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SiLibeads®

Glass Beads as Optical Elements in Concentrator Photovoltaics

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Introduction

With an annual output of approximately 600,000 kWh generated by its proprietary ground-mounted photovoltaic (PV) system, Sigmund Lindner GmbH (SiLi) has leveraged solar energy for sustainable production of its products for many years. In higher latitudes, flat-panel PV modules dominate; however, in regions with high direct solar irradiation, electricity can also be generated using concentrator photovoltaics (CPV).

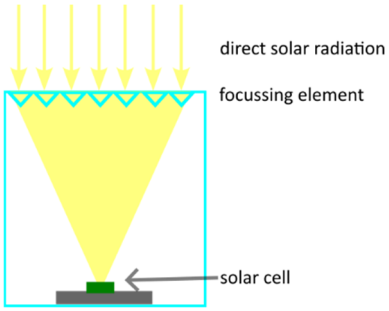

Figure 1: Schematic of CPV (Concentrator Photovoltaics)

CPV modules concentrate sunlight up to 1,000 times onto a small power-generating element (see Figure 1). This significantly reduces the need for expensive semiconductor materials. Furthermore, by combining multiple semiconductor layers within the tiny solar cells, typically only a few mm^2 in size, nearly the entire solar spectrum—from UV to IR—can be utilized. As CPV modules become increasingly miniaturized, precise illumination of the cells is critical to achieving optimal efficiency [1, 2].

Within the framework of the project "micro-CPV – Development of a CPV module based on state-of-the-art micro-manufacturing technology", funded by the German Federal Ministry for Economic Affairs and Climate Action, SiLi, in collaboration with Fraunhofer ISE and other project partners, investigated whether the efficiency and fault tolerance of CPV modules could be enhanced by incorporating SiLibeads® Glass Beads as additional spherical lenses in front of the solar cells.

SiLibeads® Glass Beads as Optical Elements

For decades, SiLi has manufactured high-quality technical glass beads using state-of-the-art technologies and facilities. These beads are applied in various industries, including pharmaceuticals (e.g., mixing beads in insulin cartridges), food (closure beads), and water treatment (support and filter materials).

SiLibeads® Glass Beads are further employed as grinding beads, dispersing balls, filling beads, reflex beads and blasting glass balls [3].

Figure 2: SiLibeads® glass beads [3]

The novel optical application introduced within this project required SiLi to consider specific glass transmission properties for the first time. Leveraging long-standing expertise in the thermal shaping of Type-S glass beads, the economic mass-production process was successfully adapted to glass beads made from low-iron "solar glass." Various post-processing steps—such as sieving, sorting by roundness, and polishing—tailored to specific application requirements, ensured precise adherence to the specified tolerances in diameter, sphericity, and surface quality.

To further enhance the efficiency of CPV modules, the fabricated spherical lenses were coated with an anti-reflective layer. Using a sol-gel process, the "moth-eye principle" was applied to the bead surface, improving transmission characteristics across the entire usable solar spectrum [4].

Use of SiLibeads® Glass Beads in Micro-CPV Modules

The solar glass beads produced during the project were spectrally analysed for their transmission properties in collaboration with Fraunhofer ISE. The average transmission of a monolayer of beads between two glass substrates was measured. While the total transmission of individual beads is higher, it could not be directly measured [5]. Figure 3 exemplifies transmission improvements achieved through various processing steps compared to a reference measurement on a monolayer of standard Type-S soda-lime glass beads in the 0.25–2.5 µm wavelength range. These measures increased the average transmission by 5–7% compared to the reference.

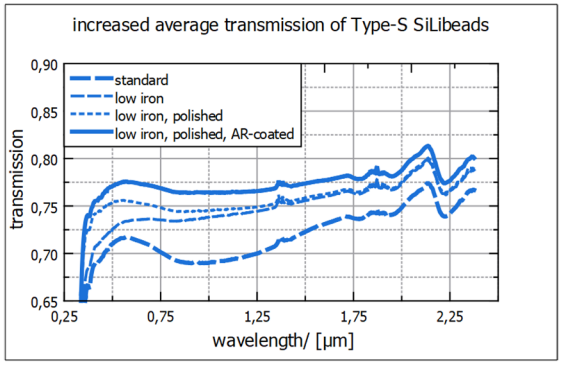

Figure 3: Achieved transmission improvement of solar glass beads through various processing steps compared to a standard glass bead reference

Fraunhofer ISE also conducted module tests as part of the project, integrating both antireflective coated and uncoated SiLibeads® glass beads into micro-CPV modules (see Figure 4).

Figure 4: Prototype of a micro-CPV module mounted on a tracking unit at Fraunhofer ISE in Freiburg with 60 solar cell-lens units (Photo: © Fraunhofer ISE)

Over a year-long period, the project demonstrated that the developed micro-CPV module enabled stable operation at high efficiencies [6]. With the success of the "micro-CPV" project, SiLi has shown that technical glass beads can contribute valuable innovations not only in traditional applications but also in cutting-edge fields such as photovoltaics.

Acknowledgements

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