



CORDIS Results Pack on harnessing solar power

A thematic collection of innovative EU-funded research results

August 2019

The background of the lower half of the cover is a photograph of a vast solar farm. Rows of solar panels are visible, receding into the distance. The sun is low on the horizon, creating a strong lens flare that dominates the right side of the image. The sky is blue with some light clouds.

The future
shines bright

Research and
Innovation

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Editorial

Solar power is a clean, abundant and increasingly competitive source of renewable energy. By helping the EU achieve its goal of transitioning from imported fossil fuels and move towards sustainable cleaner energy, solar power can also drive technological innovation and generate employment. Furthermore, solar power is already making a key contribution to the European energy mix and, based on current market trends, has the potential to meet 20 % of the EU electricity demand in 2040.

The EU's [Renewable Energy Directive](#) (2009/28/EC) set a target for all EU countries to fulfil 20 % of their energy needs through renewable sources by 2020. Following this, EU countries have made a commitment to reach their own national renewable targets and adopted [national renewable energy action plans](#) to showcase the actions they would take to meet their obligations under the directive.

The revised [Renewable Energy Directive](#) (2018/2001) in December 2018 formed part of the 'Clean Energy for all Europeans' package. Considered one of the world's most ambitious renewable energy policies, it commits EU countries to achieving a renewable energy target of at least 32 % by 2030. The new [Governance regulation](#) requires EU countries to draft 10-year National Energy and Climate Plans (NECPs) for 2021-2030, outlining how they will meet the new 2030 targets.

Meeting key renewable energy targets

Actions that support the development of renewable energy technologies are vital to meet these ambitious targets. Solar energy will therefore play a prominent role in driving the transformation of electricity generation. To ensure the technology is in place to harness the resource, research is focusing on increasing the efficiency of solar cells and modules, investigating new materials, reducing generation costs and demonstrating new production lines.

Europe's plan for the delivery of these technologies is the [Strategic Energy Technology Plan \(SET plan\)](#). This has set the research priorities for the different renewable energy technologies as well as the implementation plans for each, in particular the [Implementation Plan for PV](#).

Shining a spotlight on research and innovation

This CORDIS Results Pack focuses on 10 ongoing, or recently ended, projects funded by the EU within Horizon 2020, which address the technical and scientific challenges facing solar power.

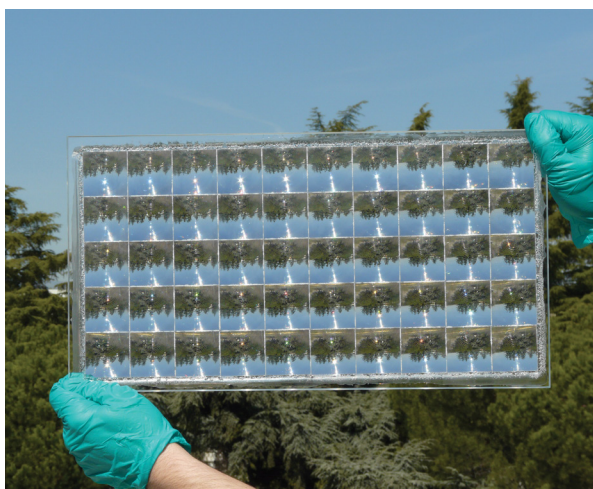
The [CPVMatch](#) project showcased the enormous potential of concentrated solar PV with Germanium substrate cells. This popular material for integrated circuits is at the forefront of next-generation, multi-junction solar cells. Another project, [Sharc25](#), set out to make efficient, thin-film (CIGS) solar cells for the next generation of more cost-effective solar modules.

[Nano-Tandem](#), using nanowires, demonstrated the major advances that can be achieved with these miniature materials in innovative solar cells. [CHEOPS](#) helped to upscale production of perovskite-based solar cells, while [PVSITES](#) is paving the way towards the global uptake of building-integrated photovoltaics (BIPV) – led by European industry. [ARCIGS-M](#)'s goal of advanced materials and nanotechnologies CIGS PV device architectures also targets the BIPV sector.

[NextBase](#) is developing next-generation c-Si solar cells and modules and [DISC](#) is harnessing the potential of silicon in PV technology through the use of carrier-selective junctions. The [AMPERE](#) project is concentrating on manufacturing more efficient and reliable PV modules. Finally, the [STARCELL](#) project is advancing the development of thin-film PV technology using exclusively materials that are abundant in the Earth's crust.

Germanium substrate: A promising platform for multi-junction solar cells

Germanium has long been a popular material for integrated circuits. Outside the core area of electronic devices, an EU-funded project is showing its great potential as a substrate to lead next-generation multi-junction solar cells.



© Gerald Siefer

The world is looking towards renewable energy such as solar power to reduce greenhouse gas emissions and solve the looming energy crisis. However, developing high-efficiency solar cells that can convert a significant amount of sunlight into electrical energy at very low costs remains a significant challenge.

Concentrator photovoltaics that use optics to focus the Sun's power on high-efficiency multi-junction solar cells can play a large role in boosting solar power generation. This technology requires sub-cells with different band gaps to absorb different parts of the solar spectrum to realise high theoretical energy conversion efficiencies. High-performance mirrors or lenses can focus over 500 times more sunlight onto these tiny cells compared to conventional flat-plate photovoltaics. However, this technology requires further cost reduction.

Perfect crystal matching

Combining two technologies is a practical step for making concentrator photovoltaic systems more competitive with other forms of energy generation. This means taking a low-cost wafer and using it as a basis for forming many highly efficient multi-junction devices featuring various compound-semiconductor layers.

"Matching the atomic spacing of successive layers is a crucial element when combining materials with certain band gap energies," notes Dr Gerald Siefer, project coordinator of the EU-funded project [CPVMatch](#). As, he further explains, several methods, including metamorphic growth and wafer bonding, can be used to overcome the lattice mismatch. However, use of materials with the same lattice parameter is preferable to propelling multi-junction cells to higher efficiencies at low cost.

