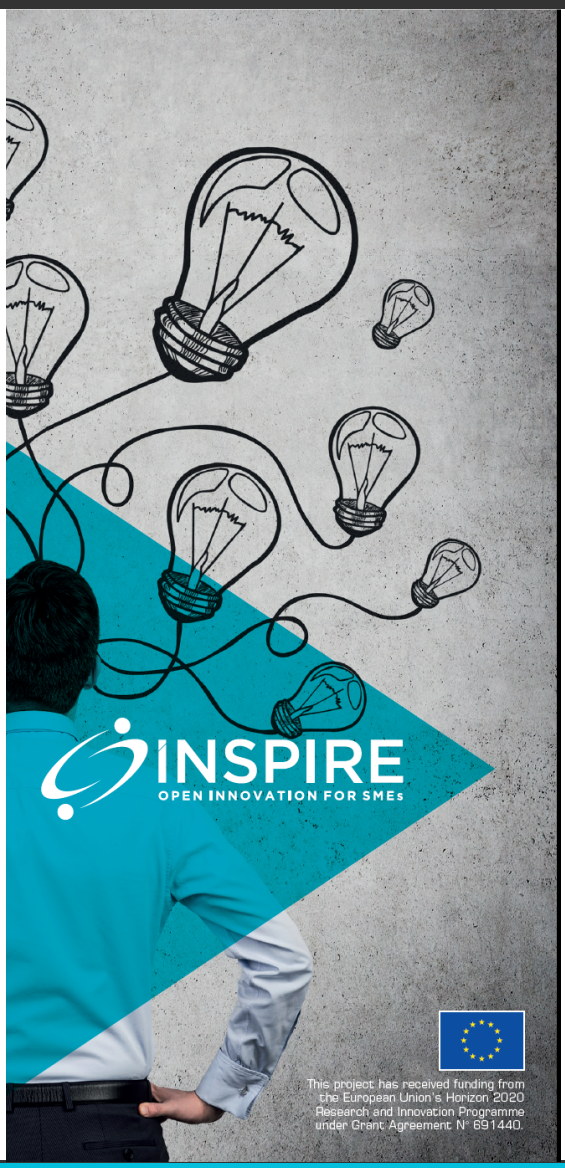

SAULE TECHNOLOGIES

Poland, www.sauletech.com

A research-based start-up founded by a Polish researcher and two entrepreneurs steer an intelligent path between intensifying their research efforts, developing a manufacturing prototype and testing applications of their technology in collaboration with relevant partners

Executive Summary

Saule Technologies was founded in 2014 to develop and commercialize an industrial production method of ultra-thin, elastic solar cells based on perovskites. The founders of the company are Olga Malinkiewicz, Piotr Krych and Artur Kupczunas. They had to address many challenges: finding investors; developing the manufacturing technology; finding suitable applications and partners.

CASE N°: EE01

SECTOR: RENEWABLE ENERGY

TECH INTENSITY: HIGH-TECH

LIFE CYCLE STAGE: START-UP

INNOVATION VECTORS: PRODUCT, PROCESS

OI PARTNERS: PSR, LARGE CORPORATION, OTHER SME, INDIVIDUAL EXPERTS, LEAD USERS/CUSTOMERS, PUBLIC SUPPORT ORGANIZATION

KEYWORDS: Photovoltaic cells, perovskites, business-oriented, research grant funding

- BACKGROUND FRAMEWORK
- INNOVATION CHALLENGE & MARKET OPPORTUNITIES
- OI TRAJECTORY
- BUSINESS IMPACT
- LESSONS LEARNED

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BACKGROUND

Olga Malinkiewicz, a PhD student studying photovoltaics, started researching perovskites at the University of Valencia in Spain. She saw the huge potential of the material for photovoltaics. By the end of 2013 Olga's work was published in Nature Photonics 2013, and she won a European student innovation prize in 2014 for coating flexible foil with perovskites. After that, investors were continuously asking her if she was going to start a company. By May 2014, she had moved from Spain to her native Poland, rented laboratory space in Wrocław and, together with two Polish entrepreneurs, Petr Krych and Artur Kupcziunas, established a company - Saule Technologies. In December 2014, Saule Technologies showcased the world's first printed perovskite.

