PROJECT FINAL REPORT

Grant Agreement number: 303429

Project acronym: EVOLVE

Project title: Evolved materials and innovative design for high-performance, durable and reliable SOFC cell and stack

Funding Scheme: Collaborative project

Period covered: from the 1st of November 2012 to the 31st of January 2017

Name of the scientific representative of the project's coordinator[1], Title and Organisation:

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

Final publishable summary report

Executive Summary

Beyond the state of the art, the EVOLVE cell concept aims at combining the beneficial characteristics of the previous cell generations, the so called Anode Supported Cells (ASC) and Metals Supported Cells (MSC) while tackling key challenges like sulfur poisoning and redox stability, typical for state of art cells implementing nickel as electro-catalyst and structural component in the nickel / zirconia standard anodic cermet. The innovation of the EVOLVE cell concept remains in its anode compartment avoiding the use of pure nickel as structural component. The substrate, providing mechanical strength to the fuel cell is based on a robust metal alloy 3D porous backbone allowing the formation of a protective alumina layer enhancing stability during re-oxidation cycles and an electronic conducting material based on perovskite oxides.

An European consortium including academics and industrial partners with complementary backgrounds and expertise has been build up, and has been granted a financial support in 2011 by the Fuel Cells and Hydrogen Joint Understanding under the Grant Agreement n° 303429, for the development of the EVOLVE cell concept. The consortium EVOLVE included: the German Aerospace Center (Germany) assuming the leadership and the coordination, Alantum Europe GmbH (Germany), ARMINES (France), Ceramic Powder Technology AS (Norway), Consiglio Nazionale delle Ricerche (Italy), Institut Polytechnique de Grenoble (France), Saan Energi AB (Sweden) and Ceraco Ceramic Coating GmbH (Germany). The project ran from November 2012 until January 2017.

In a first step, set of materials were selected based on their physico-chemical properties and inter-compatibility for manufacturing a fuel cell. Namely a NiCrAl based metal foam provided by Alantum GmbH, as 3D metal alloy porous backbone, $La_{0,1}Sr_{0,9}TiO_{3-\delta}$, produced by CerPoTech AS, as electronic conducting material for the substrate and anodic electro-catalyst in combination with Gd doped ceria in the functional anode layer, yttria stabilized zirconia for the electrolyte, in combination with GDC as cathodic barrier layer and applied as thin film by EB PVD (Ceraco GmbH), and finally a LSCF based cathode.

Taking into consideration the properties of the material a specific modular manufacturing route was specifically designed for producing the EVOLVE cell. This route was divided into 5 consecutive modules consisting in 1) substrate manufacturing, 2) processing of anode functional layer (AFL) 3) Thin film Electrolyte Processing, 4) Cathode manufacturing, and 5) activation of the anode layer.

As level of electronic conductivity and electrocatalytic activity were limited, performance of the pure nickel free EVOLVE cells were limited to ca. 120 mW/cm² at 0.7V and 750°C with hydrogen as fuel. After the midterm evaluation of the project, it was thus decided to enhance the electronic conductivity in the substrate by replacing the LST material by a cermet LST-Ni (50:50), and boost the electro-catalytic activity of the anode functional layer by surface modification of the LST-CGO composite AFL with ca. 5 to 10wt % of nickel. With those modifications, the power density was increased up to 440 mW/cm² at 0.7V and 750°C with hydrogen as fuel. Comparable level of performance were achieved for cells built up on a standard ferritic stainless porous substrate, which confirmed the modularity of the processing route i.e. materials can be easily exchanged without redesigning a full manufacturing route.

The EVOLVE cell architecture with electrolyte thickness of less than 3µm could be successfully up-scaled to a size of 90 mm x 100 mm and could be successfully integrated into 1 cell stack, similarly to anode supported cells. The tested 1 cell stack achieved a power density up to 170 mW/cm² at 0.7V and 750°C with simulated syngas as fuel and air at the cathode. The stack could be successfully operated for more than 100 hours under constant current load. With less than 2% variation for 50 redox cycles, the Open Circuit Voltage

showed an excellent stability, demonstrating that thin film electrolytes maintain integrity despite the harsh conditions.
At that point, the feasibility of the EVOLVE cell architecture has been demonstrated at the stack level. Further work would require assembly and tests of short stack fur further assessment, as well as implementation of technological improvements in the cell to enhance performance and durability.
The modular approach developed in the project for the cell manufacturing showed very promising characteristics for a quick implementation of advanced materials in the cell design and the possibility to involve different actors and processes in the fabrication process, which contrast with centralized cell production that can be observed nowadays in Europe. This modularity of the manufacturing route provides huge potential in terms of cost reduction potential on the basis of the principle of best performance / cost ratio and the flexibility offered regarding the materials that can be implemented.

