Building Integrated Photovoltaic Elements: Challenges in Design and Reliability

Ana Martins[1], Joël Sunier[1,2] ,Xavier Niquille[1], Eleonora Annigoni[1], Christophe Ballif [1,2], Fanny Sculati-Meillaud[1]

[1] *École Polytechnique Fédérale de Lausanne (EPFL), Institute of Microengineering (IMT), Photovoltaics and Thin Film Electronics Laboratory, Rue de la Maladière 71b, 2000 Neuchâtel, Switzerland*

[2] *CSEM, PV-center, Jaquet-Droz 1, 2000 Neuchâtel, Switzerland*

e-mail: ana.martins@epfl.ch

Goals and Motivations

- Only a few percentage of Photovoltaic (PV) systems fulfil the criteria for an aesthetic integration into the building envelope. Moreover, these building integrated (BIPV) solutions 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.

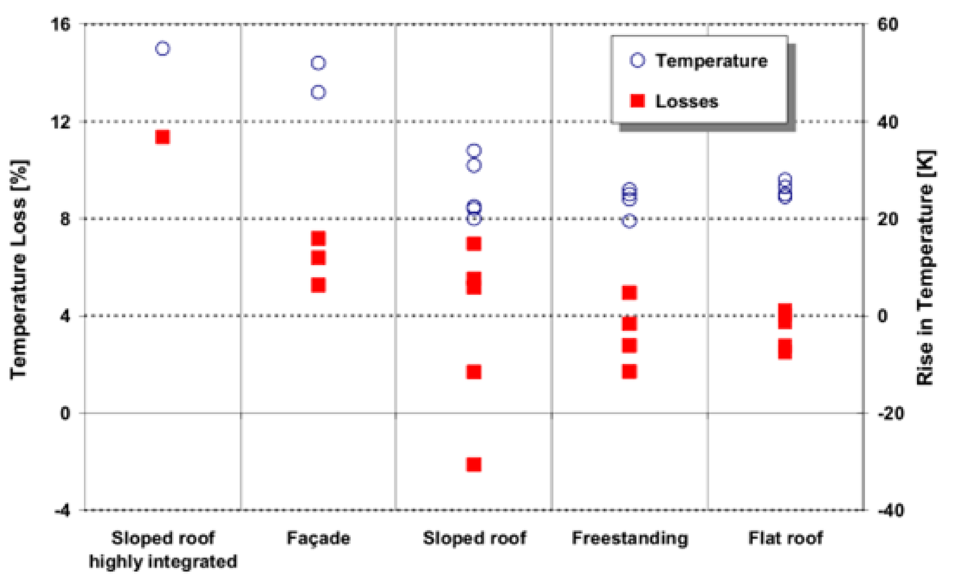
Approaches

- 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

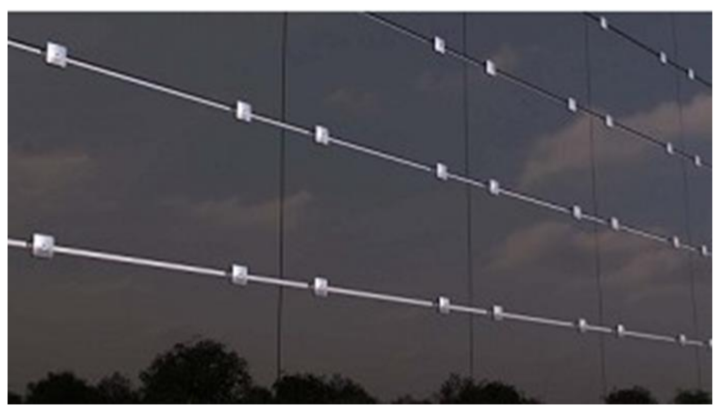


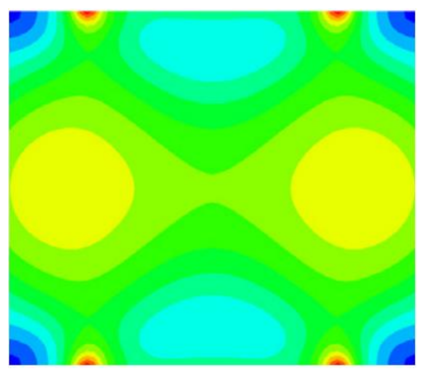
Rise in module temperature from ambient value at 1000 W/m² and corresponding relative loss in efficiency for different types of PV installations, according to [3]

- The operating module temperature (T_{mod}) varies significantly:
  - The highest T_{mod} is measured for integrated modules due to poor ventilation
  - The increase in temperature from ambient is between 40-60°C leading to a maximum T_{mod} 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**