Project researchers performed a successful proof-of-concept by using a germanium wafer and then adding a lattice-matched silicon-germanium-tin (SiGeSn) structure to form a 1 eV junction. Subsequent addition of III-V materials will allow upper junctions to be created leading to device architecture that can deliver very high efficiencies. "This is the first time that a high-quality IV semiconductor element – SiGeSn – is epitaxially grown on a germanium substrate on the same growth reactor as III-V semiconductor elements," adds Siefer.

Costing less than its counterpart

Very high-efficiency photovoltaic cells partly implement indium phosphide based (InP) substrates to efficiently convert solar radiation into electrical energy. "The world record efficiency of



High-concentration photovoltaic systems can achieve efficiency levels that flat-plate photovoltaics will never reach.

multi-junction solar cells comprising InP as a substrate is 46 %. Still, this material is much more expensive than germanium,” notes Siefer.

The new CPVMatch four-junction solar cell with a germanium substrate achieved 42.6 % efficiency. The project successfully developed and demonstrated other technical building blocks that – put together – will ultimately increase cell efficiency to 46 %.

CPVMatch demonstrated concepts that cut solar-cell costs and boosted efficiency to ensure that concentrator photovoltaic systems become more competitive in the future. “High-concentration photovoltaic systems can achieve efficiency levels that flat-plate photovoltaics will never reach. What’s more, their demonstrated lower carbon footprint – ranging from 16 to 18 grammes of CO₂ per kilowatt-hour of electricity produced – is of paramount importance for decarbonising the energy system,” adds Siefer.

PROJECT

CPVMatch - Concentrating Photovoltaic modules using advanced technologies and cells for highest efficiencies

COORDINATED BY

Fraunhofer Society in Germany

FUNDED UNDER

H2020

CORDIS FACTSHEET

cordis.europa.eu/project/rcn/193754

PROJECT WEBSITE

cpvmatch.eu/

Overcoming the drawbacks of standard lenses

Most concentrator photovoltaic modules are using the so-called silicone-on-glass (SoG) lenses. Although these lenses are cheap, they introduce chromatic aberration and their performance depends significantly on ambient temperature. Researchers experimented with achromatic lenses to reduce distortion. Despite their potential to yield a very high-performance device, they are expensive.

To skirt SoG limitations and minimise costs, researchers focused on a cheap manufacturing process for achromatic lenses as well as smart, highly compact mirror-based concentrator photovoltaic modules. Both boast a host of advantages compared to standard lenses: no issues with chromatic distortion, coupled with higher solar conversion efficiencies.



Post-deposition treatments boost efficiencies of thin-film solar cells

The solar cell industry is focused on increasing efficiency and decreasing costs. EU-funded scientists know how to play the game, achieving record-breaking efficiencies in low-cost thin-film solar cells.

Photovoltaics (PV) that convert the light energy from the sun into electricity have matured at a rapid pace. First-generation silicon solar cells continue to play a major role in meeting global energy needs.

Annual global PV module production for second-generation or thin-film solar cells has been growing. However, efficiencies have typically been less than those achieved with first-generation technologies. The ambitious EU-funded [Sharc25](#) project set out to level the playing field.

Thin-film solar cells are made by depositing very thin layers of semiconductor materials (a few micrometres or less) on a supporting substrate. Sharc25 focused primarily on copper indium gallium diselenide (CIGS) solar cells on, but not restricted to, glass substrates. Key innovations in post-deposition processing and interface design paved the way for world-class outcomes.

Novel post-deposition treatments break barriers

According to project coordinator Wolfram Witte, when the Sharc25 project started in 2015, “only a few research institutes and companies worldwide had exceeded the 20 % efficiency mark for CIGS solar cells, typically using potassium fluoride post-deposition treatment (KF-PDT).” Sharc25 partners ZSW and Empa were already among them.

Adding to the KF-PDT process for CIGS absorbers, researchers enhanced their repertoire of alkali metal PDT using rubidium fluoride PDT (RbF-PDT) or caesium fluoride PDT (CsF-PDT) as well. The improved processes for CIGS absorber fabrication and advanced interface design facilitated even higher efficiencies.

In June 2016, the project posted a new world record for small-area CIGS solar cells on glass substrates with 22.6 % efficiency. Flexible substrates provide a versatile solution for both building and portable applications. Sharc25 has advanced this field as well, achieving another world record efficiency for a CIGS solar cell on a flexible substrate with 20.8 % efficiency.

Publication of the results and associated processes has sparked a new wave of research and development worldwide utilising RbF-PDT or CsF-PDT, continuing to push the frontiers of the technology.

An eye on the future

Partner companies are commercialising the high-efficiency thin-film technology, implementing the alkali metal PDT processes to produce large-area solar modules from CIGS thin-film solar cells.



Sharc25 has provided deep insights into the physics of highly efficient CIGS thin-film solar cells using advanced characterisation methods, analytical tools, device simulation, and density functional modelling.



© ZSW

In addition, Sharc25 thin-film technologies could soon find their way into third-generation perovskite photovoltaics. Perovskite is attracting global attention due to demonstrated efficiencies above 20 % together with its high band gap energy.

Sharc25 scientists fabricated an 18 % efficient CIGS solar cell with RbF-PDT and a low band gap energy of 1.0 eV. As Witte explains: "This material is an ideal candidate for a bottom cell in a tandem application with a high band gap material like third-generation perovskite as the top cell."

The team has been spreading the word through numerous presentations at conferences and prolific publication in peer-reviewed scientific journals. The consortium also organised two successful international public workshops.

"Sharc25 has provided deep insights into the physics of highly efficient CIGS thin-film solar cells using advanced characterisation methods, analytical tools, device simulation, and density functional modelling," Witte concludes. Thanks to this complementary approach, Sharc25 has developed new

efficiency-enhancing methods, some of which have already been successfully transferred into production. With new records in the efficiency of CIGS solar cells, the team has raised the bar in the thin-film solar cell field.