Summary description of project context and objectives

Emission of greenhouse gases (GHG) from industry, transportation and agriculture has played a major role in the recently observed global warming. In order to reduce the impact on environment, zero or near-zero emission energy systems, converting fuel efficiently into useful energy are increasingly investigated. Unprecedented rise in the fossil fuel prices has led to a growing economic concern towards the need of such energy systems. Additionally, geopolitical priority of reducing the dependence on foreign energy resources emphasizes the development of systems that may work with a variety of fuels and eventually with renewable energy resources such as hydrogen or bio-fuels.

Solid Oxide Fuel Cells (SOFCs) are one of the most attractive energy conversion devices, owing to the potential of operating at high efficiency of about 60% in standalone condition and over 80% (net) if waste heat is used for cogeneration. SOFCs do not require noble metals for catalysis in electrodes and may use a variety of fuels including hydrocarbons, CO and bio-fuels, besides hydrogen. These low-noise convertors thus offer very high potential in stationary application and combined heat and power units (CHP) for decentralized energy. Despite all the promising advantages and the unparalleled progress in its power output, SOFC faces critical challenges in term of its poor reliability, low durability and higher cost. Unless addressed meticulously, these obstacles will impede large-scale commercialization of fuel cells. **Reliability and durability are adversely affected by a number of factors of which the following two can be considered as the route cause: 1) high operating temperatures (800-1000°C) of SOFC and 2) the need to use materials that provide multiple functionalities.** This includes structural support, electrochemical activity, and electrical or ionic conduction, as well as at the same time compatibility with neighbouring components during the manufacturing process and fuel cell operation. This has so far made an optimization of each individual functionality impossible.

Improving the anode compartment of the SOFC can address several issues of cell degradation in static and cyclic conditions including: Ni coalescence and agglomeration, carbon and sulphur tolerance, robustness of the cell during thermal and redox cycling. We propose to split the functionality of anode materials, thus relaxing the stringent materials demands and opening the way for these necessary improvements. **This project focuses on an innovative concept for SOFC, particularly for the anode compartment, incorporating advanced materials with an approach in which each material performs only one functionality and aims at cell operation at reduced temperature of 750 °C.** This concept, which has led to a patent application[2], is expected to enhance the durability and reliability of SOFC while exhibiting performance level equivalent to

[2] A. Ansar, R. Costa, "Composite current collector supported cell" Patent pending.

main-stream anode-supported cells. The scope of the project aligns itself with the objectives set in the call under the topic of SP1-JTI-FCH.2011.3.1. It is thus targeted:

-to reduce the amount of Nickel in the anodic substrate also called current collector,

-to replace Nickel within the Anode Functional Layer by a composite LST ($La_{(1-x)}Sr_xTiO_{3-x}$)-GDC modified by catalysts

The main objectives of EVOLVE are:

- the demonstration at the stack level of a SOFC implementing an innovative substrate resilient toward redox cycles with higher durability than mainstreams Metal Supported Cells implementing porous ferritic stainless steel substrates and cyclability than mainstreams anode supported cells implementing the Ni based cermet.

- the identification of innovative combinations of advanced materials with reduced amount of nickel, showing improved tolerance against sulphur poisoning compared to mainstreams nickel based cermet Anode and higher resilience toward redox cycles.