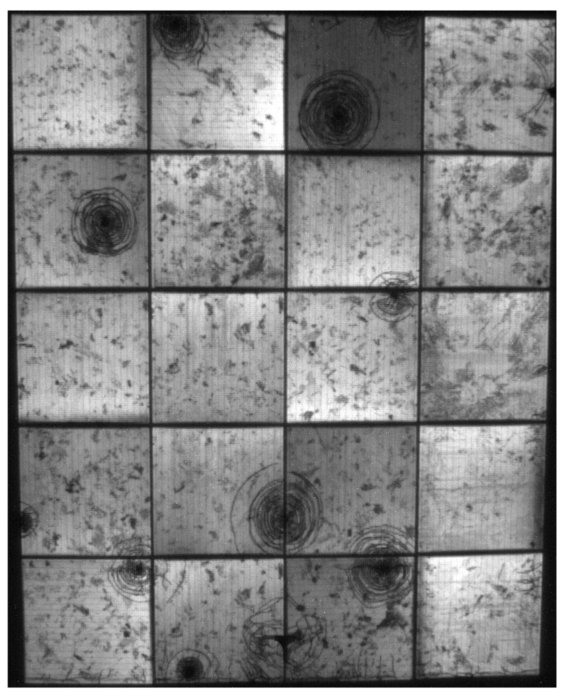
BIPV elements: the lightweight approach

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 200cycles → **Hail Test** 25mm diameter ice ball at 23 m/s → **Damp Heat** 85°C at 85% for 1000h

→ Various types of failures were observed



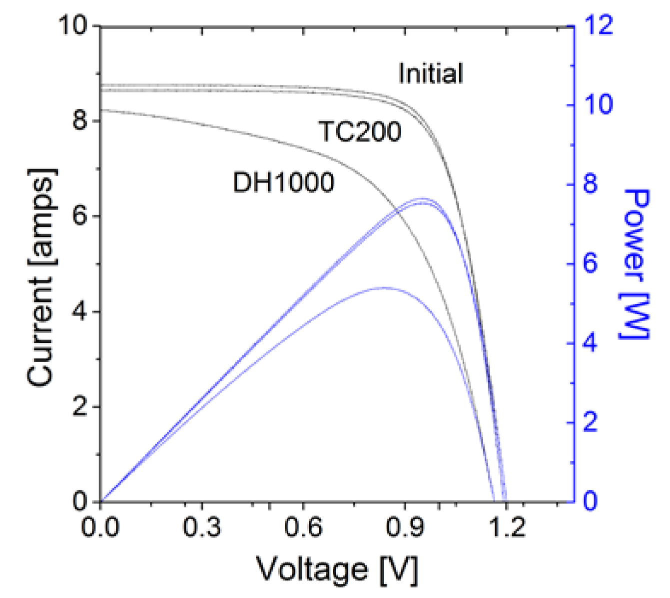
Cracked cells due to hail impact

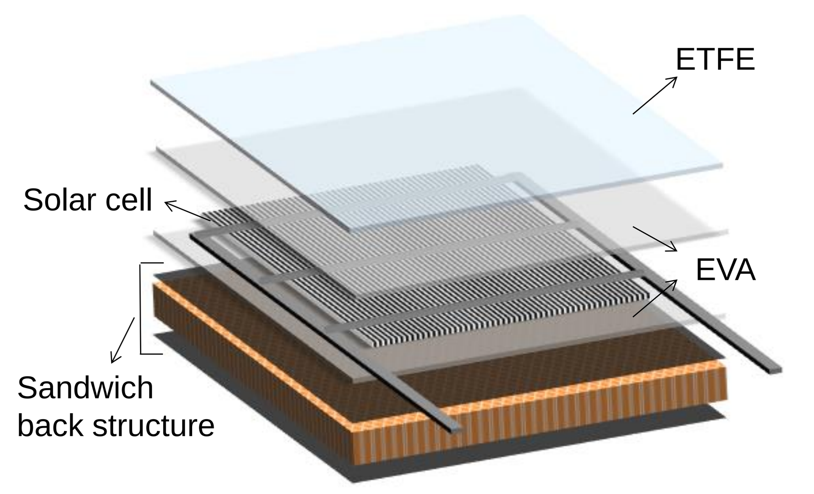
Thermal-expansion mismatch

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

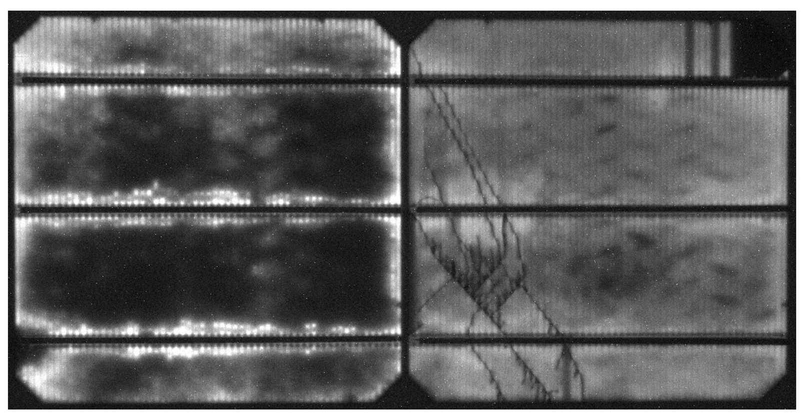




Prototype design

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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Acknowledgements

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