PROJECT

Sharc25 - Super high efficiency Cu(In,Ga)Se_2 thin-film solar cells approaching 25%

COORDINATED BY

Centre for Solar Energy and Hydrogen Research
Baden-Württemberg (ZSW) in Germany

FUNDED UNDER

H2020

CORDIS FACTSHEET

cordis.europa.eu/project/rcn/193776

PROJECT WEBSITE

sharc25.eu/



Silicon solar cells get a charge from nanowire top layers

Nanowires have unique optical and electrical properties emerging from their incredibly small dimensions. EU-funded scientists have made major advances using these miniature materials in innovative solar cells.

Silicon continues to dominate the solar cell industry. However, emerging technologies are using it in innovative ways.

Exploiting tried and tested silicon as a base cell in tandem with nanowires of III-V semiconductors (alloys of elements from Group III and Group V of the Periodic Table) as the top cell, the EU-funded [Nano-Tandem](#) project set out to break barriers to increasing efficiency at lower cost.

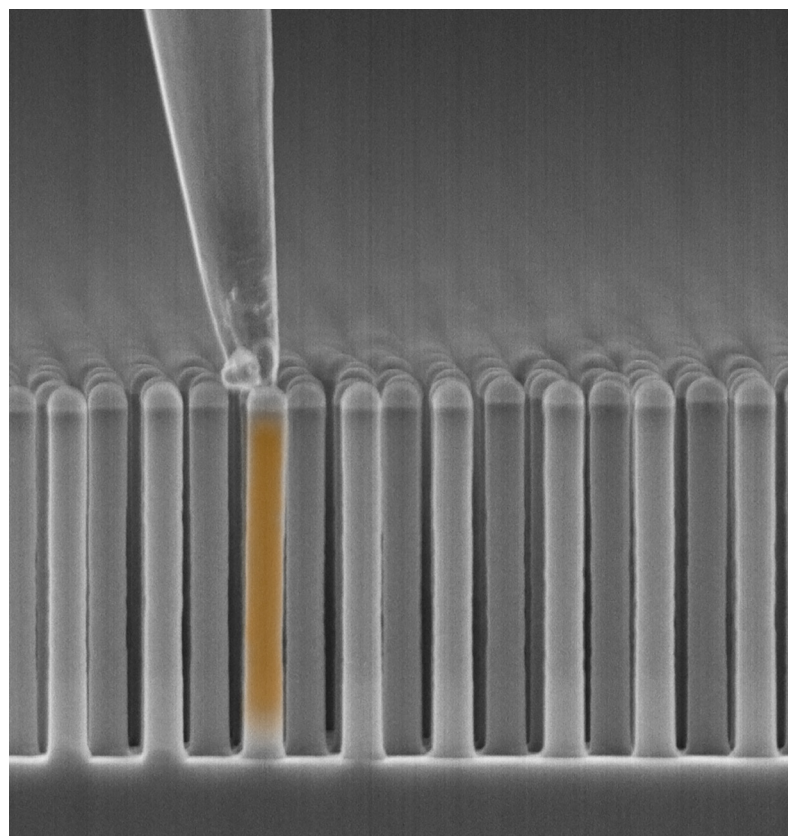
Breakthroughs in nanowire function and cost

Nanowires are very tiny rods, approximately 100 nanometres wide and 10 micrometres long. The tandem cell exploits them in vertical configuration with about 6-7 million nanowires per square millimetre of cell.

Template-assisted selective epitaxy (TASE) was used for growth of nanowires directly on silicon. Using this process, researchers demonstrated active p-n junctions in indium gallium phosphide (InGaP) nanowires grown with TASE.

Nanowire nucleation on a III-V substrate rather than on silicon provided more than seven-fold improvement in the efficiency of indium phosphide (InP) nanowire solar cells – a record 15 %.

Functional nanowires require tunnel diodes, something that has been quite challenging to achieve. Nano-Tandem removed this roadblock, demonstrating the ability to produce InP/InGaP nanowire tunnel diodes for the first time. Characterisation of the tunnel diodes by electron-beam-induced current (EBIC) was integral to improving alloy composition and thus the quality of the diodes.



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To transfer the nanowires to silicon, scientists embedded them in a polymer membrane, peeled the membrane off, and bound it to its new bottom cell. After three uses, the original substrates were unchanged, supporting even more uses and further cost savings.

Finally, the team optimised a highly promising technique, aerotaxy, that enables growth of nanowires from seed particles directly in the gas phase without a substrate. Growth rates are 100-1 000 times faster than in conventional epitaxial growth, promising a radical reduction in cost.



The expected price of a 28 % efficient GaAs/Si nanowire tandem module produced with the aerotaxy process is 0.296 USD/W. The expected future price of conventional crystalline silicon modules is 0.39 USD/W for a 25 % efficient module.

Project coordinator Lars Samuelson explains: "Forming the aerotaxy nanowires into a membrane was really challenging." Nano-Tandem scientists benefited from a specialised ink process for aligning the wires.

With this high-throughput technique, the team fabricated high-quality gallium arsenide (GaAs) nanowire p-n junctions. According to project leaders: "The expected price of a 28 % efficient GaAs/Si nanowire tandem module produced with the aerotaxy process is 0.296 USD/W. The expected future price of conventional crystalline silicon modules is 0.39 USD/W for a 25 % efficient module."

Higher efficiency at a significantly lower cost should make Nano-Tandem's solar-cell technology a winner for global renewable energy markets.

Applications in solar energy and beyond

Nano-Tandem's process optimisation and characterisation developments have improved nanowire growth and functionality, while enhancing the efficiency of the silicon-bottom cell. Detailed results can be found in the 38 peer-reviewed scientific publications.

Outcomes pave the way to low-cost large-area tandem-nanowire III-V/silicon solar cells and European leadership in the growing PV market. They should also generate innovation in devices including LEDs, microelectronics and sensors.

