PROJECT FINAL REPORT

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[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement.

[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

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4.1 Final publishable summary report

4.1.1 An executive summary

The Sugar project aims at reducing the thickness of the Si substrates used in nowadays photovoltaic cells. To be able to realize photovoltaic devices on thin Si substrates, two bottlenecks need to be overcome. First of all, there is no proven cost-effective method to manufacture Si substrates of 50 µm. Secondly, the experience in industry with handling and processing such thin and fragile devices is very limited. Consequently, the two main objectives of the project are to tackle these two bottlenecks. The first objective is the design of a processing sequence that takes as input thick Si wafers and gives as output large-area (30 cm^2) ultra-thin wafers (~50 µm) by an industrial viable process. The second objective is the demonstration of a PV module process adapted to ultra-thin material fully based on carrier processing, including on definitive glass superstrate, with a module consisting of at least two cells and a conversion efficiency of 17% or more. The expected impact of the project is to further reduce costs of solar modules, by accelerating the move towards higher efficiency solar cells and the move towards thinner silicon wafers. At the start of the project, the partnership consisted of four academic and/or research institutes (imec, Fraunhofer IPA, Armines – Centre de Mise en Forme des Materiaux and FFCUL – University of Lisbon) and six companies (Bosch – Rexroth, Ferro, Dow Corning, AMAT – Baccini, Semilab and 4Pico). At the very beginning of the project Bosch – Rexroth decided to leave the consortium. At the same moment a new partner was asked to join the consortium: Ferro Hanau. This new partner was able to supply know-how related to the first objective.

To address the first objective, the Sugar consortium proposes an innovative method to manufacture 50-µm thick wafers without kerf loss. This method, called Slim-cut, relies on the application of a stress-inducing layer on top of the Si substrate. Upon a thermal treatment, the induced stress in the substrate leads to controlled crack propagation parallel to the surface at a given depth. At the start of the project, the consortium worked on a Slim-cut process based on a stress-inducing layer of two metal pastes. This process had some drawbacks. From the modelling work it was inferred, and later on experimentally verified, that materials other than the original Ag-Al paste system could be used as a stress-inducing layer. A dispensed epoxy was selected as an alternative. By this material, and assisted by simulations, thin Si foil could be obtained with a limited thermal budget (curing at 150 °C followed by cooling at room temperature). The resulting foils have an effective lifetime ~50 µs, a thickness of ~100 µm and an area up to 7x7 cm^2. Multiple lift-off from the same substrate was demonstrated. Cost of one lift-of has been calculated to be 0.89 €/foil for a 156x156 mm^2 foil.

The work related to the second objective focusses on cell processing at module level. This implies that the thin Si foils are permanently bonded to their module glass as early as possible in the process flow. Once bonded, the fragile foils are mechanically supported by the glass. The rest of the process flow is executed on the cells bonded to the glass. The required process steps for this flow are developed during the project. This includes a process to apply uniform thin silicone layers on glass, which allows bonding thin foils to the substrate. One of the other developed steps was the realization of an interdigitated pattern of a-Si:H emitter and a-Si:H BSF on the rear of the cells. This low temperature process is compatible with the bonding. This complete process is demonstrated in functional devices with efficiencies up to 17.9%. To be able to combine several cells on the same substrate into a module, also the required module steps were demonstrated: cell-to-cell interconnection, additional silicone and backsheet application. These techniques allowed not only fabricating single cells bonded to glass, but also mini-modules of several wafers or cells bonded to the same glass superstrate. Reliability tests on these mini-modules showed the reliability of the cell-to cell interconnection. Instability in damp heat of a-Si:H passivating layers on encapsulated wafers was identified. Approaches to solve this problem were investigated, and solutions were found. A concept for volume manufacturing, following this complete flow, has been studied. This included not only a conceptual study but also the development of several handling steps: application of laser notches to induce the crack propagation in the Slim-cut process, gripping of thin wafers and precise and fast placement of wafers on the silicone-covered glass.

4.1.2 A summary description of project context and objectives

Industrial solar wafers are today in the range of 160 µm, a thickness that embodies the compromise between breakage rate (industrial yield) and silicon material cost. However, arguments remain to keep on reducing the thickness of the material used:

- The cost of the raw material (feedstock) is estimated to still account for 15% of the module cost.
- Literature shows that when limited by Auger recombination, the performance of solar cells peaks at a thickness of approximately 50 µm.

At this moment, there are two main drivers to keep the thickness relatively large at 160 µm. Both drivers are technological:

- There is nowadays no proven cost-effective method to **manufacture solar substrates** of 50 µm.
- There is nowadays no industrial method to **process solar cells** on 50-µm wafers.

The Sugar project proposes two innovative technologies which can be developed and used independently, the first one to produce solar wafers of 50 microns, and the second one to process them into solar cells.

a. First Sugar objective: wafering 50-µm thick wafers

The first bottleneck is tackled in Sugar by proposing an innovative method to manufacture 50-µm thick wafers without kerf loss. This method, called Slim-cut, relies on thermo-mechanical treatments: a high stress field is applied to a silicon wafer by a stress inducing layer. Upon a temperature treatment, a crack propagates in the silicon substrate parallel to the surface at a given depth. The top silicon layer is separated from the parent substrate and processed into a solar cell. The parent substrate can be re-used.

