers include Meier company in Germany, which is in the leading position of laminating machine technology in the world and the innovator of multi-layer press, and spaleck Stevens company, which can complete preheating, lamination and cooling in one machine, so as to reduce space occupation [5]. Although many countries can produce more equipment for solar cell module, there are few packaging equipment that can be used in BIPV.

## 3. Research Status of Encapsulation Technique of Domestic Solar Cell Module for BIPV

The production and R & D of solar cells for BIPV started relatively late in China. With the development of photovoltaic industry, more and more solar cell modules can be applied to BIPV, such as double glass modules, transparent and opaque design modules, laminated tile modules, MWT modules with customized patterns and patterned thin film modules [6]. However, at present, the solar cell module products used in BIPV are less concerned about the impact on building decoration, and less solar cell modules meet the demand of building materials. Most of the current photovoltaic building integration projects install solar cell modules as photovoltaic curtain walls on the facade of buildings, which is the "primary version" of photovoltaic building integration. Therefore, the domestic photovoltaic building integration market is still in the stage of market introduction [6].

At present, there are many representative enterprises producing packaging equipment for solar cell modules in China. Although these enterprises have independently developed various types of packaging equipment, they have significantly narrowed the gap with developed countries in photovoltaic manufacturing and application. Compared with corresponding foreign manufacturing enterprises, they lack innovation and have serious technology homogenization. The manufacturing of their products mostly stays in the imitation stage, which is in the key technology leading position. There is still a big gap compared with international well-known brands, mainly in the aspects of low efficiency, high comprehensive energy consumption, low degree of automation and intelligence, and the key problems restricting the healthy and sustainable development of photovoltaic industry need to be solved.

## 4. Problems to Be Solved in Encapsulation Technique of Solar Cell Modules for BIPV

(1) In order to break through the technical bottleneck of high efficiency solar cell module packaging, the packaging technology and process parameters of solar cell module for BIPV are explored.

(2) In order to meet the needs of the market, the technology equipment for large-scale BIPV solar cell module is developed.

(3) It is necessary to improve the automation and intelligence level of solar cell module packaging equipment.

## 5. Conclusion

Building-integrated photovoltaic is an effective way to reduce building energy consumption and increase building energy demand. It is urgent to develop packaging process equipment for BIPV and solve the key technology in its manufacturing. Under the national policy support and market demand for BIPV technology, the packaging technology and equipment used for BIPV solar cell modules will be constantly updated and upgraded.

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