PROJECT

Nano-Tandem - Nanowire based Tandem Solar Cells

COORDINATED BY

Lund University in Sweden

FUNDED UNDER

H2020

CORDIS FACTSHEET

cordis.europa.eu/project/rcn/193777

PROJECT WEBSITE

nano-tandem.ftf.lth.se/

Innovative light-trapping for nanowire-based solar cells

Conventional high-efficiency silicon solar cells use light-trapping mechanisms that exploit front-side structuring to boost absorption. This is not an option for tandem nanowire/silicon solar cells, so Nano-Tandem developed a rear-side photonic-light-trapping structure. With it, scientists achieved a new world record in conversion efficiency (33.3 %) for a tandem III-V/silicon thin-film solar cell.



A push for perovskite-silicon tandem solar-cell technology

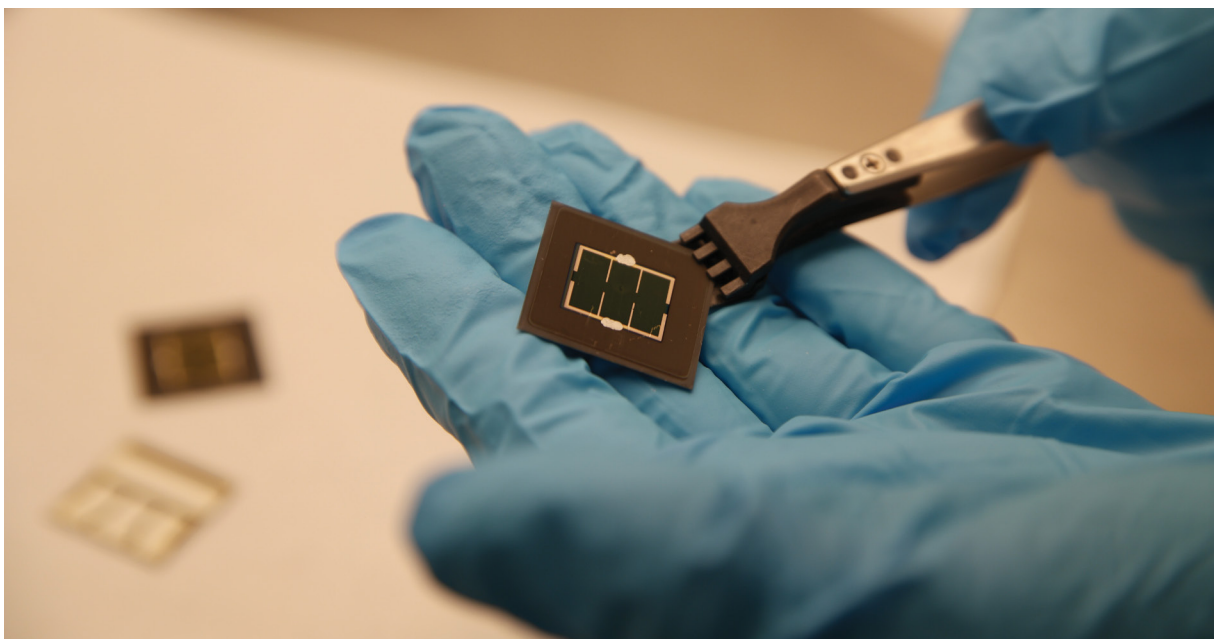
Unlike the predictable nature of the light emitted by our own star, the solar cell industry is continuously evolving. Now, EU-funded researchers have achieved world-record conversion efficiencies with a third-generation material deposited on silicon.

Photovoltaic (PV) technology has advanced rapidly since the first demonstration of a practical crystalline silicon solar cell by Bell Labs in 1954. However, as efficiencies reach their theoretical limit, the search continues for new materials and methods to increase efficiency and decrease cost.

Among the most promising third-generation technologies under development are those utilising perovskites, a class of crystalline organometal halides in which many different cations can be integrated. Efficiencies have improved exponentially over

the last decade and the market is predicted to grow to over USD 500 million by 2028. The EU-funded CHEOPS project set out to achieve breakthroughs in efficiency and processes for upscaling production of perovskite-based solar cells.

Standard silicon absorbs low-energy photons. Perovskite offers the opportunity to harvest more of the light's energy as it is uniquely qualified to take advantage of high-energy blue photons. Using perovskite in their active layers, researchers sought to exploit the material's potential for large-scale production at low cost.



Advancing the frontiers of perovskite-based solar cells

Technologically, the first goal was to enhance the efficiency of single-junction perovskite cells, and then to exploit so-called tandem technology by growing a layer of perovskite over silicon.

CHEOPS researchers upscaled a 1x1 cm² low-lead perovskite single-junction lab prototype with 15 % efficiency to a 10x10 cm² demonstrator module with minimal loss in efficiency. This was a major accomplishment. It also highlighted a remaining challenge for the new technology, controllability of the processes. The team is working on developing new deposition techniques to enable uniform large-area coating of compact films compatible with industrial requirements.



CHEOPS demonstrated for the first time the possibility to grow perovskite top cells on silicon-bottom cells with a fully textured surface. Since the standard silicon PV market is using this kind of textured cells, being able to use them this way is critical for future perovskite development. In addition, world record efficiencies were demonstrated by several CHEOPS partners.

Regarding the perovskite-silicon tandem technology, project coordinator Nicolay Sylvain explains: "CHEOPS demonstrated for the first time the possibility to grow perovskite top cells on silicon-bottom cells with a fully textured surface. Since the standard silicon PV market is using this kind of textured cells, being able to use them this way is critical for future perovskite development. In addition, world record efficiencies were demonstrated by several CHEOPS partners." The perovskite-silicon heterojunction tandem cell (1.43 cm²) achieved a power conversion efficiency of 25.4 %, surpassing the previous world record of CHEOPS partners.

Scientists also developed unified and standard protocols for measurement to ensure more accurate comparisons of different approaches. As Sylvain explains: "Currently, there are a lot of different protocols used to measure perovskite-based PV devices, which makes comparison difficult. CHEOPS partners have agreed on a unified measurement protocol which will be communicated in the form of a white paper."