The cell, represented schematically, will consist of functional layers supported on an innovative anode current collector. This current collector will be a ceramic metal composite in form of metallic foams, between 0.6 and 1 mm in thickness, impregnated with conductive ceramics. In the current collector, no Ni particles will appear as structural component or for current collection. Because percolation of Ni is not necessary in the new concept, the nuisance of Ni coalescence and redox failure in state-of-the-art cells will be avoided. The metallic foam will be of an alloy composition that can form a thin continuous stable oxide layer of Al_2O_3. The main advantage of this oxide is in its thermal stability and its ability to slow down the oxidation kinetics of the underlying metal in case of exposure to oxidant environment. Al_2O_3-forming alloys are therefore significantly more durable compared to Cr-forming alloys at elevated temperatures. Metallic foams will be first anodized in order to form a continuous thin protective layer of Al_2O_3. The metallic component will provide a robust structural integrity of the cell whereas thin alumina scale will enhance its chemically stability under cell fabrication and operating conditions. This formation of Al_2O_3 will, however, render the metal foam electronically non-conductive (or poorly conductive). The backbone of oxidized metal foam will therefore be impregnated with conductive ceramics such as LST ($La_{(1-x)}Sr_xTiO_{3-x}$), which will lead to a percolating phase of electron conductor. In this manner, the mechanical and chemical stability will be attained by oxidized metallic foam whereas the electronic (and ionic) conductivity will be guaranteed by the impregnated ceramic. Using doctor blade method or a modified screen printing technique the ink will be then pushed into the upper surface to create a very low roughness topography on which functional layers can be produced. An anode layer of 10 to 30 µm in thickness and composed of LST-GDC will then be coated on top of the impregnated foam by colloidal suspension spraying or screen printing (this layer will be infiltrated with catalyst in the final stage). A thin electrolyte layer of YSZ (thickness between 1 to 5 µm) will be coated using fine-grain-sized powder in order to decrease the sintering temperature below the upper limit of the stability of the metal substrate. The half-cell will be sintered. GDC of 0.1 to 0.5 µm in thickness will be deposited on top of zirconia electrolyte as diffusion barrier layer. A 15 to 30 µm thick cathode, based on LSCF, will be finally coated on top of the interlayer. At the last stage, suitable catalysts such as Co, Ni will be infiltrated (in restricted quantity) within the electrodes as salts before integration and testing of cells.

The objectives of the project will be targeted by correlating in detail the manufacturing processes for different cell components with their microstructure and with the electrochemical performance of electrodes.

The latter two will be undertaken by sophisticated experimental tools and by modelling approaches. 3D-microstructural analyses coupled with microstructural and electrochemical modelling will be extensively employed to generate an effective map of process-microstructure-performance relationships. Based on this map, the optimal cells will be produced – split into intermediate milestones defined in the work packages. The processes considered for the electrode layers are colloidal spraying, screen printing and suspensions plasma spraying. In the case of the electrolyte, the ultra-thin layer of thickness of 1 to 5 µm, assisting in reducing the ohmic ASR of the cell, will be coated by colloidal spraying or sol-gel techniques. The degradation of the cell will be targeted by introducing a two-way strategy: 1) the fuel tolerance of the anode will be targeted by incorporating materials reported to have better tolerance against coking and sulphur poisoning such as LST along with dispersed nickel. Doped cerium oxide will be added by infiltration techniques in the ceramic matrix of anode to further enhance carbon and sulphur tolerance. These materials will be tested in carbon and sulphur containing fuel gases. 2) Lower operating temperature of 750 °C will be considered as high operating temperature is one of the major causes of the degradation. 750 °C is opted to maintain a respectable performance level of the cell and to avoid enhanced sensitivity against carbon and sulphur. On the cathode side, LSCF-CGO composite cathodes will be produced after depositing an electron beam physical vapour deposition (EB-PVD) barrier layer of CGO on the zirconia-based electrolyte. Alternatively nickelate based cathode materials that do not react readily with the zirconia based electrolyte will be exploited. Besides, 3D analysis and modelling will be utilized to optimize the microstructure of electrodes leading to lowest degradation and highest performance. The tolerance of the SOFC in transient conditions (thermal and redox) will be improved by avoiding Ni as the structural component. Instead, the structural stability will be given by the metallic foam forming a stable and protective thin oxide layer (Al_2O_3) at elevated temperature. Redox cycling is thus expected not to introduce stresses in the cell. The performance criteria will be still fulfilled by the ceramic current collector impregnated within the substrate, like LST. However, it needs to be confirmed if LST loose conductivity during reducing and oxidizing cycles. Resistance against thermal cycling will be enhanced by adjusting precisely the coefficient of thermal expansion (CTE) the components. This will be done by adopting the stoichiometry of perovskite materials and adjusting the volume percentage of different phases in the anode. The process development for the functional layers will be again based on modelling to recommend the appropriate microstructure of layers to reduce the risks of failure under transient conditions. The developed cell will be up-scaled to industrially relevant size of a footprint of around 100 cm² and will be integrated into stacks.

Main S&T results/foregrounds

Reference materials for the anodic compartment, namely $La_{0,1}Sr_{0,9}TiO_{3-\alpha}$ (LST) as anode material was synthesized and successfully combined with a metal foam based on the NiCrAl alloy for manufacturing the current collector (Figure 1).

