

4. FINAL REPORT

4.1 Final publishable summary

4.1.1 Executive summary

ThinSi is an ambitious project to develop a solar cell processing chain for high throughput, cost-effective manufacturing of thin film silicon based solar cells on low-cost silicon substrates. The Si powder based substrates are made on the basis of an innovative powder-to-substrate concept. In line with the current trends in PV, this project aims to reduce the cost of solar cells and modules compared to those made by the conventional wafer based approach. The solar cell structure, which was the main subject for all ThinSi solar cell fabrication related developments, is very similar to a conventional bulk crystalline Si solar cell. The "ThinSi" solar cell structures consists of a low-cost Si powder supporting substrate (processed within the "powder-to-substrate" approach) and an active high- quality layer on top, which serves as a solar cell base. Thus, thin Si film based, but at the same time "all silicon" structure substitutes the Si wafer. The final structure can be called also as a "Si wafer equivalent".

It has been demonstrated that advanced silicon based substrates can be processed from Si powder using following state-of-the-art innovative technologies: (i) Thermal spraying; (ii) Hot pressing; (iii) Spark plasma sintering (SPS); (iv) block casting growth using low-cost Si powder feedstock followed by sawing of the grown Si ingots. It was established that all Si substrates, processed in frame of the mentioned above innovative technologies, have good enough mechanical and electrical properties to be considered as a supporting part of the Si wafer equivalent structure.

In addition to well established chemical vapour deposition (CVD) process for deposition of thin (~20-30 μm) Si layers, a set of innovative lower cost processes have been developed to realise the new concept: (i) thermal spraying, (ii) magnetron sputtering and plasma enhanced chemical vapour deposition (PECVD). New tools for deposition of thin Si layers (active layers in "Si wafer equivalent" structure) have been developed. High temperature sputtering and PECVD tools have been developed for in-situ deposition of poly or crystalline Si layers. All tools are designed for large scale silicon deposition, with capability to process 156mm $\times$ 156mm Si wafers. Moreover, an advanced Electrostatic Spray Assisted Vapour Deposition (ESAVD) tool has been developed and offer a non-vacuum and cost-effective coating method for deposition of transparent conducting oxide films. **AFM/Raman/Ellipsometer/SNOM** combined measurement tool and relevant methodology for the analysis of solar cell structures on nano-scale have been developed.

Four approaches have been investigated to make thin Si layer based solar cells: (i) the 'high-temperature approach' based on implementation of diffused or epi- emitters, (ii) the 'low-temperature approach' (hetero-emitter), (iii) the 'diffused emitter" combined with TCO, (iv) the exfoliation and bonding of epitaxial silicon foils on low-cost Si powder based substrates. The highest solar cell efficiency achieved on Si powder based substrates in frame of "high-temperature approach was 11.9%. By using the exfoliation and bonding of epitaxial silicon foils with an implemented Bragg reflector, free standing structures were obtained which could be processed to solar cells and bonded to low-cost Si powder based substrates with efficiencies over 14%. It is concluded that approach bases on exfoliation and bonding of epitaxial silicon foils is a promising advanced technology for prospective thin Si based solar cell processing on low-cost Si based substrates.