Perovskite-based solar cells get the green light

The team conducted critical socio-economic analyses, demonstrating that development of the technology is warranted. According to Sylvain: "Perovskite is indeed a technology which can strongly modify the PV landscape by allowing us to achieve more efficient and lower-cost PV modules."

Building on their major successes in demonstrating evaporation of perovskite on fully textured silicon-bottom cells and the low cell-to-module efficiency loss for single-junction perovskite cells, several partners are already in talks with manufacturers to capitalise on project outcomes.

The future is bright for perovskite PV modules, and CHEOPS' contributions pave the way for European leadership in this important field.

PROJECT

CHEOPS - Production technology to achieve low Cost and Highly Efficient photovoltaic Perovskite Solar cells

COORDINATED BY

Swiss Center for Electronics and Microtechnology (CSEM) in Switzerland

FUNDED UNDER

H2020

CORDIS FACTSHEET

cordis.europa.eu/project/rcn/199296

PROJECT WEBSITE

cheops-project.eu/



Solar technology brings Europe closer to nearly-zero energy buildings

Building-integrated photovoltaics (BIPV) technology incorporates solar features into buildings to produce electricity. Several market barriers need to be overcome to achieve the ambitious energy efficiency targets set by the EU.

The BIPV market is growing, thanks mainly to increasingly demanding legislation on the energy performance of buildings. However, market uptake has been hindered by the lack of holistic solutions that comply with key demands from decision-makers and end users.

Overcoming existing BIPV technology challenges

"A combined industrial effort is needed to develop highly efficient and multifunctional energy-producing construction materials in order to provide market opportunities worldwide for European PV and construction industry value chains," says Dr Eduardo Roman, coordinator of the EU-funded [PVSITES](#) project. Standing in the way of market deployment are cost reduction, design flexibility, high performance, long-term reliability, aesthetics, and legal regulation

standardisation and compliance. Overall, the aim is to "pave the way towards a BIPV global market uptake led by European industry."



PVSITES will enhance the visibility of BIPV technology across and beyond Europe and strengthen the European BIPV and construction industries through a significant increase in installed capacity.

Now in its final year, PVSITES is already demonstrating a broad range of BIPV solutions that are fully aligned with European policy and legal frameworks. It has developed a large variety of aesthetic, high-performance and cost-effective glass-based silicon modules and thin-film copper-indium-gallium-selenide (CIGS)-on-metal module technology.

The PVSITES team successfully tested the crystalline silicon and CIGS BIPV modules and demonstrated their compliance with

PV and construction standards. "It's one of the first – if not the first – thorough applications of the new European standard for BIPV," notes Dr Roman. The team has installed and monitored several products at outdoor test benches in France and Spain.

In the power electronics field, project partners have manufactured an inverter prototype based on silicon carbide (SiC), and completed the first testing. They have also designed, validated and fully characterised a low-cost 10 kW storage inverter according to relevant standards.

Team members have developed a [software platform](#) to jointly simulate building energy performance and BIPV systems production in real operating conditions. A pre-commercial version has been launched and it is available for free. Webinars on the software tool and its use will be organised.

Seven demonstration installations have been completed in residential, commercial and industrial buildings in Belgium, France, Spain and Switzerland. These installations will be monitored for at least a year to gather first-hand data on technology performance. Free how-to training sessions held at the demo sites will provide both professionals and students with an opportunity to learn about BIPV products, installation, design, application and safety considerations.

BIPV products slated for wider deployment

According to Dr Roman: "PVSITES will enhance the visibility of BIPV technology across and beyond Europe and strengthen the European BIPV and construction industries through a significant



© Maider Machado

increase in installed capacity.” Commercial success has arrived early, thanks to strong business strategies of manufacturer companies tailored to each and every developed technology.

Several project partners have managed to sell PVSITES BIPV products to markets in Africa, Europe and the United States. “We will not only boost stakeholder and public awareness of BIPV solutions, but also of renewable energy generation as a whole,” concludes Dr Roman.

PROJECT

PVSITES - Building-integrated photovoltaic technologies and systems for large-scale market deployment

COORDINATED BY

TECNALIA Research & Innovation in Spain

FUNDED UNDER

H2020

CORDIS FACTSHEET

cordis.europa.eu/project/rcn/200257

PROJECT WEBSITE

pvsites.eu/



A silver lining lights the way to thinner, more efficient solar cells

Building-integrated photovoltaic systems represent a powerful means to meet increasing demands for zero-energy and zero-emission buildings. Contributing to this is a 13-strong consortium pioneering solar-cell technology and production with a focus on low cost and high efficiency.



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Thin-film solar cells based on an absorber layer of $\text{Cu}(\text{In,Ga})\text{Se}_2$, so-called CIGS, offer low weight, low-light efficiency, flexibility, competitive production costs and, importantly, good aesthetics. The EU-funded [ARCIGS-M](#) project is working to capitalise on this potential by developing advanced solar cell architectures. The ultimate aim is to further drive down the production costs of CIGS solar modules.

Single-step, silver-laced production

"The ARCIGS-M project focuses on low-cost thin-film solar cells with very high efficiency suitable for integration in buildings,"

project coordinator Prof. Marika Edoff sums up. "We use two types of substrates, either ordinary soda-lime glass or low-cost steel substrates." A layer of electric insulation is used to coat the steel substrates, enabling single-step production of solar-cell modules without the need for soldering single cells.

All thin-film solar cells consist of two contacts: an absorber layer, where sunlight is absorbed, and a transparent front contact. The absorber layer in ARCIGS-M solar cells consists of CIGS, a semiconductor material with a direct band gap. The band gap is a material property and corresponds to the minimum photon energy (from sunlight) required to excite an electron. However, in materials with direct band gap, the absorption has a very high probability and therefore allows for very thin layers of just a few micrometres.



The ARCIGS-M project focuses on low-cost thin-film solar cells with very high efficiency suitable for integration in buildings.

