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# Investigation of non-toxic dye-sensitized solar cell materials for circular design approaches

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Abstract (English)

The climate crisis and the resource crisis are great challenges of our time. To combat the effects of these crises, it is necessary to increase the use of renewable energies and use resources more efficiently. Dye-sensitized solar cells (DSSCs) are an upcoming technology, which could support the move to more resource-efficient green energy supplies.

In this dissertation, circular design approaches for non-toxic DSSCs are investigated. Therefore, an overview of the research in the field of recycling DSSCs is given. There are only a few scientific approaches in which recycled materials, e.g. from cell phone screens or flat-screen TVs, are used as a conductive substrate for the production of DSSCs. However, the term "sustainability" appears only in 49 out of 27,014 publications in the bibliographic study conducted for this dissertation. There are no recycling experiments of DSSC materials, although the environmental impact of DSSCs could be significantly reduced if their glass components, the manufacturing of which is the most energy-intensive step in the production of DSSCs, were to be recycled.

Therefore, a melting experiment with DSSC materials was performed to fill the research gap. The glass substrate of the used DSSCs was investigated using inductively coupled plasma optical emission spectrometry (ICP-OES), and the glass' surface was examined by scanning electron microscopy energy dispersive X-ray (SEM-EDX). The DSSCs were shredded and then melted in a furnace and compared to a standard glass recycling process. The melting experiment showed that the material is potentially suitable for a glass recycling process. However, more research on, for instance, chemical resistance, transparency and viscosity of the recycled glass is required.

The next step according to the framework of the circular economy is remanufacturing. In a series of experiments, old DSSCs were disassembled and their conductive glass substrates were reused to build new DSSCs. This process is promising, since the remanufactured DSSCs have comparable efficiencies to newly-manufactured DSSCs and can be remanufactured multiple times.

In the final investigation, a potential circular DSSC was illustrated using the Circo method. This method is a framework to transform a linear product into a circular one coupled with a suitable business model. The business model described is a performance-based model, integrating DSSCs into a customer's building and offering green energy as a service. The circular design of a product is key to enable an efficient recycling or remanufacturing process.