Building Integrated Photovoltaic Elements: Challenges in Design and Reliability

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Goals and Motivations

• Only a few percentage of Photovoltaic (PV) systems fulfill the criteria for an aesthetic integration into the building envelope. Moreover, these building integrated (BIPV) systems usually present a high price and limited warranty compared to the building lifetime [1].
• In order to increase the lifetime of BIPV elements, a detailed analysis of the specific constraints and a deep understanding of the related failures is crucial [2].
• The design of lightweight solutions is critical for further BIPV deployment as the typical module weight is between 13-20 kg/m², which can be too high particularly in the case of building renovation.

Approaches

• Intimate knowledge of the constrains and failures of BIPV installations by means of literature review and reports from existing installations
• Based on this information, develop dedicated sets of accelerated lifetime tests (ALTs) and participate to the development of a predictive model for long-term performances of BIPV elements
• Develop lightweight prototypes to obtain:
  ➢ Cost-effective solutions
  ➢ Further inputs on possible failures arising when non-standard materials are used

Module Reliability: identification of constraints and impact on failure modes

• The constraints on standard PV modules can be very different depending on the type of installation, here two examples:

Operating temperature

The operating module temperature (Tmod) varies significantly:
➢ The highest Tmod is measured for integrated modules due to poor ventilation
➢ The increase in temperature from ambient is between 40-60°C leading to a maximum Tmod of 85°C
→ This has an impact on
➢ The module performance with relative annual losses between 5 and 11%
➢ The triggering/increase of failures modes which are driven by temperature: adhesion issues, potential induced degradation, etc.

Mechanical stress

Façade composed of frameless modules fixed with clamps (left) and FEM calculations for such modules with a load of 1.8 kN/m² [4].

• In case of façade application, frameless glass/glass modules are generally fixed with clamps to improve the esthetics
→ This can induce:
➢ A non homogeneous stress on the module.
➢ An increase of the risk of cells micro-cracks

BIPV elements: the lightweight approach

Failure Modes observed on lightweight commercial modules

• Sets of first ALTs where performed on flexible and rigid lightweight solutions available on the market (not primarily intended for buildings)

Module characterization

➢ Thermal cycling 40/85°C for 200 cycles
➢ Hail Test 25mm diameter (ice ball at 23 m/s)
➢ Damp Heat 85°C at 85% for 1000h

→ Various types of failures were observed

Cracked cells due to hail impact

Thermal-expansion mismatch

Interconnection failure

Prototypes of lightweight solutions

• Prototypes were developed where the front glass is replaced by ETFE and the typical backsheet by a composite structure with glass fiber

Major observations:

• After thermal cycling a few cracks are observed but no impact on electrical performance
• Cell corrosion and yellowing of the backsheet (thermal oxidation of the glass fiber) appear during damp heat
• Cell corrosion due to high humidity content

Conclusions/Outlook

• Assessing the specific requirements of BIPV and their impact on potential failure modes is necessary to increase the lifetime of BIPV elements: e.g. measurements confirm that in highly integrated roof installations the module temperature can reach 85°C vs ~ 60°C for a well ventilated one
• Lightweight solutions are particularly attractive for BIPV: unfortunately, present commercial lightweight modules tested do not have the adequate design to offer a minimum lifetime of 30 years with very poor results after ALTs, confirming the necessity to develop more reliable designs
• In-house developed prototypes also demonstrated weaknesses in terms of design such as a high permeability to water leading to cell corrosion: the impact of water ingress can however be limited by the choice of a more appropriate encapsulant and new prototypes are under test

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