First mechanical study on a lightweight microconcentrator design for space applications

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Future spacecraft will require higher-powered photovoltaic subsystems in order to achieve missions that are more ambitious. For space applications, constraints on solar array size, mass, and storage volume have encouraged the development of efficient Multi-Junction Solar Cells (MJSC). While their higher power levels have helped to increase spacecraft payload capabilities, MJSC for space are composed of expensive III-V materials. One of the approaches is Concentrator PhotoVoltaics (CPV) arrays, which demonstrated the highest efficiency ever achieved by any solar technology at the cell, module, and system levels [1]. CPVs systems use optical elements to focus the sunlight onto a much smaller solar cell area, typically MJSC.

The key interest of concentrators is to rely on the usage of these high-efficiency MJSC while reducing the cells' area by orders of magnitude, then reducing the cost. In addition, the use of CPV also enables significantly higher conversion efficiency than cells operating under AM0 conditions and increased radiation hardness [2]. However, in CPVs, the supplementary mass due to the optical system and mechanical support structures is a drawback. Furthermore, advanced approaches designs including microscale ($< 900\ \mu m^2$) photovoltaics have the potential to extremely reduce the optical profile, thus lowering mass, while having moderate concentration factors (< 50X). Moreover, other advantages of using micro-cells include passive thermal dissipation, which avoids heat sinks and reduce mass through the mitigation of CTE mismatch effects between cell and substrate, due to small dimensions [3],[4].

Our new innovative design integrates a network of optics inserted in a honeycomb structure [5], which suggest that high power levels per unit mass (W/Kg) can be achieved. Taking into account the mass of PVA mechanical support, it could realistically exceed 150W/kg (at incident AM0 spectrum). This work aims to study the mechanical behaviour, in particular the bending stiffness of the design. The structure is as presented on the scheme below (Figure 1). A first honeycomb core structure on the bottom is made of two face sheets bonded to both faces of the honeycomb, using epoxy-based adhesive. A second honeycomb (top) is then bonded to the bottom one using the same adhesive. The cells of the top honeycomb are partially filled with silicone. The front glass plate is ultimately bonded to the top honeycomb. Integrating the optics into the top honeycomb removes the need for an additional support for the optics, which would increase the mass of the overall system while maintaining high mechanical properties. To reach our stiffness and mass goals, 4-point bending tests were performed on different configurations with variable parameters: the bottom honeycomb thickness (*th*) and cell size (*c*) and the thickness of the carbon composite sheets (*tf*) and the glass (*tg*) (see Figure 1). Figure 2 shows an example of the load-displacement curves obtained.

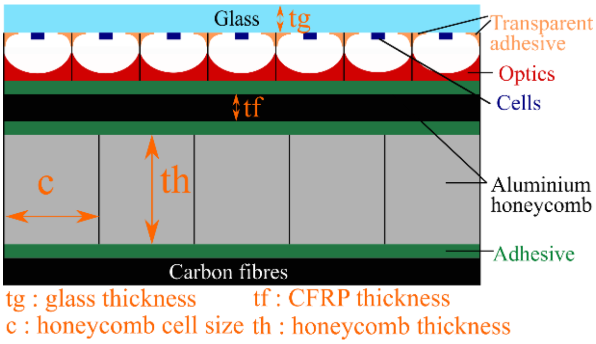

Fig 1: Scheme of the complete structure

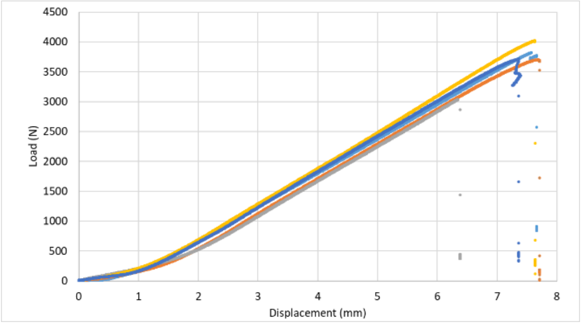

Fig 2: Load-displacement curves for a structure (tg = 0.3mm, tf=2 plies, c = 1/4 in., th = 20mm). Each colour corresponds to a test sample

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