The first Sugar objective: Design of a processing sequence, consisting of tools and proven handling concepts, that takes as input Si tiles (wafers with a thickness > 1 cm) and gives as output large-area (30 cm^2) ultra-thin wafers (~50 µm) by an industrial viable process. This sequence will be comprised of a number of process and handling steps that will be developed in the course of the project.

b. Second Sugar objective: thin-film-like high efficiency module level processing of bulk solar cell

The second bottleneck is related to the wafer-based approach that is nowadays dominating the standard c-Si technology. In the module concept developed within Sugar, the cell processing will be achieved on module level and not on wafer level.

The general description of the process resembles very much the standard thin-film process: deposition on several square meters of a-Si, metallization and patterning. The difference lies in the starting material. Instead of starting from TCO-covered glass, our approach starts from a set of ultra-thin Si wafers bonded to the glass. The thin crystalline Si wafers in combination with the amorphous-Si emitters guarantee high conversion efficiencies, while the module glass (superstrate) fully supports the fragile wafers during cell processing. Moreover, processing at module level provides an additional volume cost reduction potential.

In this flow, the ultra-thin Si material can be obtained by the Slim-cut method, but not necessarily.

The second Sugar objective: Demonstration of a PV module process adapted to ultra-thin material fully based on carrier processing (including on definitive glass superstrate), with a module consisting of at least two cells and a conversion efficiency of 17% or more (aperture area).

These two main objectives led to two lines in the strategy of the Sugar project, as depicted in Fig.1. This strategy has been translated in seven work packages:

- WP1: Project management
- WP2: Slim-cut development
- WP3: Gripping and handling

- WP4: Bonding and encapsulation
- WP5: Module level processing
- WP6: Characterization and reliability testing of modules
- WP7: Integration, demonstration, concept and cost modelling

Most of the work packages are arranged along one of the lines, but they come together in the final work package seven.

Figure 1: High level strategy of the Sugar project.

At the start of the project, the partnership consisted of four academic and/or research institutes (imec, Fraunhofer IPA, Armines – Centre de Mise en Forme des Materiaux and FFCUL – University of Lisbon) and six companies (Bosch – Rexroth, Ferro, Dow Corning, AMAT – Baccini, Semilab and 4Pico). At the very beginning of the project Bosch – Rexroth decided to leave the consortium. At the same moment a new partner was asked to join the consortium: Ferro Hanau.

4.1.3 A description of the main S&T results/foregrounds

This part describes the main results achieved per work package.

WP2: Slim-cut development

The goal of this work package was to develop the Slim-cut process. At the start of the project, the consortium worked on a Slim-cut process based on a stress-inducing layer of two metal pastes. This process had some drawbacks. The process needed a high temperature step (650-900 °C) to induce lift-off. The metal pastes are rather expensive layers. Next to that, the electronic quality of the foil was low due to structural defects and possibly metal diffusion from the pastes during the high temperature step. Moreover, the metals proved to be difficult to remove from the foil after lift-off. From the modelling work it was inferred, and later on experimentally verified, that materials other than the original Ag-Al paste system could be used as a stress inducing layer. Consequently, glass pastes, Ni layers and polymers were compared on their deposition method, ability to lift-off a Si foil, quality of the foil after lift-off and easiness of cleaning the foil after lift-off.

A dispensed epoxy was chosen to be the most suited one based on these criteria. The process with the epoxy material has a much lower thermal budget (curing at 150 °C followed by cooling at room temperature). Effective lifetimes ~50 µs were reproducibly obtained at the sites of FFCUL and imec. By studying the crack propagation in the foil, foils with an area up to 7x7 cm^2 could be realised. Also multiple lift-off from the same substrate was demonstrated: three foils could be lifted-off, one after the other, from the same parent substrate.

This development of the Slim-cut process was supported by the realization of simulation model at Armines. A static numerical approach was developed using finite element software, resulting in a model that is easy to use and can predict the depth of crack propagation depending on the epoxy thickness. Next to that, a monolithic method with a Lagrangian approach was introduced to model the 2D dynamic crack propagation of the Slim-cut process.

WP3: Gripping and handling development

Work package 3 and the according tasks aimed at the development of an automated approach for ultra-thin wafer handling. The transfer of thin wafers and the development of an appropriate handling technique were investigated first. The goal was to identify the additional challenges in terms of automated ultra-thin (<100 µm thickness) wafer handling. The benchmarking and evaluation of gripping principles and prototype grippers, as well as market products was performed and delivered. The gripper investigation and performance testing for mass manufacturing was ongoing in parallel. To do so, a setup and integration of a handling prototype based on a SCARA-robot for the ultra-thin wafer handling and precise module assembly was performed. Side by side with a prototypic position measurement system, the developed handling equipment demonstrates an integrated and automated process flow for ultra-thin wafers, able to interface with neighbouring processes.

The development of a gripping-mechanism for curled wafers was undertaken as well. A prototype gripper, a modified Bernoulli-gripper, has been designed, manufactured and tested for feasibility with curled wafers among other grippers.

Also to pick up a foil from a liquid, a gripping method was developed. Due to the advanced requirements of the handling situation in the liquid environment, a more systematic approach was developed for the testing of suitable gripping techniques. The process conditions of the dynamically changing liquid, such as contaminated solution or alcohol, require a certain automatic control system. This automated gripping-in-liquid was successfully demonstrated at Fraunhofer.