ARCIGS-M targets a thickness of only 0.5 μm . The professor notes: "This is not enough for full absorption. Therefore, we have changed our back contact from a layer of molybdenum to a multilayer stack with silver, which provides very high reflectivity, close to 90 %."

Ongoing achievements

Among the project's main achievements, one of the most important is the back-reflector layer "that we have proven works well together with the CIGS layers," Prof. Edoff says. To prevent the loss of electrons from the back contact, a layer of a passivating material is added that consists of aluminium oxide perforated with nano-sized openings.

"Patterning of the back-contact passivation layer is done in nano-scale with nano-imprint lithography, a method that we show to be scalable for this type of device for the first time," the coordinator reports. The team has also developed an opto-electric model that is used to provide feedback.

Beyond tech developments

Notably, the project is making strides outside the lab too. "We have strived to achieve a good gender balance in a field that traditionally is strongly dominated by men," Prof. Edoff states.

The project's coordinator and co-coordinator are both women, "and for the total project we have managed to get about 40 % female participants in the meetings."

"We hope our project will contribute to new business opportunities for our partners who come from many different complementary fields," Prof. Edoff comments. These include a utility company, a steel manufacturer and equipment manufacturers. A quote from a [2018 interview](#) sums up the professor's vision: "Photovoltaics is the present and the future! It is the most democratic way of generating electric power."

PROJECT

ARCIGS-M - Advanced aRchitectures for ultra-thin high-efficiency CIGS solar cells with high Manufacturability

COORDINATED BY

Uppsala University in Sweden

FUNDED UNDER

H2020

CORDIS FACTSHEET

cordis.europa.eu/project/rcn/206842

PROJECT WEBSITE

arcigs-m.eu/



Novel crystalline-silicon solar cells take photovoltaics technology light years ahead

Photovoltaics (PV) technology is based on crystalline silicon (c-Si) solar cells. To corner the global market, highly efficient c-Si PV modules with improved energy conversion efficiency and reduced production costs are required.

The successful commercialisation of high-efficiency PV modules based on c-Si solar cells will depend on their cost advantage over existing conventional c-Si technology. Despite their higher efficiency compared to standard cell technology, a large-scale industrial changeover hasn't taken place yet.

The EU-funded [NextBase](#) project is developing next-generation c-Si solar cells and modules that "go far beyond the state of the art in industry-compatible approaches," says coordinator Dr Kaining Ding. It aims at fostering the energy transition from fossil fuels to renewable energies by improving the energy conversion of PV modules while reducing their cost.

Solar cells and modules
with unparalleled
efficiency values

The NextBase team seeks to develop interdigitated back-contacted silicon-heterojunction (IBC-SHJ) solar cells in a cost-effective manner. "IBC-SHJ solar cells have already been proven to be the ultimate architecture for high efficiency in c-Si solar cells," he continues. To achieve its aims, NextBase has set several targets: solar cells and corresponding modules with efficiencies that exceed 26 % and 22 %, respectively. This



NextBase will revitalise the European PV industry by providing Europe with a leading position in advanced, world-class high-performance c-Si PV technology.

efficiency boost will be achieved by applying cost-effective processes to reduce module costs to under EUR 0.35/Wp.

Project partners have set out to prove that IBC-SHJ solar cells and modules can be produced at competitive costs. To date, they have demonstrated IBC-SHJ solar cells with a certified efficiency of 25 %. "In practical terms, this means that NextBase has given Europe the c-Si solar cell world record for efficiency while employing a simple process flow for this device type," notes Dr Ding. In addition, they have demonstrated a novel interconnection technology for IBC-SHJ solar cells, based on a multi-wire approach with a module efficiency of up to 23.2 %. When the targets are met, the efficiency gains will help "boost the confidence of investors to reinvest in European PV companies and PV technology."

Driving innovation in the
IBC-SHJ field

The researchers are busy producing high-quality n-type mono-c-Si wafers and an industrial prototype plasma-enhanced chemical vapour deposition reactor for IBC-SHJ solar cells. They are also examining the reliability and lifetime of IBC-SHJ solar modules for the industry, and preparing a life-cycle cost analysis for NextBase technologies.

"NextBase will revitalise the European PV industry by providing Europe with a leading position in advanced, world-class high-performance c-Si PV technology," concludes Dr Ding. Successful outcomes would enable cost-effective high-quality PV module manufacture in Europe for the first time in an Asia-dominated market. "This would fill an important gap that's missing in the PV system value chain in Europe."

PROJECT

NextBase - Next-generation interdigitated back-contacted silicon heterojunction solar cells and modules by design and process innovations

