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Editorial

Challenges for photovoltaic silicon materials ☆

This special issue is dedicated to the 2nd workshop on Silicon Materials. These Si Materials workshops address a specific issue in the field of crystalline silicon for photovoltaic applications. The first workshop, organized in 2008, focused on specifications for solar-grade feedstock as a response to the polysilicon shortage [1]. A definition of Solar Grade (SoG) Silicon categories based on the usage for solar cell manufacturing was proposed in 2008 and a tentative and approximate standard set of specifications aimed to the fabrication of solar cells was provided. The workshop also gave input to start an initiative [2] for the industrial standardization of silicon feedstock specifications with the institution by SEMI of the silicon feedstock task force.

In the last 5 years the global situation changed considerably from several perspectives [3,4]. The feedstock shortage regime for the PV industry ended. There was a delay of a few years before extra polysilicon capacity could enter into the market because of the large capital expenditure and the time needed for the construction and ramping up of poly-silicon production plants. Despite the credit crunch hitting the financial sector, PV flourished with record installations in 2010 and 2011. Eventually, the economic stagnation and the abrupt reduction of subsidies affected the PV market causing an oversupply of PV modules. As a consequence, profit margins strongly reduced and the market stabilized in 2012. All these factors initiated an even stronger drive towards cost reduction pushing the PV industry in a consolidation period. Currently (mid-June 2014), we observe a mild readjustment of the module price towards a more healthy economy of profit and a market that is growing again significantly.

Initially triggered by the shortage of feedstock and by the need of a clear understanding of the polysilicon limitation factors, research on silicon materials and on new silicon purification methods multiplied in the past years. However, due to the rapid change in the economic and market situations, an alignment between the short-term industrial needs and the long-term research performed by research institutes is not always straightforward. Despite the proliferation of conferences related to photovoltaics, it was felt that a dedicated event in the form of an actual workshop with ample discussions on “Silicon material” research was desirable. Therefore, the aim of this 2nd Silicon Materials workshop was to provide a worldwide platform where industry and research groups would discuss their programs and future targets with the ambition to find new synergies for the development of PV solar energy. For these reasons, the second edition of the workshop was dedicated to the definition of future challenges for Silicon material research and to discuss industrial needs versus research efforts.

1. Online survey

In preparation of the workshop discussions and to sketch a roadmap for Si material research, a survey was carried out among a large number of international experts. The result of the survey was presented during the workshop. This allowed us to identify the most crucial topics that were then discussed in detail during the workshop. The survey focused on the properties and challenges of Si materials for photovoltaics. The input for this survey came from 44 experts working in the industry, research institutes and universities worldwide (Fig. 1) [5].

The respondents do not form a representative sample of the entire scientific community but they did include a significant share of the experts in Si materials for photovoltaics. This is complementary to other initiatives like the ITRPV[iii] and it is expected to give a more visionary interpretation of enabling technologies and challenges for Si materials as seen from the expert point of view.

1.1. Methodology

The survey contained open questions and multiple choice questions. This was chosen in order to obtain an easy aggregation of the input data for the discussion and at the same time keeping a certain freedom for out of the box thinking and to have room for identifying new trends. The survey was structured in 4 sections listed in Table 1. The main question concerned the identification of technology combinations that will enable the next steps towards PV cost reduction. *Short term* refers to about 1 year and *longer term* to the 5–10 year range. The idea to specify tentative cost targets arose from the need to select feasible technologies combining high performance together with cost effectiveness. The costs are merely indicative and should be read as a qualitative indicator for the impact of the technology. Figs. 2–6

1.1.1. Roadmap of technologies that will enable cost reduction

In this section we report on the main results of the survey together with part of the discussion that happened at the workshop.