For the module level processing sequence the ultra-thin wafers need be placed on a silicone coated superstrate (bonding-on-glass) with high precision. The identification of positioning accuracies was one major challenge in this activity. A work piece carrier has been designed. A positioning accuracy of ~50 µm has been demonstrated.

The consortium had chosen for laser notches to create a starting position for crack propagation during the Slim-cut process. A Crack Initiation Module (CIM) with a micron resolution motorized xyz-stage and a nanoseconds pulsed fiber infrared laser was designed and realized by 4Pico in the course of the project. It was demonstrated that the CIM is able to create precisely parallel notches in silicon material. Successful lift-off is obtained on samples with these laser notches. Samples with these notches were used throughout the project for the development of the Slim-cut process in work package 2.

At AMAT several tests were performed regarding dispensing. For the dispensing of the silicone encapsulant, the installation of an automatic alignment system allowed a more accurate alignment. Dispensing this encapsulant was applied to fill the gap in between two wafers on a module. Tests showed that the shape and the thickness of the dispensed silicone depend strongly on the gap between the wafers.

WP4: Bonding and encapsulation

In this work package, the requirements for the adhesive and encapsulant were first identified, and a suited set of silicone materials (front adhesive, gap filler, rear encapsulant) was developed. The application of these materials to create the target structure was demonstrated.

A process to apply very uniform thin silicone layers (50 to 100 µm thick) on glass was developed and perfected, and a process sequence was established. A specific advantage of the method is that the silicone can be printed selectively, forming the desired pattern. The established process for wafer bonding consists in applying the silicone, curing the material, placing the wafer at the precise location, and applying a slight vacuum. With the appropriate silicone material and this method, large area wafers could be bonded to glass in a bubble-free structure.

Processes for precise placement of wafers on the silicone-covered glass were developed. There was both a lab process developed, but an automated pick-and-place process using a fast speed robot was demonstrated, even with very thin wafers. No issue were observed concerning breakage, and accurate and good bonding was achieved.

The rear encapsulation process was developed, which included the selection of the other materials needed to complete the laminate, in particular the backsheet.

A process for silicone dispensing for gap filling was developed and optimized.

Finally complete encapsulated devices were made combining the various developments in the work package, and the mini-modules were passed on to work package 6 for accelerated aging tests.

WP5: Processing steps for module level cell processing

The work performed in this work package was needed to develop all the processing steps to realize cells. In the envisaged process flow, the front side of the cell is processed first, followed by permanent bonding of this front side to a glass superstrate. After bonding, the remaining processing steps are executed while the partly processed cell is bonded to the superstrate.

Regarding the front side of the cell, a complete low-temperature (<250°C) technology, including texturing, passivation and anti-reflective coating, has been developed. The compatibility of this front-side processing with a temporary bonding method using a temporary adhesive has been studied.

In strong collaboration with work package 4, a flow has been developed that allows processing partly processed cells which are bonded to the glass. One of the main difficulties to overcome was the interaction between the silicone material used to bond the wafers and the subsequent PECVD depositions of a-Si:H. These silicone-plasma interactions lead to low quality of the a-Si:H deposition. At the end of the project, a flow overcoming this problem was demonstrated. In this flow, a blanket silicone layer was used to bond the wafers, omitting the need to pattern this silicone layer. Despite this blanket layer, interaction of the silicone with the plasma could be completely avoided by implementing the proper processing steps.

To realize the emitter and BSF regions at the rear of the cells, the consortium chose for doped a-Si:H as this is a low temperature process being compatible with the bonding. Within the project, a process flow was developed to realize interdigitated regions of n+ a-Si:H for the BSF and p+ a-Si:H for the emitter. This processed was demonstrated in functional devices with efficiencies up to 17.9%.

Also for the metallization of the cells a process needed to be developed. The consortium realized a metallization stack allowing contacting both a-Si:H emitter and a-Si:H BSF. The value of this stack was demonstrated in devices. Next to that, a method based on screen printing a low temperature Ag paste was developed to interconnect thin cells bonded to glass.

WP6: Characterization and reliability testing on module level

The stability of silicone encapsulation was investigated. The material turns out to have outstanding stability in various testing conditions. Modules made with traditional cells, but using silicone encapsulation instead of traditional encapsulants in a glass-encapsulant-backsheet structure showed superior stability in damp heat conditions.

Experiments at mini-module level were carried out using MWT cells bonded on glass using silicone and interconnected by soldering while bonded on glass showed that such structures could pass the reliability requirements in terms of damp heat and thermal cycling. The reliability of interconnection with low temperature metallization paste printed over a gap-filled trench also indicated that such structure did not degrade under damp heat and thermal cycling. Finally, an issue of instability in damp heat of amorphous Si passivating layers on wafers encapsulated in a glass-silicone-polymer backsheet was identified. Approaches to solve this problem were investigated, and solutions were found to avoid this degradation.

WP7: Integration, demonstration, concept and cost modelling

In this work package, several tasks related to demonstration and industrialisation of the cell concept, were grouped.

One of the constraints for the cell concept of the project is that after bonding the half-processed wafers on the glass superstrate, all processing steps need to be executed on the area of the glass, which can be a few m^2. To demonstrate that this constraint is not a showstopper for the cell concept, the consortium developed and demonstrated a representative set of the processing steps on large-area superstrates. The involved steps include the deposition of silicones, the application of large area resist patterns and the deposition of a-Si:H layers on large areas.