COORDINATED BY

Forschungszentrum Jülich GmbH in Germany

FUNDED UNDER

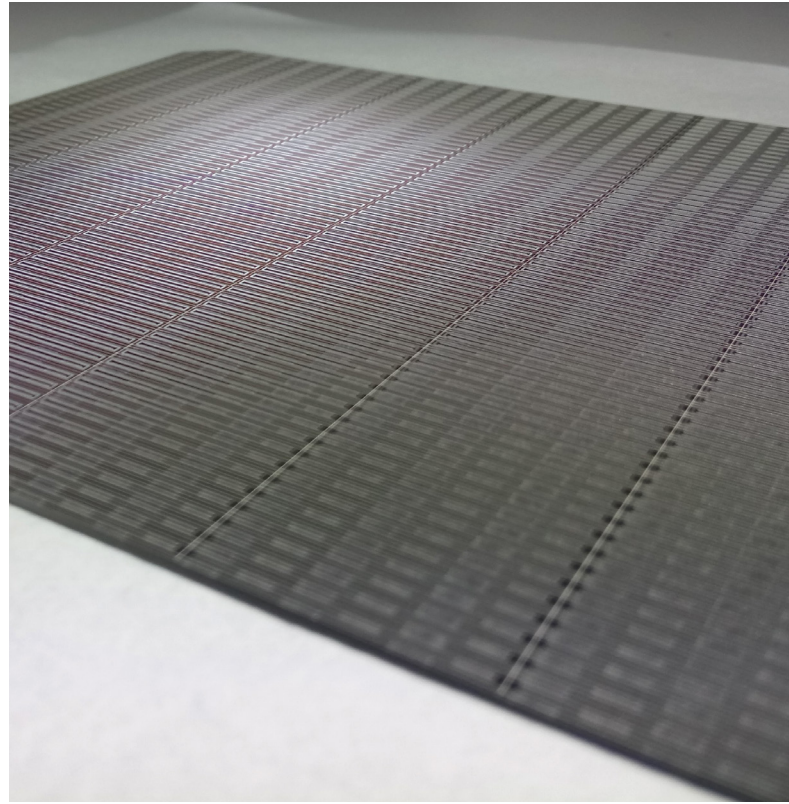
H2020

CORDIS FACTSHEET

cordis.europa.eu/project/rcn/205821

PROJECT WEBSITE

nextbase-project.eu/



© Kaining Ding



Silicon key to low-cost, ultra-efficient photovoltaics

Silicon photovoltaics (PV) are likely to dominate PV markets in the coming decades. An EU initiative wants to harness the potential of silicon in PV technology.



Together with a reduction in the consumption of silver and indium used in PV, and an improvement in the energy yield, DISC is contributing to making PV one of the cheapest electricity sources around.

The EU-funded [DISC](#) project addresses the need to reduce the consumption of fossil fuels by developing key technologies for the next generation of high-performance PV solar cells and modules.

The DISC approach “focuses on the only way to fully exploit the potential of silicon: using so-called passivating contacts or carrier-selective contacts and junctions, that is, contacts that allow the carrier to cross without recombination,” says coordinator Dr Byungsul Min. “Such contacts allow for simple device architecture, reduce silicon wafer thickness and enhance the energy yield – all key elements for achieving very low electricity costs with minimum environmental impact.” The team is evaluating the industrial feasibility of double-sided contacted solar cells with carrier-selective junctions (CSJs), optimised metallisation and transparent conductive oxides (TCOs).

based passivating contacts suffers significantly during the TCO deposition step. “As a result, the process step needs modifications to reduce the degradation of the passivation quality caused by sputter damage,” explains Dr Min. The DISC team has successfully evaluated TCOs with hydrogen additives as possible solutions.

Towards energy-efficient, affordable PVs

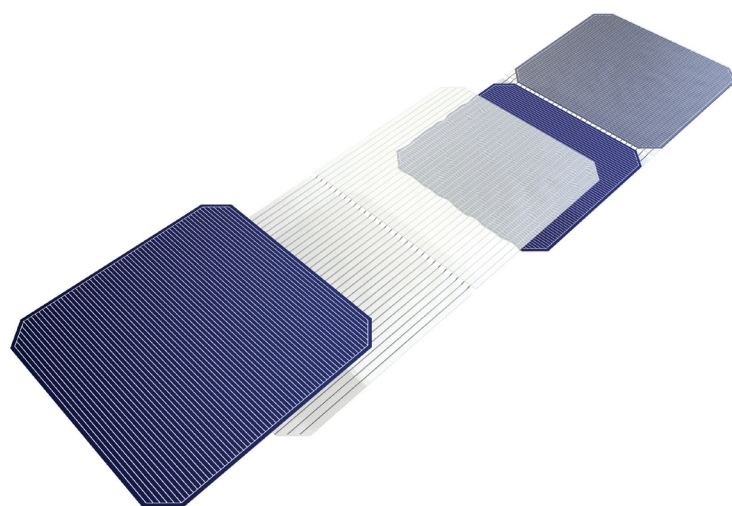
To enhance the viability and attractiveness of the PV prototypes, the researchers will assess their environmental, social and economic impacts and benefits across the entire value chain. They plan to extend the shelf life of the installations by improving the PV modules’ reliability and durability. By boosting the efficiency, reliability and durability of modules, solar-cell and PV-module producers should strengthen their market position.

Highly efficient PV cells and modules

Project partners are identifying and developing single components with the highest potential for significant advancements in CSJs, TCOs, metallisation subjects and final devices.

From a technological standpoint, DISC is targeting efficiencies that exceed 25.5 % on large-area cells and over 22 % for modules. A cell efficiency of up to 21.2 % has been obtained in the first common experiment. Dr Min calls the results for these ambitious targets ‘encouraging’.

A detailed characterisation and simulation study revealed that TCOs limit higher cell efficiency. This is because the excellent surface passivation quality of polycrystalline silicon-



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The project team will also demonstrate pilot manufacturing readiness at a competitive cost.

By obtaining high PV module efficiency, DISC aims to achieve a very low levelised cost of electricity (LCOE) in Europe. LCOE determines how much money needs to be made per unit of electricity to recover the system's lifetime costs. "Together with a reduction in the consumption of silver and indium used in PV, and an improvement in the energy yield, DISC is contributing to making PV one of the cheapest electricity sources around," concludes Dr Min. "We have an opportunity to mitigate the impact of climate change, improve energy access and reposition Europe at the forefront of PV technology."

PROJECT

DISC - Double side contacted cells with innovative carrier-selective contacts

COORDINATED BY

Institute for Solar Energy Research in Hamelin (ISFH)
in Germany

FUNDED UNDER

H2020

CORDIS FACTSHEET

cordis.europa.eu/project/rcn/205805

PROJECT WEBSITE

disc-project-h2020.eu/



Cutting-edge solar panel and cell technology to restore Europe's leading position in photovoltaics

The sustainability of photovoltaics (PVs) has rapidly improved in recent years, but the European PV manufacturing industry has been struggling to be competitive in the global arena. An EU initiative is looking to reverse this trend.

"The European PV industry can't fall behind; it must reclaim its market share to become a major player in the energy transition and address its energy independence," says Claudio Colletti, coordinator of the EU-funded [AMPERE](#) project. To tackle this issue, it's developing PV modules that are more efficient and reliable with a longer shelf life. "These modules will ensure high efficiency and energy production levels on the one hand, and low deterioration rates on the other."