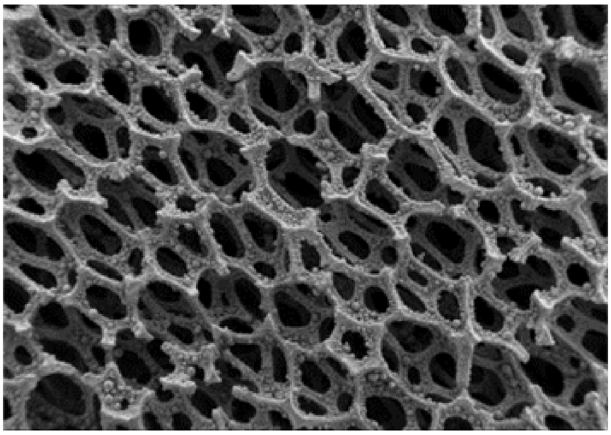

Figure 1 NiCrAl foam from Alatum GmbH showing a cell size of 450µm.

A first prototype has been developed using the Plasma Spraying technique for electrolyte deposition, $La_{0,1}Sr_{0,9}TiO_{3-\alpha}$ (LST) as reference material (Figure 2) for the anode and the cermet NiCrAl / LST as current collector. Implemented in full cell with a LSM based cathode and thick YSZ electrolyte (ca. 100µm) to achieve sufficient gas tightness, the performance of the first prototype was limited to 30mW/cm² at 750°C but remarkably stable over a period of time of 180h in tested conditions. As a further development step an approach using thin film electrolyte has been developed aiming at reducing the cell polarization.

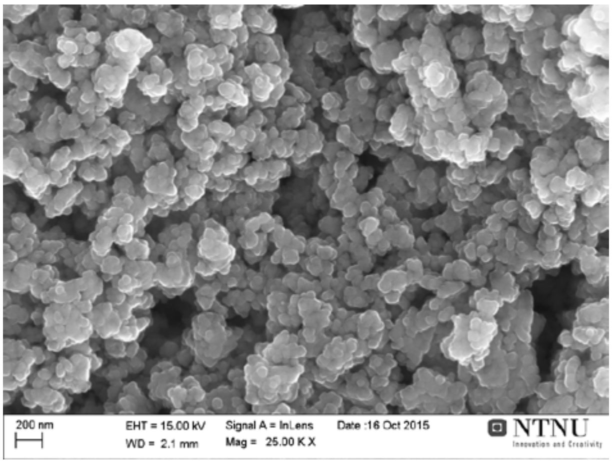

Figure 2 : SEM image of the LST powder produced by CerPoTech.

The dip-coated YSZ layer and the EB-PVD GDC layer have been homogenously deposited on top of the LST-GDC anode layer. The thickness of the calcined LST-GDC anode layer is about 20 µm. The thickness of the thin-film YSZ layer and the gas-tight GDC layer was approximately 1 µm and 2 µm, respectively. With the homogenous YSZ layer and the dense GDC layer, some of the produced half cells realized excellent gas-tightness. Despite the extremely thin electrolyte, button cells with size up to 25 cm² were produced showing an air leakage rate down to $7.0*10^{-4}$ $(hPa*dm^3)/(s*cm^2)$. Full cells with LSCF cathodes were produced for further electrochemically tests. It is interesting to mention that a yield of 100% was obtained on the last produced batch. This demonstrates the reliability of the coating approach for producing the electrolyte. However, it must be mentioned, that co-firing the half cells at elevated temperature (1000 ^{o}C) in air, the leak rate of the cells increase significantly due to the structural changes in the bi-layer electrolyte. Further work needs to be performed to stabilize the microstructure and avoid degradation of leak-rate in case of thermal ageing. It was found that the success rate of the thin film deposition approach is largely dominated by the density of macroscopic defects (>200nm in size) in the underlying layers.

By reducing electrolyte thickness down to 3 µm in total, the performance of EVOLVE cells could be increased to about 100 mW /cm² at 750°C and 0,7V. From the electrochemical investigation, it resulted that high ohmic resistance coupled with high polarization resistance were jointly responsible for the moderate level of performance achieved. Posttest analysis of the electrolyte revealed the presence of cobalt in the porous YSZ supporting layer and originating from the cathode. For this reason, an additional dense YSZ layer produced by EB-PVD was incorporated in the multi-layer structure of the electrolyte between the porous YSZ layer and the dense and gas tight GDC layer.

In this first nickel free prototype, Electronic conductivity of the LST was evaluated below 10 S/cm^{-1} at our operating conditions which makes questionable its relevance for use as current collector. For this reason, it was considered to incorporate Nickel (up to 57wt % of NiO in the slurry) both in the current collector and as catalytic material in the functional anode layer (between 5 to 10 wt%).