To demonstrate the viability of the module level processing steps developed in work package 3, 4 and 5, being the application of the silicones, the precise placement of the cells and the metal interconnection between the cells, these steps were demonstrated with up scalable equipment at partner`s site. This resulted in a functional mini-module.

In terms of the development of a pilot line for Slim-cut manufacturing and the development of a concept for volume manufacturing, a detailed analysis of the process steps has been conducted in parallel to the continuous demonstration of single processes by each partner. Moreover, thanks to data collection and adaptation of a recent PV cost model, a comparison of Slim-cut based PV with standard PV could be calculated. Cost of one lift-of has been calculated to be 0.89 €/foil for a 156x156 mm^2 foil.

4.1.4 The potential impact and the main dissemination activities and exploitation of results

Potential impact

The potential impact of the Sugar project is:

a. Solving the issue of availability of Si material of required quality

Sugar is almost fully dedicated to the more efficient use of the silicon solar-grade feedstock, both from the wafering, as from the module level processing perspectives. Four major features of the project foresee a more efficient use of silicon:

- The wafers produced by Slim-cut will be thinner.
- The wafers are produced with a much lower kerf loss.
- The solar cell process developed is amongst the most promising solar cell structure in development regarding conversion efficiency. Producing more cells with higher conversion efficiency also makes the use of silicon more efficient (less g/$Watt_{peak}$), regardless of the foil production method used.
- Part of the processing issues related to working with thin material will be solved, as dedicated thin film handling and operations will be developed, also regardless of the foil production method used.

b. Further reducing costs of solar modules

According to Crystal Clear, the module cost is indeed driven at 45% by the cost of a wafer. Coming to an accurate figure of the production cost of the solar cells with the proposed Slim-cut method is very delicate at the beginning of this very innovative project since the method diverges very much from what is currently proposed.

Still, as substantially more wafers can be gained out of the same ingot (3 versus 1 wafer for conventional wire sawing due to thinner wafers and less kerf loss), a strong potential to decrease wafer and as such module cost is present.

The techno-economical evaluation will be detailed as an output of Sugar. Envisaging industrialisation of the technology will not go without a cost study.

c. Accelerate the move to higher efficiency solar cells (>20%)

The most efficient industrial solar cells concepts are the interdigitated back-contact cells and the heterojunction cells. The process developed in Sugar is the combination of both technologies and carries therefore a very high efficiency potential.

d. Accelerate the move to thinner silicon wafers (<100 µm, and as thin as 50 µm)

Sugar is an ambitious project that integrates modifications of all the value chain of a PV module production line to propose a solution specifically adapted to ultra-thin wafer processing. Sugar proposes a method to obtain these thin Si foils and on top of that a method to produce them into modules with a very high efficiency potential.

The standard technology (wire sawing) has no potential for slicing 50-um thin wafers. The Slim-cut method proposed by Sugar is one of the few methods having this potential, and probably the one who carries the most cost-effectiveness potential

The industrial technology of today will not be able to process such wafers with acceptable yield. Sugar proposes a suitable technology based on processing on carriers. The wafers positioned on a glass carrier are processed into solar cell on module level. This technology therefore carries in addition a substantial cost-reduction potential, making it a very probable technology for the future.

These two technologies are developed simultaneously. This continuous survey ensures that the technology development will not be hindered by a delay in the development of another part of the technology: despite the noticeable synergies between the different Sugar technologies, the success and implementation to industry might come from any independently developed aspect of the technology.

Communication and dissemination

A public website of the Sugar project is available at https://projects.imec.be/sugar. Its content includes a general presentation of the project. Updates concerning public dissemination and events were made on a regular basis.

The consortium has published 15 scientific papers in peer-reviewed journals with results obtained within Sugar. Next to that, the consortium has presented 25 contributions at international conferences and workshops in the form of oral presentations and posters. Conferences included top conferences in the field such as the European Photovoltaic Solar Energy conference, the IEEE Photovoltaic Specialists conference and the MRS spring meeting. Moreover, at least three PhDs theses have been and will be defended on the research done within the Sugar project.

Exploitation

The Sugar project led to one patent application, which is joint patent between two partners of the consortium: Dow Corning and imec.
The main exploitable results generated by Sugar include:

- A Slim-cut process by an epoxy stress-inducing layer and with small thermal budget resulting in high quality Si foils
- A process flow to realize solar cells with on the rear an interdigitated pattern of an i/p+ emitter and an i/n+ BSF.
- A process flow which allows to process thin wafers bonded to glass.
- A printing technique to deposit very thin and uniform layers of silicone liquid encapsulant, which allows to bond thin wafers to glass in a bubble-free way.
- Laser assisted cutting of sharp notches in Si wafers, with a high precision and high repeatability.
- Handling and assembly process for accurate bonding-on-glass assembly of ultra-thin substrates
- Automated pick-and-place of sensitive substrates in liquid media with advanced process control
- Control of silicon substrate failure mechanism under thin films compressive loadings
- Crack propagation modelling under thermomechanical loading using a level-set framework and anisotropic mesh adaptation
- Dispensing of silicone encapsulants
- Printing of resist materials

4.1.5 The address of the project public website and relevant contact details

The address of the Sugar project website is: https://projects.imec.be/sugar

The list of main project contacts is:

- imec - coordinator: Maarten Debucquoy, maarten.debucquoy@imec.be, Tel: +32 16 287593
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4.2 Use and dissemination of foreground

Section A

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[3] (if available)	Is/Will open access[4] provided to this publication ?
1	Advanced gripper development and tests for automated photovoltaic wafer handling	T. Giesen	Assembly Automation	33			2013	334-344	10.1108/aa-09-2012-075	No
2	New concepts for crystal growth for photovoltaics	J.M. Serra	Energy Procedia	10			2011	303-307	10.1016/j.egypro.2011.10.195	Yes
3	Silicon processing for photovoltaics based on incoherent radiation power	J.M. Serra	Physica Status Solidi (C)	9			2012	2169-2173	10.1002/pssc.201200254	No
4	Analysis of stress intensity factors and T-stress to control crack propagation for kerf-less spalling of single crystal silicon foils	P.-O. Bouchard	Computational Materials Science	69			2013	243-250	10.1016/j.commatsci.2012.10.033	No

[3] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

[4] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

5	Three novel ways of making thin-film crystalline-silicon layers on glass for solar cell applications	I. Gordon	Solar Energy Materials & Solar Cells	95			2011	S2-S7	10.1016/j.solmat.2010.11.031	No
6	Epoxy-induced spalling of silicon	R. Martini	Energy Procedia	27			2012	567-572	10.1016/j.egypro.2012.07.111	Yes
7	Effect of an in-situ H2 plasma pretreatment on the minority carrier lifetime of a-Si:H(i) passivated crystalline silicon	S. Granata	Energy Procedia	27			2012	412–418	10.1016/j.egypro.2012.07.086	Yes
8	Development of a-Si:H/c-Si heterojunctions for the i2-module concept: Low temperature passivation and emitter formation on wafers bonded to glass	J. Govaerts	Solar Energy Materials & Solar Cells	113			2013	52-60	10.1016/j.solmat.2013.01.029	No
9	18% efficiency IBC cell with rear-surface processed on quartz	F. Dross	IEEE Journal of Photovoltaics	3			2013	684-689	10.1109/jphotov.2013.2239359	No
10	Thermo-mechanical and fracture properties in single-crystal silicon	A. Masolin	Journal of Materials Science 48, 979-988 (2013).	48			2013	979-988	10.1007/s10853-012-6713-7	No
11	Defects in Si foils fabricated by spalling at low temperature: electrical activity and atomic nature	A. Masolin	Journal of Physics D: Applied Physics	46			2013	155501	10.1088/0022-3727/46/15/155501	No
12	Improved surface cleaning by in-situ hydrogen plasma for amorphous/crystalline silicon heterojunction solar cells	S.N. Granata	Solid State Phenomena	195			2013	321-323	10.4028/www.scientific.net/SSP.195.321	No
13	Plasma silicone interaction during a-Si:H deposition on solar cell wafers bonded to glass	S.N. Granata	Solar Energy Materials & Solar Cells	Submitted			2013			No

14	Heterojunction interdigitated back-contact solar cells fabricated on wafer bonded to glass	S.N. Granata	IEEE Journal of Photovoltaics	Submitted			2013			No

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[5]	Main leader	Title	Date/Period	Place	Type of audience[6]	Size of audience	Countries addressed
1	Presentation	imec	Evidence and characterization of crystallographic defect and material quality after Slim-cut process	25-29.04.2011	Materials Research Society Spring Meeting (MRS Spring meeting 2012) San Francisco, CA, USA	* Scientific Community (higher education, Research) * Industry	> 250	Worldwide
2	Presentation	imec	Progress in i-module: towards improved performance, reliability and module level fabrication technologies for back-contact PV-modules based on ultra-thin silicon solar cells	05-08.09.2011	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2011) Hamburg, Germany	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide
3	Poster	imec	Epoxy-induced spalling of silicon	03-05.04.2012	International Conference on Crystalline Silicon Photovoltaics (SiliconPV 2012) Leuven, Belgium	* Scientific Community (higher education, Research) * Industry	> 250	Worldwide

[5] A drop down list allows choosing the dissemination activity: Publications, Conferences, Workshops, Web, Press releases, Flyers, Articles published in the popular press, Videos, Media Briefings, Presentations, Exhibitions, Thesis, Interviews, Films, TV clips, Posters, Other.

[6] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

4	Presentation	imec	High quality epitaxial foils, obtained by a layer transfer process, for integration in back contacted solar cells processed on glass	03-08.06.2012	IEEE Photovoltaic Specialists Conference (IEEE PVSC 2012) Austin, TX, USA	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide
5	Presentation	imec	Cell-module integration concept compatible with c-Si epitaxial thin foils and with efficiencies over 18%	24-28.09.2012	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2012) Frankfurt, Germany	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide
6	Presentation	imec	Cell-module integration concept compatible with c-Si epitaxial thin foils and with efficiencies over 18%	24-28.09.2012	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2012) Frankfurt, Germany	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide
7	Presentation	imec	Improved surface cleaning by in-situ hydrogen plasma for amorphous/crystalline silicon heterojunction solar cells	16-19.09.2012	International Symposium on Ultra Clean Processing of Semiconductor Surfaces (UCPSS 2012) Gent, Belgium	* Scientific Community (higher education, Research) * Industry	> 250	Worldwide
8	Presentation	imec	Low-temperature Slim-cut	08-10.10.2012	International Workshop on Crystalline Silicon Solar Cells (CSSC 2012) Aix-les-Bains, France	* Scientific Community (higher education, Research) * Industry	> 250	Worldwide
9	Publication	imec	Crystalline silicon thin foils: where crystalline quality meets thin-film	02.2012	Photovoltaics International 15, 107-113	* Scientific Community	> 1000	Worldwide

