Project full title: "Nanowire based Tandem Solar Cells"

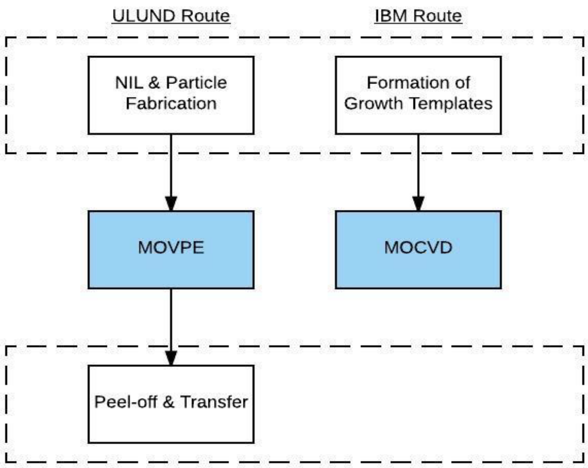
Project acronym: Nano-Tandem **Grant agreement no: 641023**

Deliverable D 7.4

Publishable summary of the preliminary life cycle assessment

Authors: Leiden University, Lund University, IBM Research
Date: July 2017

Here, we summarize the results of the preliminary life cycle assessment of the laboratory production of the NanoTandem photovoltaics technologies and the exploratory assessment of the environmental health and safety of nanowires. The assessment is focussed on a comparison of the manufacturing routes developed by Lund University and IBM, as schematically depicted below (MOVPE = Metal organic vapor phase epitaxy, MOCVD = Metal organic vapor phase deposition):



Results: Preliminary life cycle assessment showed that IBM manufacturing route for the production of one 4-inch nanowire silicon wafer in the lab performs better compared to the Lund University route, in terms of carbon emissions. The reason is the additional process steps for the production of the III-V substrate that is used to grow nanowires in the MOVPE process, and the stamp fabrication that is used in the nano-imprint lithography in the route used by Lund University. In order for the two technological routes to break even in terms of carbon emissions, reuse of the substrate and stamp needs to be realized. Moreover, the analysis showed that electricity requirements of the laboratory processes is the major contributor in carbon emissions and that material use and disposal has a very small contribution on the total impact. For the environmental health and safety of nanowires a literature and a database search were conducted. Results showed that similar to nanoparticles, dissolution of unstable nanowires is an important property that might well determine the toxicity of nanowires composed of for instance Ag, Cu, Zn, Ga/As. In addition, the aspect ratio is of importance in modulating adverse effects of nanowires. Shorter nanowires tend to be more toxic than nanowires of higher aspect ratio. Tentatively, nanowires above a critical length of ~200 nm are to be assumed non-toxic. Further verification of this rule of thumb is however needed. Lastly, the literature search showed that in general, toxicity of nanowires is limited as reported effect levels are in general quite high (up till 190 mg/mL). The aspect ratio is again shown to be of importance in modulating adverse effects of nanowires. In addition to the finding deduced from the database search of shorter nanowires in general being more toxic than nanowires of higher aspect ratio, it is stressed that fragmentation of nanowires is an issue to be considered during fate and effect testing. This implies, amongst others, that vigorous treatment of suspensions of nanowires (like prolonged sonication) is to be avoided: upon fragmentation, shorter fragmented nanowires are obtained that are commonly more toxic than the nanowires initially produced.

Outlook: The preliminary life cycle analysis will serve as the basis to build scenarios of how the laboratory processes will look like in a future industrial production. Human health impact for the manufacturing, operation and end-of-life treatment of the up-scaled NanoTandem technologies will be assessed during the next two years. Furthermore, the up-scaled technology will be compared with already existing commercial technologies of crystalline photovoltaic systems and other thin-film technologies.