By modifying the original concept with further addition of Ni within the current collector – for enhancing the electronic conductivity – and in the functional anode layer – for enhancing the electro-catalytic behavior – a power density of 340 mW/cm² at 750 °C and 0.7 V is demonstrated. Further modification of substrate consisting in the addition of pore former led to an increase of power density up to 440 mW / cm² at 750 °C at 0.7 V. This corresponds to an increase of performance of about 30 % at reference voltage compared to previous generation. The implementation of a 0,5µm thick Yttria stabilized zirconia layer by PVD in the multi layered structure of the electrolyte impacted positively the Open Circuit Voltage of the cell, and durability of the performance. The precise quantification of its impact on Open Circuit Voltage remains nonetheless difficult to quantify exactly as this parameter still remains highly sensitive to density of defects in the electrolyte. The same performance level was achieved by transferring the functional layers - Anode functional layer, Electrolyte and Cathode – on a porous ferritic stainless steel substrate with the same manufacturing route. This result highlighted the modularity of the processing route and its compatibility with other substrate. This provides evidence that a modular manufacturing of the cell is possible with possibility to exchange elementary components without having to redesign a manufacturing route. The redox tolerance was assessed by exposing for 30mn the anode functional layer to a stream of pure oxygen. With less than 2% variation for 50 cycles, the Open Circuit Voltage showed and excellent stability as a function of redox cycles, demonstrating that thin film electrolyte maintain integrity. Electrochemical measurements were performed on two cells by adding 5 ppm H_2S at the anode side at 750 °C. Operating the EVOLVE cell with 5 ppm H_2S did not result in significant decrease of performances for both cells. During sulfur exposure, nickel free cell showed better performances but a higher degradation rate was recorded during recovery. On the other side, only a small continuous performance drop was recorded on cell modified with nickel. Though the reason are not yet clearly understood, this result clearly indicates that modifying the original concept of the EVOLVE cell by introducing nickel is beneficial to operate in harsh conditions.

Advanced contact materials for the air side in SOC stacks were investigated. They consist in flexible and inexpensive metal foams produced by Alantum GmbH, able to be converted into an electronic conductive oxide when exposed to air at high temperature. CoNi based metal foams were tested as contact material for the air side for more than 1000 hours of operation and showed very promising performance: No quantifiable performance loss could be attributed to the contact degradation. This material was considered for stack integration in the EVOLVE project, nonetheless considering the importance of the commissioning of the foam to achieve his full function and the time constraints of the project, this solution could not be implemented within the project. This material provide nonetheless huge potential in terms of performance/cost ratio for the future, in comparison with the main stream contact solution based on ceramic pastes.The EVOLVE cell architecture could be successfully up-scaled to a size of 90 mm x 100 mm (Figure 3) and could be successfully integrated into 1 cell stack (Figure 4). The tested 1 cell stack could show a power density up to 170 mW/cm² at 0,7V and 750°C with simulated syngas as fuel at the anode and air at the cathode. The stack could be successfully operated for more than 100 hours under constant current load. At that point, the feasibility of the EVOLVE cell architecture at the stack level. Further work would require assembly and tests of short stack fur further assessment, as well as implementation of technological improvements in the cell.

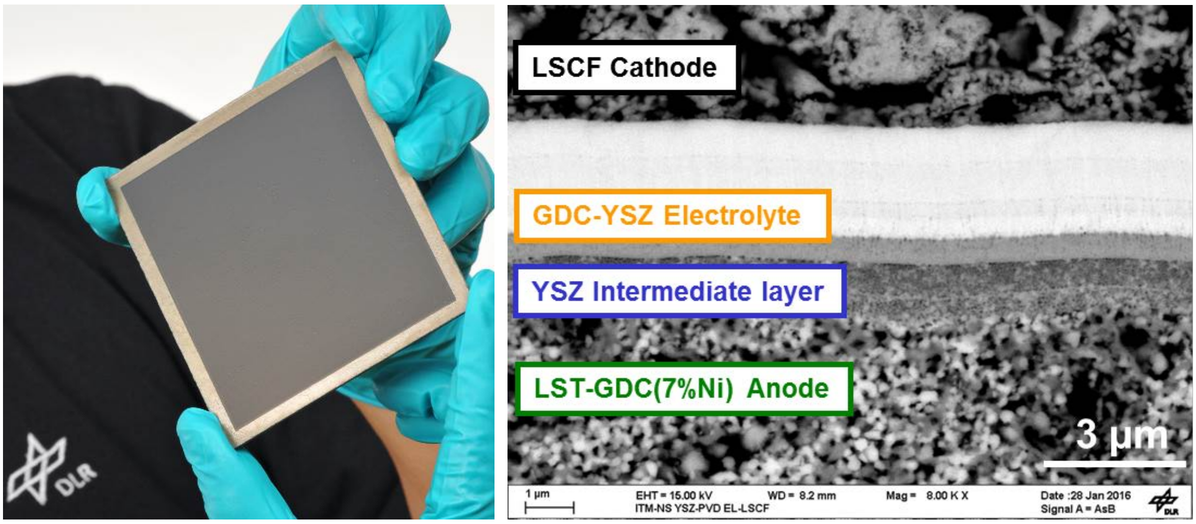

Figure 3 Evolve cell for stack assembly (left), SEM cross section (right)