			processing			(higher education, Research) * Industry		
10	Presentation	imec	Sugar: manufacturing of thin crystalline Si wafers by the Slim-cut process & solar cell production starting from thin Si wafers	20-22.06.2012	Advanced Concepts in Silicon Based Photovoltaics Workshop (ACPV Workshop) Oslo, Norway	* Scientific Community (higher education, Research) * Industry	> 50	European
11	Poster	imec	Effect of an in-situ H2 plasma pretreatment on the minority carrier lifetime of a-Si:H(i) passivated crystalline silicon	03-05.04.2012	International Conference on Crystalline Silicon Photovoltaics (SiliconPV 2012) Leuven, Belgium	* Scientific Community (higher education, Research) * Industry	> 250	Worldwide
12	Presentation	imec	i-module technology: evaluation and evolution	30.09- 04.10.2013	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2013) Paris, France	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide
13	Presentation	Armines	Anisotropic mesh adaptation dedicated to 2D/3D crack propagation	10-14.09.2012	European Congress on Computational Methods in Applied Science and Engineering (ECCOMAS 2012) Vienna, Austria	* Scientific Community (higher education, Research) * Industry	> 250	Worldwide
14	Presentation	Armines	A novel monolithic approach for modelling crack propagation	13-17.05.2013	Colloque national en calcul de structures	* Scientific Community (higher education,	450	French essentially

						Research) * Industry		
15	Presentation	Fraunhofer	Development and optimization of automated dry-wafer separation	15-17.01. 2012	World Academy of Science, Engineering and Technology (WASET 2012) Zurich, Switzerland	* Scientific Community (higher education, Research) * Industry	> 250	Worldwide
16	Poster	Fraunhofer	Advanced production challenges for automated ultra-thin wafer handling	24-28.09.2012	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2012) Frankfurt, Germany	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide
17	Poster	Fraunhofer	Analysis of influences on solar wafers during pick-and-place operations	24-28.09.2012	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2012) Frankfurt, Germany	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide
18	Publication	Fraunhofer	How automation can benefit the PV industry	05.2012	Photovoltaics International 16, 15-24	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide
19	Poster	Fraunhofer	Gripping-in-liquid: handling challenges for automated ultra-thin wafer production	30.09- 04.10.2013	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2013) Paris, France	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide

20	Poster	Fraunhofer	Development and evaluation of a prototypic automated high precision assembly of ultra-thin miniaturized silicon wafers	30.09- 04.10.2013	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2013) Paris, France	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide
21	Presentation	FFCUL	New concepts for crystal growth for photovoltaics	09-13.05.2011	European Materials Research Society Spring Meeting (EMRS Spring meeting 2011) Nice, France	* Scientific Community (higher education, Research) * Industry	> 250	Worldwide
22	Presentation	FFCUL	Silicon ribbons for photovoltaic application	19-26.10. 2011	Low Carbon Earth Summit (LCES 2011) Dalian, China	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide
23	Poster	FFCUL	Thin wafers by the slim-cut process using a halogen lamp furnace	24-28.09.2012	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2012) Frankfurt, Germany	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide
24	Presentation	FFCUL	Thin silicon foils obtained by a kerfless technique	08-10.10.2012	International Workshop on Crystalline Silicon Solar Cells (CSSC 2012) Aix-les-Bains, France	* Scientific Community (higher education, Research) * Industry	> 1000	Worldwide
25	Presentation	FFCUL	Comparative study of stress inducing layers to produce kerfless thin wafers by	16-21.06.2013	IEEE Photovoltaic Specialists Conference (IEEE PVSC	* Scientific Community	> 1000	Worldwide

			the Slim-cut technique		2013) Tampa, FL, USA	(higher education, Research) * Industry			

Section B

Part B1

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[7]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Patent	No		WO 2013/02890	Method of fabricating solar modules and solar module obtained thereby	Beaucarne Guy, Norris Ann, Govaerts Jonathan, Dross Frederic

[7] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2

NO.	Type of Exploitable Foreground[8]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[9]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
1	General advancement of knowledge	Slim-cut lift-off by an epoxy stress-inducing layer	No		Wafering, Solar cells	1. Energy (solar cells) M72.1 Research and experimental development on natural science and engineering	Open for licensing	Internal know-how	imec, FFCUL
2	General advancement of knowledge	a-Si heterojunctions as interdigitated BSF and emitter and ways to pattern them	No		Solar cells	1. Energy (solar cells) M72.1 Research and experimental development on natural science and engineering	Further development	Internal know-how	imec
3	General advancement of knowledge	Processing on wafers bonded to glass and interactions with silicone bonding material	No		Solar cells	1. Energy (solar cells) M72.1 Research and experimental	Open for licensing	Internal know-how	imec, Dow Corning

[19] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, Exploitation of results through EU policies, Exploitation of results through (social) innovation.
[9] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