1.2. Feedstock

The large majority of the respondents opted for the optimized Siemens process as the technology suitable to reach a PV module cost reduction down to 50$c/Wp in the very near future. Major challenges identified here are the large investment cost, the fact

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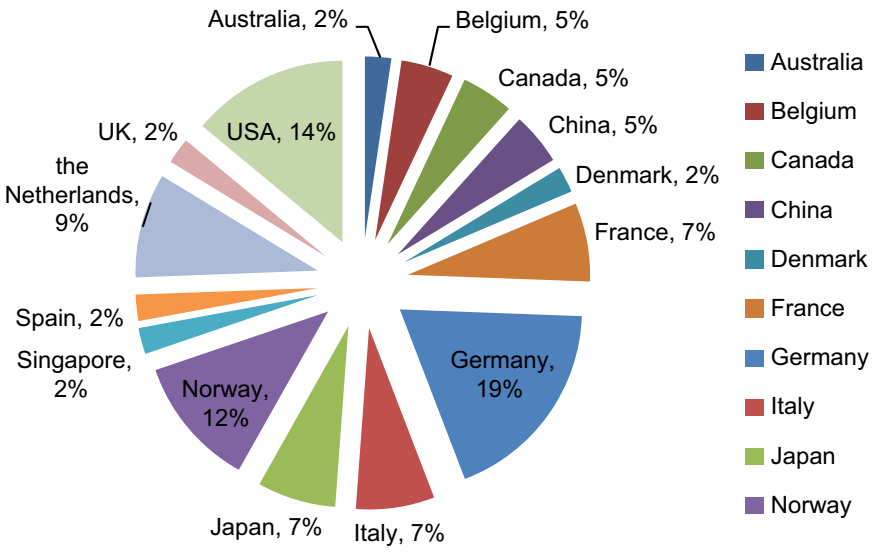

Fig. 1. Participant country of origin.

Table 1
Structure of the survey.

Topic	Question	
1	Which are the technology combinations enabling the next steps towards PV cost reduction? (e.g. towards 50$c/Wp and 20–30$c/Wp)	Feedstock Crystallization Wafering Cell technology
2	What is the key parameter to enable the next step towards PV cost reduction?	Wafer physical parameter Other
3	Tentative outline of technology roadmap	Wafer thickness Kerf loss Minority carrier diffusion length Efficiency % n-type versus p-type % mono/multi/cast mono wafers Wafer production cost Expected module production cost Other items or parameters
4	Open questions	Topics for R&D How should a roadmap look like

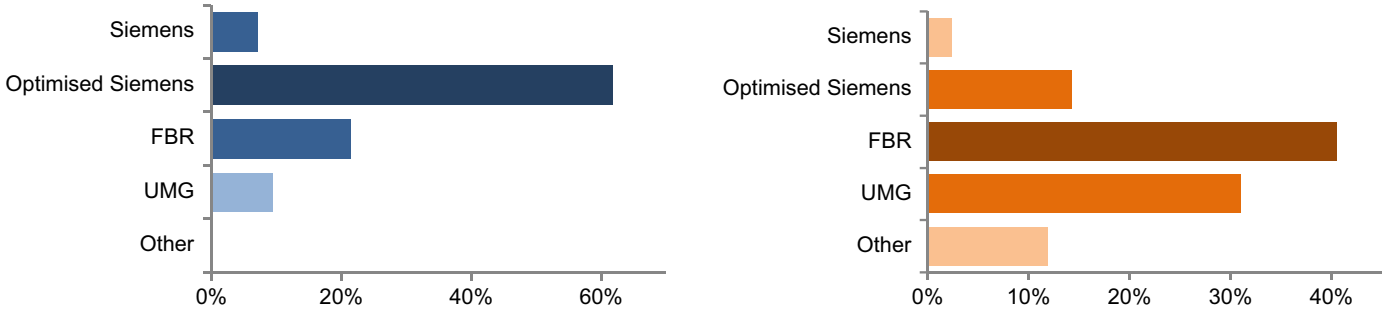

Fig. 2. Feedstock frequency distribution: Which key technology will allow us to reach rapid module cost reduction on the short term (left) and on the longer term (right)?

that the absolute cost limit may be approaching, and the need to check if maximization of by-product reuse can give room to further cost reduction.

On the longer term, the respondents were almost equally distributed between Fluidized Bed Reactor (FBR) and Upgraded Metallurgical Grade (UMG) feedstock to reach further cost reductions in the next five years. Among the challenges identified for FBR are the difficulty to scale up and the monopolistic situation including IP protection. For UMG, the main unknowns are whether the cost target for this type of technology is really competitive with respect to FBR and Siemens, the demonstration of a clear performance validation and showing that there is no significant efficiency penalty.