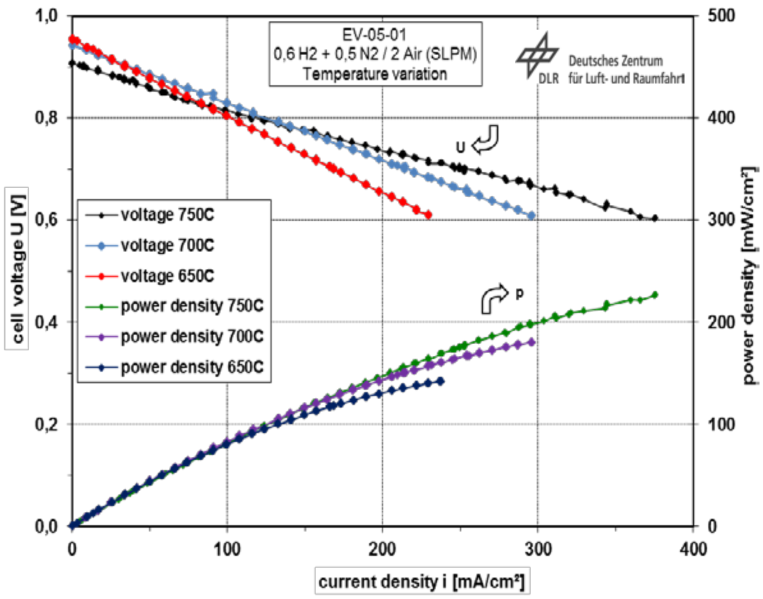

Figure 4 i-V characteristic of a 1 level stack at different temperature

At current technology, extrapolated to large scale production (ca. 10 MW/year) the cost for cells at stack level is estimated below 2500 € / kW, with perspective to reduce well below 1000 € / kW. The main cost drivers being the yield mainly governed by the surface quality of the substrate, the cost of the substrate itself and manufacturing of the electrolyte layer. Performance increase through further component improvement as well as automation of the PVD process might bring the cost down to a value comparable to the cost estimation of other competing ceramic cell architecture like ASCs.

Respect to the manufacturing route, the production of the substrate with a smooth surface remains the key challenge for the successful manufacturing of complete cell. The yield in terms of manufacturing for the stackable cells was around 21% for the premium quality. Improvement in terms of quality and performance could be achieved through implementation of a rationalized manufacturing route. It appears from modeling and experimental work that, with the current set of materials, there is an upper temperature limit above which keeping flatness of the substrate is difficult. This upper limit ranges between 1000°C and 1100°. Therefore it is important to design a rational and smart manufacturing route at low to mild temperature to produce the cells. The production of an advanced metallic substrate with tope pore size below 30µm would be highly advantageous for manufacturing at higher yield the cell.

The extended testing at operating conditions, including redox and thermal cycling has shown excellent stability of the composite EVOLVE substrate consisting in a mixture of LST and NiO infiltrated in a NiCrAl foam structure. The structure seems unaffected by testing and conductivity of the substrate is not deteriorated. Contacting also did not appear as a critical issue. Nonetheless the evolution of the interface with the bi-polar plate is subject to caution as an oxide scale growth was noticed when contact with CroFer 22 APU was used as interconnect material. The protection against corrosion of the steel surface even at the fuel electrode appears meaningful.

The manufacturing route was divided into module for each elementary component of the cell. The maximal firing and sintering temperature achieved overall did not exceed 1000°C, and were always performed in air atmosphere which contrast significantly with the usual hydrogen atmosphere used in the processing of standard metal supported cells. This modular approach of cell manufacturing route is expected to provide subsequent advantages for future development, by offering a huge flexibility in terms of used materials. This allows the implementation of optimized materials designed for specific application, the reduction of the lead time to implement new advanced materials. Furthermore this provides significant possibility for cost reduction by offering flexibility in the coating technology to be used.