NO.	Type of Exploitable Foreground[8]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[9]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
						development on natural science and engineering			
4	General advancement of knowledge	Printing very thin and uniform layers of silicone liquid encapsulant using blade coating	No		PV modules	1. Energy (solar cells) M72.1 Research and experimental development on natural science and engineering	Licensing, either directly or through a 'free license to use' offered together with commercial encapsulant offering	Internal know-how	Dow Corning, imec
5	General advancement of knowledge	Laser assisted cutting, engraving and ablation of various materials with micrometer accuracy	No		Laser cutting, marking and drilling equipment	C18 Printing and reproduction of recorded media C26 Manufacture of computer, electronic and optical products C28 Manufacture of machinery and equipment n.e.c.	Equipment offering	Internal know-how	4Pico
6	General advancement of knowledge	Handling and assembly process for an accurate bonding-on-glass of ultra-thin substrates	No		Process automation for next generation PV-modules	M72.1 - Research and experimental development on natural sciences and engineering	Open for licensing	Internal know-how	Fraunhofer

NO.	Type of Exploitable Foreground[8]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[9]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
7	General advancement of knowledge	Automated pick-and-place of sensitive substrates in liquid media with advanced process control	yes	31/12/2014	Process automation for sensitive substrates and small area foils	M72.1 - Research and experimental development on natural sciences and engineering	Further development	Internal know-how	Fraunhofer
8	General advancement of knowledge	Control of silicon substrate failure mechanism under thin films compressive loadings	No		Theoretical and numerical results	Fracture Mechanics		Internal know-how	Armines
9	General advancement of knowledge	Crack propagation modelling under thermomechanical loading using a level-set framework and anisotropic mesh adaptation	No		Numerical results	Computational mechanics		Internal know how	Armines
10	General advancement of knowledge	Dispensing the encapsulant	No		Solar cell	1. Energy (solar cells)	We would like to implement this knowledge within our new products	Internal know-how	AMAT
11	General advancement of	Handling of thin wafers	yes		Solar cell	1. Energy (solar cells)	We would like to implement this	Internal know-how	AMAT, Fraunhofer

NO.	Type of Exploitable Foreground[8]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[9]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
	knowledge						knowledge within our new products		
12	General advancement of knowledge	Printing of resist	yes		Solar cell	1. Energy (solar cells)	We would like to implement this knowledge within our new products	Internal know-how	AMAT

Additional information

NO.	Description of exploitable foreground	Additional information
1	Slim-cut lift-off by an epoxy stress-inducing layer	We developed a Slim-cut process relying on an epoxy stress-inducing layer. This results in foils of several cm^2 with thicknesses <= 100 µm. Compared to a metal stress inducing layer, the processing temperatures can be kept lower, the electronic quality of the obtained Si foil is higher and the stress induced layer can be removed more easily from the foil. Integration of these foils in a solar cell has to be completed to fully demonstrate their suitability for high efficiency solar cells.
2	a-Si heterojunctions as interdigitated BSF and emitter and ways to pattern them	A process flow to realize an interdigitated pattern of p-type a-Si and n-type a-Si has been successfully demonstrated. This process flow allows realizing heterojunction IBC cells, a cell type combining low temperature processing and possibly high efficiencies due to the excellent surface passivation quality. The obtained cell efficiencies are promising. One topic that needs to be tackled in further research to further improve cell efficiencies is the metallization on top of the a-Si layers.
3	Processing on wafers bonded to glass and interactions with silicone bonding material	Handling thin solar wafers requires bonding to a substrate, but the bonding material can complicate further processing. We have developed a process flow by which interaction with a silicone bonding material can be minimized. This flow allows further developing our thin solar cell processing flow.
4	Printing very thin and uniform layers of silicone liquid encapsulant using blade coating	The module cost is to a large extent dominated by the materials cost. At present, in standard technology, a fairly thick layer of encapsulant is used. This is because the interconnection ribbons require a certain encapsulation thickness (~400 um). However, as back-contact cells are introduced, there is no need anymore for very thick encapsulant, and in fact a thinner encapsulant layer is preferred for cost reasons. It is however challenging to make a very thin sheet-based encapsulant layer. In the project, it was shown that it was possible to achieve uniform layers of around ~ 50 µm thickness. This know-how can be useful for various types of future modules.
5	Laser assisted cutting, engraving and ablation of various materials with micrometer accuracy	In the project it was shown that sharp notches can be laser grooved in Si wafers, with a high precision and high repeatability. This experience is being expanded to other materials (anodized aluminium, stainless steel and glass) and to other lasers than the IR laser applied in the project.
6	Handling and assembly process for accurate bonding-on-glass assembly of ultra-thin	An assembly process was developed based on prototype handling equipment. The developed assembly process meets the requirements for the automated placement of pre-processed substrates on a silicone coated glass substrate. The so called automated assembly process is an essential step for the production of thin-film like processed crystalline photovoltaic modules.