To produce the PV bifacial silicon heterojunction technology (HJT) modules and solar cells, AMPERE is developing a sustainable, full-scale automated 200 MW manufacturing line. It will be set up for production in an industrial environment at one of the largest PV production plants in Europe based in Catania, Sicily. The factory will work on a continuous cycle, 24 hours a day, 365 days a year, and will produce about 1 400 PV panels a day, making about 500 000 a year.



© Claudio Colletti



A trailblazing PV-cell-and-module manufacturing plant

Team members are converting the Italian plant's silicon thin-film production line into a production line that can manufacture HJT modules and cells for greater cell efficiency and more PV module power. To do so, they have upgraded the obsolete technology facilities into an innovative industry 4.0 plant "that can be a springboard for a new network of PV manufacturing plants to be established in Europe," says Colletti.

Project partners created a new assembly line of monocrystalline cells for the production of the panels with bifacial architecture. They installed a new production line for HJT cells. The newly fabricated HJT solar modules are expected to enhance electricity production capacity by 15 % compared with the PV market mainstream technologies. This will lower the cost of produced electrical energy.

The manufacturing plant in Catania started production in summer 2019 with a ramp-up to full production capacity of 200 MWp/y. Many process developments are in the qualification phase and will be integrated into the manufacturing line. Reliability studies on materials and modules are underway and will be made available to the scientific community when complete. The main results of this first production phase will be presented at major industry conferences.

Our ultimate goal is to regain a competitive edge across the entire PV value chain, from materials to equipment and cell and module manufacturers, by developing innovative manufacturing solutions at a competitive cost for the European PV industry.

Powering up the European PV ecosystem

The AMPERE team is conducting a series of studies to validate the technical, economic and environmental sustainability of the new technology and the 200 MW production plant.

The viability of the technology in terms of throughput, reliability, costs, efficiency and project bankability will be demonstrated, showing the final products' potential for cost and performance competitiveness. "Our ultimate goal is to regain a competitive edge across the entire PV value chain, from materials to equipment and cell and module manufacturers, by developing innovative manufacturing solutions at a competitive cost for the European PV industry," concludes Colletti. "This should pave the way for the first factory in Europe capable of producing a gigawatt peak of electricity-generating capacity."

PROJECT

AMPERE - Automated photovoltaic cell and Module industrial Production to regain and secure European Renewable Energy market

COORDINATED BY

Enel Green Power S.p.A. in Italy

FUNDED UNDER

H2020

CORDIS FACTSHEET

cordis.europa.eu/project/rcn/209763

PROJECT WEBSITE

ampere-h2020.eu/



Scientists look to the Earth's crust to securely advance PV technology

Development of photovoltaic (PV) technologies free of critical raw materials is of high relevance for Europe. An EU-funded team is developing technology that avoids the use of all elements identified by the European Commission as critical raw materials.



© STARCELL

STARCELL was established to advance the development of a thin-film PV technology based exclusively on materials that are abundant in the Earth's crust. This is a critical undertaking, as

the main PV solutions available in the market contain at least one element that the European Commission regards as a high supply risk – i.e. a critical raw material. Indium is one such element, widely used in the semiconductor industry and the manufacture of coatings.

The project joins leading institutions in Europe that are at the forefront of the development of this technology. Together with partners from Japan and the United States, STARCELL is working “to identify and solve main fundamental problems that are currently limiting the conversion efficiency of the solar cell devices,” reports Dr Edgardo Saucedo, project coordinator.

Easing the shift to low-supply-risk materials

Targeted materials belong to a group of semiconductors generally called kesterite and formed by copper, zinc, tin, sulphur and selenium. These elements are considered to have low supply risk for Europe. Kesterite also presents very similar properties to another family of PV-relevant materials, the chalcopyrites. “This ensures that most of the factories producing Cu(In,Ga)(S,Se)_2 , the most relevant thin-film PV technology in Europe, can easily shift or complement their production with kesterite,” Dr Saucedo reveals.

STARCELL targets device efficiencies in the range of 15-18 %. “This is very challenging for these technologies,” the coordinator explains, “but very competitive, considering that kesterite is formed by relatively cheap materials, which can have a strong impact on cost reduction of the PV technologies.”

Challenges to conversion efficiency and limitations

Of all the results being obtained through STARCELL efforts, Dr Saucedo believes one of the most significant will be “the combination of materials modelling, customised synthesis and advanced characterisation to identify the main mechanisms that are limiting further progress in the conversion efficiency of the solar cell devices.”



Being fully free of critical raw materials, kesterite is compatible with the mass production of PV modules without any material constraints, reducing the supply risks for the industry.

Solutions based on doping and alloying strategies are also being applied with success. “This allows us to obtain quite reproducible efficiencies in the range of 11-13 % in the consortium by developing innovative solutions,” Dr Saucedo states. He adds that such advances also lay the ground for bringing kesterite towards technology readiness level 5 by the end of the project in 2019.

“There are many challenges still to solve in this very complex and fascinating material,” the coordinator goes on to say, noting that the main challenges are related to the understanding of the most relevant efficiency limitations. Notwithstanding, “all these challenges are under intensive research in STARCELL.”

Future impact

The STARCELL technology can have a long-term impact on consolidation of a strategic European PV industry. Dr Saucedo elaborates: “Being fully free of critical raw materials, kesterite is compatible with the mass production of PV modules without any material constraints, reducing the supply risks for the industry.”

It also promises benefits for Europe’s citizens. Access to a fully sustainable PV technology that can be completely produced in Europe will enhance energy security, create high-quality jobs, and help improve society’s perception of green energy production. Continuing project work also aims to “bring relevant insights for the future exploitation and commercialisation of the technology.”

PROJECT

STARCELL - Advanced strategies for substitution of critical raw materials in photovoltaics

COORDINATED BY

Catalonia Institute for Energy Research in Spain

FUNDED UNDER

H2020

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cordis.europa.eu/project/rcn/206577

PROJECT WEBSITE

starcell.eu/



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