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Release of hazardous substances from photo-voltaic modules

Most photovoltaic modules contain pollutants such as lead, cadmium, tellurium, copper and other heavy metals. The aim of this project was to clarify mechanisms that can lead to the release of pollutants from modules in case of improper disposal and to identify weak points.

The project showed leaching of pollutants from module pieces cut from commercially available photovoltaic technologies. Crystalline silicon (c-Si), amorphous silicon (a-Si), CIGS (copper indium gallium diselenide) modules, and cadmium telluride (CdTe) modules were studied. Leaching of the pollutants in aqueous solutions begins as soon as open edges or glass breaks occur. The delamination of the module pieces is not a prerequisite for leaching.

The results of the measurements of the leached elements were expressed as a percentage of the total content of the elements in the modules. The measurements of the total contents of the module pieces by means of a mass spectrometer (ICP-MS) was accompanied by a verification of the elements in the layers via an X-ray analysis in a scanning electron microscope (SEM). Conventional leaching tests for waste use a fixed solid to liquid ratio, for example in DIN EN 12457-4 a ratio of 1:10. In contrast to other leaching tests, which only last 18 to 48 hours in distilled water or in aqueous solutions with a pH of 4.93, in this project long-term tests over 1.5 years in pH 3, pH 7 and pH aqueous solutions 11 were performed.

The leaching of the elements from the module pieces depends strongly on the pH and redox potential of the aqueous solutions. The used pH values 3, 7 and 11 cover the range of pH values which can occur in the environment. Thermodynamic stability considerations, as in Pourbaix diagrams, make the mobilization of the elements predictable. The type of acid or the corresponding counter ion play less of a role.

In all experiments, a steady increase in the leached elements could be observed. Experimental parameters such as agitation, elevated temperature or lighting do not always lead to an acceleration in the leaching of the respective elements.

In the case of c-Si module pieces, the back contact of Al dissolves particularly well in acidic solutions. In the case of a-Si module pieces, Ni could be measured from the back contact and Cu, which is located both in the back contact and in the solder strips, in solutions of pH 3 and pH 7. The elements Cd, Te and Mo from CdTe module pieces show a particularly strong dissolution behavior. Cd and Te come from the active layer and Mo from the back contact of the CdTe module pieces. From CIGS module pieces, both Zn from the front contact, and Cd from the window layer and molybdenum from the back contact dissolve to large proportions.

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