NO.	Description of exploitable foreground	Additional information
	substrates	
7	Automated pick-and-place of sensitive substrates in liquid media with advanced process control	The automated pick-and-place in liquid process environment enables the manipulation of sensitive substrates or small area foils by using a certain grippers. An individually developed advanced process control allows the pick-and-place of, e.g. ultra-thin wafers, between liquid and dry environment. Single pick-and-place of wafers in wet bench environment enables the wet wafer or foil processing, where state of the art batch or inline processes are limited due to thickness and/or size of the substrate. The application in this project was given by the process task, which is removing the epoxy form the detached Slim-cut foil.
8	Control of silicon substrate failure mechanism under thin films compressive loadings	Based on Cotterell&Rice and Xu&Blum theories, the failure of silicon substrate due to the presence of compressive thin films was analysed both in terms of crack propagation and directional stability of crack propagation. The analysis shown that the developed model is able to predict horizontal crack propagation parallel to the film/substrate interface for specific geometrical conditions and intrinsic stress in the film.
9	Crack propagation modelling under thermomechanical loading using a level-set framework and anisotropic mesh adaptation	A monolithic method with a Lagrangian approach was introduced to model crack propagation in silicon during the Slim-cut process. Our method is based on the use of level-set functions for interface description, on dynamic mesh adaptation and on the choice of an appropriate Lagrangian convection velocity. The latter is a combination between the mechanical velocity and the speed at the crack tip obtained using the $G\theta$-method.
10	Dispensing the encapsulant	We developed a semi-automated tool able to dispense the encapsulant on waters with high precision [automation]. We acquired a good knowledge about the process parameters required to have good encapsulant performance. [process]
11	Handling of thin wafers	We developed a tool for high precision centring of the wafer. [automation] Thanks of this tool, it would be possible to improve wafer performance (as better positioning in the following process steps). [process]
12	Printing of resist	Thanks to the project we were able to tests some resists. The possibility of printing also the resist would be a good improvement for our tools.

4.3 Report on societal implications

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when* ***Grant Agreement number*** *is entered.*	
Grant Agreement Number:	*256752*
Title of Project:	***Silicon substrates from an integrated automated process***
Name and Title of Coordinator:	***Dr. ir. Maarten Debucquoy***

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***No***
2. Please indicate whether your project involved any of the following issues (tick box) :	
RESEARCH ON HUMANS	
• Did the project involve children?	***No***
• Did the project involve patients?	***No***
• Did the project involve persons not able to give consent?	***No***
• Did the project involve adult healthy volunteers?	***No***
• Did the project involve Human genetic material?	***No***
• Did the project involve Human biological samples?	***No***
• Did the project involve Human data collection?	***No***
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	***No***
• Did the project involve Human Foetal Tissue / Cells?	***No***
• Did the project involve Human Embryonic Stem Cells (hESCs)?	***No***
• Did the project on human Embryonic Stem Cells involve cells in culture?	***No***
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	***No***
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	***No***
• Did the project involve tracking the location or observation of people?	***No***
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	***No***

• Were those animals transgenic small laboratory animals?	***No***
• Were those animals transgenic farm animals?	***No***
• Were those animals cloned farm animals?	***No***
• Were those animals non-human primates?	***No***
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	***No***
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	***No***
DUAL USE	
• Research having direct military use	***No***
• Research having the potential for terrorist abuse	***No***

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	***0***	***1***
Work package leaders	***0***	***4***
Experienced researchers (i.e. PhD holders)	***5***	***19***
PhD Students	***0***	***6***
Other	***12***	***20***

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	***6***
Of which, indicate the number of men:	***3***

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	○ *X*	Yes ***No***

6. Which of the following actions did you carry out and how effective were they?

	Not at all effective				Very effective
❑ Design and implement an equal opportunity policy	○	○	○	○	○
❑ Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑ Organise conferences and workshops on gender	○	○	○	○	○
❑ Actions to improve work-life balance	○	○	○	○	○

○ Other:

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

X No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

X Yes- please specify *Master and Phd students*

○ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

○ Yes- please specify

X No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

X Main discipline[10]: ***2.2***

X Associated discipline[10]: ***2.3*** X Associated discipline[10]: ***1.2***

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	○ *X*	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

○ No
○ Yes- in determining what research should be performed
○ Yes - in implementing the research
○ Yes, in communicating /disseminating / using the results of the project

[10] Insert number from list below (Frascati Manual).

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ○ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	

13c If Yes, at which level? ○ Local / regional levels ○ National level ○ European level ○ International level	

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	*14*
To how many of these is open access[11] provided?	*3*
How many of these are published in open access journals?	*3*
How many of these are published in open repositories?	*0*
To how many of these is open access not provided?	*11*
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[12]: ……………	***Lack of information on open access***

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		*1*
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	*0*
	Registered design	*0*
	Other	*0*
17. How many spin-off companies were created / are planned as a direct result of the project?		*0*
Indicate the approximate number of additional jobs in these companies:		

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑ Increase in employment, or	❑ In small & medium-sized enterprises
❑ Safeguard employment, or	❑ In large companies
❑ Decrease in employment,	❑ None of the above / not relevant to the project
X Difficult to estimate / not possible to quantify	

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	***Difficult to estimate / not possible to quantify***

[11] Open Access is defined as free of charge access for anyone via Internet.
[12] For instance: classification for security project.

Difficult to estimate / not possible to quantify	*X*

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes *X* ***No***

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes *X* ***No***

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

❑	Press Release	❑	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
X	***Brochures /posters / flyers***	*X*	***Website for the general public / internet***
❑	DVD /Film /Multimedia	*X*	***Event targeting general public (festival, conference, exhibition, science café)***

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	*X*	***English***
❑	Other language(s)		

***Question F-10*: ** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]