Among several improvement routes, one could list following guidelines to improve durability and performance of cells:

- Stabilizing the interface between the ionic conductors in the multi-layer electrolyte, especially from the nano-porous supporting layer. This could be performed by increasing the gap between the manufacturing temperature (annealing, PVD deposition) and the operating temperature. Use of sol-gel process might be beneficial to stabilize the microstructure.

- Enhancing contact of the cathode with the electrolyte, by sintering the cathode at low temperature. The activation of the surface of the electrolyte by plasma etching showed improvement of the adhesion of the cathode and deserves further improvement.

- The set of electro-catalysts to be used as functional anode material is still subject to improvement as infiltrated nickel and $La_{0,1}Sr_{0,9}TiO_{3-\alpha}$ are known to react under certain conditions with each other which hinder the performance. Pd could be an alternative.

4.1 Use and dissemination of foreground

During the project, results were disseminated via 4 peer reviewed article and 44 actions of dissemination including presentation and posters at conferences, mostly with international public, and industrial fair like the Hannover Fair. Those are reported in template B2. This count reflect the actions undertaken by the consortium at the date of April 2017, and does not include future publication and dissemination action which may come in the near future based on the foreground generated by the project EVOLVE. Beside this specific dissemination of knowledge, the foreground generated by the partners in general and the industrial partner in particular is described in the section B here after.

- Section B

Alantum plans to produce and supply advanced foam structures.
The NiCrAl alloy foam, which is used in the project, shows sufficient durability, especially with respect to oxidation resistance and might be used in other applications ie. for methane steam reforming. Therefore Alantum is in exchange with major companies from the chemical and petrochemical industry to evaluate the use of foam as a catalyst carrier. In case of successful development the production of metal foams in Europe is being favored.

Cerpotech is ready to commercialize LST powders using the protocols developed and optimized in the frame of this project. The LST powder has already been added to Cerpotech portfolio and is available for purchase through website and upon inquiry. Upon successful outcomes of this project, sales of small to medium size batches (up to 20kg) for R&D projects by industrial customers are envisioned for prototype and pilot-scale demonstration. However, upon validation of the new technology and full commercial application, production protocols for batches of more than 100 kg would require further adjustments, qualification and certification.

As thin film manufacturer Ceraco could demonstrate in the frame of the project that our deposition technology - initially developed for high temperature superconductor thin films - can also be used for growth of oxide functional layers in the field of SOFC. This opens a completely new market to Ceraco.
A patent has been filed together with partners from DLR Stuttgart to protect the invention that has been made in the project.
As part of the EVOLVE consortium, Ceraco became visible to companies and institutes working on fuel cells and power-to-gas applications, a research field to which our company had no connections so far.
Due to the positive results achieved in EVOLVE, contacts with SOFC manufacturers like Solid Power, Italy, have already been established.
In the near future Ceraco expects to participate in research projects to further optimize SOFCs or related components with thin film electrolyte layers based on the experience made in EVOLVE. Such funded work will help to develop the thin-film based devices to be ready for the market.
In the medium-term Ceraco´s plan is to utilize the gained know-how for the set-up of a pilot line using PVD coatings for SOFCs together with selected partners.

Thanks to EVOLVE project, Saan Energi has been successful in progressing its know-how and product portfolio and clear value propositions and market positioning could be attained. Some of the key products and components and know-how that Saan Energi could develop in the project include:

- Water based inks consisting of conventional and new materials for SOFCs suitable for dip coating, impregnation and tape casting such as inks of yttrium stabilized zirconia (YSZ), inks of YSZ + NiO, inks of Lanthanum Strontium Titanate (LST) and inks of LST+NiO. Such water based inks are much challenging to develop compared to organic solvent based inks but have clear advantage of lower cost and environmental impact.

- New up-scaled industrial relevant sized substrates combining novel architecture and materials. These substrates consist of metals frame work with impregnated (using water based inks) ceramics can be tailored to offer unique combination of functionalities of conductivity, gas permeability and high temperature stability and can attain desired performance in operating condition.
- New cathode side protective coatings for interconnect plates with promising results
- Improved processing to produce half cells (anode functional layer and electrolyte) produced by thermal spraying – the method was not developed in the later part of the project but led to exploitable know-how development
- Lastly, sintered based conventional anode supported cells were developed in the initial phase of the project. Though the approach was no longer used in the project and is not a product offered today, the work led to know-how development

These developments have assisted in enhancing our market competitiveness which has already started to translate in better market visibility, and increased exchange with potential customers. These are encouraging outcomes for a young SME. Still, more work is needed to conclude on this progress through follow-up projects which will cement market positioning.