In August 2015, the company received a government grant of 25 million PLN (~€ 6 million) from the National Centre for Research and Development (NCBR). In September 2015, Saule Technologies signed a 20 million PLN (~ €5 million) agreement for 25% of the shares with Hideo Sawada, a Japanese investor. Hideo Sawada, a leading Japanese entrepreneur, owns shares in several companies, mainly in the financial sector, energy, tourism / hospitality and transport. He is particularly interested in renewable energy sources and new technologies associated with them. The agreement with Saule Technologies is Sawada's second investment in a project related to renewable energy sources

In March 2016, the first prototype flexible perovskite photovoltaic cells were presented at the International Conference on Perovskite Thin Film Photovoltaics (ABXPV) in Barcelona. At the moment, the team is working on improving the design of the solar cells so that they can be directly incorporated into portable devices, such as smartphones or laptops, making them completely wireless. Currently, Saule Technologies is preparing a patent application for the perovskite production technology, and is looking for investors and business partners to finance its commercialization.

In the medium term, they want to start production of flexible perovskite PV cells, but they have also a collaborative project that is researching possibilities to integrate PV with electronics and sensors.

INNOVATION CHALLENGE & MARKET OPPORTUNITIES

The main challenge for perovskite solar cells is overcoming the competitive edge held by silicon-based panels which have fallen in price by more than 95% over the last decade. Another technical challenge to the perovskite solar cells is water: they decompose in it. Perovskite solar panels must therefore be totally watertight. A further drawback is their lifetime which must exceed 1 000 hours at 85% humidity and 85°C. Most of the cost of today's systems is in the protective glass and wiring. When all these costs are factored in, perov¬skites might save money only if they can overtake silicon in efficiency, if used as a replacement. Development is therefore costly and there is a need to find investors.

The other challenges are on application side. Which application, from many, to choose first?

Unlike silicon, perovskites are cheap to turn into cells. A perovskite cell can be made by mixing some chemical solutions and pouring the result onto a suitable backing, or by vaporizing precursor molecules and letting them condense onto such a backing. If these processes can be commercialized, silicon solar cells will have a serious rival. The combination of low cost and efficiency means that perovskite cells could, in theory, make solar power cheaper to generate. Perovskite-based solar cells can absorb light at a different spectrum range than silicon, and hybrid cells could surpass a 30% efficiency rate. There are also opportunities in niche applications, e.g. flexible PV cells for consumer electronics, cars, military and space applications.

OPEN INNOVATION TRAJECTORY

Concept development

Unlike other companies, Saule focuses on combining their inks with the foil, which is much more technically demanding, but also opens up a wider range of potential applications than simple deposits on glass. It also means a lower cost of production, assembly and transport. On the technical side, they decided not to pursue maximum PV efficiency in the laboratory setting, rather going for one acceptable to industry

(e.g.10%) and developing stable manufacturing. Their calculation was that efficiency could be increased later. On the application side, they look for where this combination has best value.

The development process, IPR and competition strategy

Saule's primary objective is to develop a scalable manufacturing process to deliver flexible and light-weight photovoltaic modules for a vast range of applications. The cost-effective technology employs inexpensive raw materials and ink-jet printing technology as an industrialization method. The technology invented by Olga Malinkiewicz involves a low temperature perovskite application onto PET foil to create a semi-transparent PV cell. The process involves digital ink-jet printing of perovskites in a vacuum-free process, spraying perovskite precursors onto adhesive backings. This allows the cells to be stuck onto any device that needs power.

Perovskites and electrodes and special ink are produced in their laboratory. In a laboratory environment, they have achieved 12% efficiency. The process may seem quite simple; however, it requires special laboratory conditions to make the foil effective. Now they are focusing on printing technology for industrial use. The printing technology is developed in-house with the support of undisclosed partners (under NDAs).

In terms of applications, many potential clients have expressed interest, including the Polish army and ESA. They have several partners with whom they develop applications – in the car industry, consumer electronics, space - to name a few (undisclosed). Saule Technologies is carefully selecting lead customers for application development (based on a business case evaluation). The first working prototype of the photovoltaic module can power devices like smartphones as when exposed to light, it provides enough power to charge up a phone battery. This can be the first commercial use of perovskite technology.

The development is capital-intensive. The first investors were the two entrepreneurs (still channelling cash from profitable ventures). They also found a public investment partner – the National Centre for Research and Development (NCBR), and Hideo Sawada, a Japanese investor. Then they could start their flagship project worth PLN 34 million (approximately €8.15 million).

Ultimately, the foil should resist for 20 years, while for the moment the firm has managed to achieve a product life-span of three years. To address that challenge, Saule Tecnologies initiated an EU research project PERLE (PERovskite Lifetime Enhancement Survey). The objective of the project is to prolong the lifetime of perovskite cells through modelling and synthesis of some types of perovskites (from a number of available types) to ensure their commercial use. The partners are: University of Mons (Belgium), Interuniversity Micro-Electronica Centrum (Belgium), Ecole Polytechnique Federale de Lausanne (EPFL, Switzerland), Consiglio Nazionale delle Ricerche (Italy), University of Würzburg (Germany), University of Linköping (Sweden), iCFO (Spain).

The original IP is shared between the University of Valencia and EPFL, while Saule Technologies is filing its own patents for the manufacturing process.

There are no competing solutions on the market yet. First, Saule Technologies is relying on their printing technology which they want, at least for a while, to keep proprietary. Secondly, Saule Technologies is entering the market with niche products, taking advantage of the printability and flexibility of printed PV cells, and their low cost. The company plans to develop the technology which can integrate perovskites with existing products. They select applications which are not feasible for silicon.

Commercialization and follow-up

Saule Technologies had to predict the difficulties of scaling up production in industrial conditions already at the laboratory stage. The solar cells will be printed onto foil in one-meter rolls. They also have to think how to respond to the needs of potential clients, because any change, after the project is finished, can be very expensive or difficult to introduce. Having a lab prototype is only 5% of effort and investment, according to Piotr Krych. They are not considering selling the technology licenses.

Currently, the company is working on a test production line and opening the second investment round, which will allow them to start mass production of perovskite cells on flexible foils. The company aims to produce panels with perovskite-based solar cells in 2017.

The company has an international team of some 30 people, most of them researchers and engineers. They plan to strengthen their marketing & sales team and have opened an office in Warsaw near the airport.

Saule's first markets will be in Europe and the US, while China will be more difficult to enter. They expect that their Japanese investor will help them to enter the Asian market, and a number of

meetings have already been arranged with potential customers. They are relying on lead customers developing applications for specific markets. Saule participates in conferences and fairs (e.g. Hannover Messe) and has many informal contacts. (For example, a businessman of Polish origin based in London introduced them to Hideo Sawada, the Japanese investor.)

Saule is part of a programme launched by the Polish Information and Foreign Investment Agency to provide individual support to Polish companies whose innovative projects have a chance to conquer the global market. The Agency is focusing primarily on start-ups and innovators with products or technologies which are ready for commercialization.

Saule Technologies is currently focusing on scaling up and entering the market with their first applications. At the same time, they are engaged in research for the future as well. They are involved in a collaborative project called Hypernodec (HYbrid PERovskites for NOvel DEvice Concepts) whose objective is to create conceptually new and potentially better electronic devices through a unique combination of piezoelectric, ferroelectric and semiconducting properties in a single type of material. Equipment based on metallo-organic perovskites may be ahead of today's solutions of data storage or production of electricity from e.g. waste heat. The project partners are CSIC – Consejo Superior de Investigaciones Cientificas, Spain; Linköping University, Sweden, University of Groningen, Netherlands and University of Valencia, Spain.

The company is also considering cooperation with a Barcelona-based research facility which has been working on developing technology for incorporating graphene into photovoltaics. Graphene would replace the material used to produce the electrodes applied in their photovoltaic cells.

BUSINESS IMPACT

Saule Technologies' open innovation approach has led to the filing of PV cells printing technology patents and the development of a prototype for their manufacturing technology.

Through this experience the company had learned how to find investors and select partners based on the value of the business case, i.e. carefully calculating prices, overheads, etc. before entering into an agreement. The management has developed a strong business orientation (a remarkable attitude for a research-driven start-up). For example they decided not to pursue further efficiency enhancement after reaching 12% (that was enough for many applications); instead, they decided to focus on scaling and manufacturing technology. Another example of their business sense is that they even considered rejecting a grant from regional government on the grounds that it might jeopardize their time-frame. Piotr Krych said that the company is oriented towards business, not grants. For the moment, the company is not making any revenues yet.

LESSONS LEARNED

The case reveals a rather typical situation of a technology start-up trying to commercialize its research results. Two tasks are carried out in parallel – development work and the search for investors (substantial investments are necessary for the development work). While chasing investors, they do not forget customers. The case is remarkable, because from the start the team included two experienced serial entrepreneurs which ensures a strong business orientation. What is interesting is the careful selection of applications and lead customers.

Main lessons learned:

1. Business rather than research orientation from the early days.
2. Product development should be oriented to an acceptable performance first. It has then to be tested on the market. Performance can always be improved later.
3. Partners should be carefully selected. They have to be business-oriented.
4. Not all investments are suitable.
5. First applications should be carefully selected - based on strategy and business impact.
6. Having a serial entrepreneur in the founder team is an asset.