In the frame of EVOLVE, DLR acted as the main architecture developer of the concept and developed specific know how for the manufacturing of the full EVOLVE cell based on components delivered by CerPotech (Powder), Alantum (Foam) and Ceraco (PVD coating for the Electrolyte). Based on the knowledge generated by the project and the results obtained at stack level, DLR is currently evaluating to set a follow up project in partnership with industry partner to further develop a MSC technology based on the know how generated within EVOLVE. This project would aim at establishing a full scale prototype of stack in the sub-kW range which can compete in terms of cost/performance ratio with state of art technology and evaluating different market possibility, mainly propulsion for aircraft or stationary application. When successful, the creation of a spin-off will be considered to valorise the established technology, by involving the department of the technology marketing from DLR which help the establishment of spin-off and pilot line.

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[3]:	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		EP3022789	A FUEL CELL AND A SUPPORT LAYER THEREFORE	*A. Ansar,* SAAN ENERGI
Patent	YES		DE102016112125.8	„Verfahren zur	*F.Han, R. Costa,* DLR (60%)*, R. Semerad,* Ceraco

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

				Herstellung eines Festelektrolyts, Festelektrolyt- und Festoxidbrennstoffzelle“	(40%)

Part B2

Type of Exploitable Foreground[4]	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[5]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D resutls	*optimised LST powder*	*NO*	*n/a*	*SOFC*	*Energy*	*2018*	*n/a*	*Cerpotech (owner)*
Know-how on EVOLVE cell and stack	*Cell technology*	*YES*	n/a	*SOC cell and stack*	*Energy*	***2022-2025***	Patent of the EVOLVE substrate concept Patent of the Thin film Electrolyte	***DLR (**Owner) Ceraco (co-owner of one patent) Alantum (possible component supplier) CerPoTech (possible powder supplier)

[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.
[5] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Section A (public)

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[6] (if available)	Is/Will open access[7] provided to this publication?
1	Towards understanding surface chemistry and electrochemistry of $La_{0.1}Sr_{0.9}TiO_{3-a}$ based solid oxide fuel cell anodes	Vitaliy Yurkiv, Guillaume Constantin, Aitor Hornes, Angela Gondolini, Elisa Mercadelli, Alessandra Sanson, Laurent Dessemond, Rémi Costa	Journal of Power Sources	287	*Elsevier*	*Amsterdam, Netherlands*	2015	p. 58-67	10.1016/j.jpowsour.2015.04.039	no
2	Fourier based schemes with modified Green operator for computing the electrical response of heterogeneous media with accurate local fields	F. Willot, B. Abdallah, Y.P. Pellegrini	International Journal for Numerical Methods in Engineering	98 (7)	*Wiley*	*Hoboken, New Jersey, USA*	2014	p. 518 -533	10.1002/nme.4641	no
3	Stokes flow through a	B. Abdallah, F.	Transport	109(3)	*Springer*	*Berlin,*	2015	p. 711-726	10.1007/s11242-	no

[6] 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).
[7] 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.

	Boolean model of spheres: Representative volume element	Willot, D. Jeulin	in Porous Media			*Germany*			015-0545-2	
4	On the manufacturing of low temperature activated $Sr_{0.9}La_{0.1}TiO_{3-\delta}$-$Ce_{1-x}Gd_xO_{2-\delta}$ anodes for solid oxide fuel cell	A.Gondolini, E. Mercadelli, G. Constantin, L. Dessemond, V. Yurkiv, R. Costa and A. Sanson	Journal of the European Ceramic Society	Accepted (July 2017)	*Elsevier*	*Amsterdam, Netherlands*	Accepted for publication (July 2017)	Accepted for publication (July 2017)	10.1016/j.jeurceramsoc.2017.07.035	no
5	The Permeability of Boolean Sets of Cylinders	F. Willot, B. Abdallah, D. Jeulin	Oil & Gas Science and Technology – Rev. IFP Energies nouvelles	71(4)	*IFP Energies nouvelles*	*Rueil-Malmaison, France*	2016		10.2516/ogst/2016003	yes
6	Evolved Materials and Innovative Design for High Performance, Durable and Reliable SOFC Cell and Stack Presentation and Status of the European Project EVOLVE	R. Costa, A. Ansar	ECS Transactions	Vol. 57/Issue 1	*The Electrochemical Society*	*United States*	2013	533-541	10.1149/05701.0533ecst	no
7	Beyond the 3rd Generation of Planar SOFC: Development of Metal Foam Supported Cells with Thin Film Electrolyte	F. Han, R. Semerad, G. Constantin, L. Dessemond, R. Costa	ECS Transactions	Vol. 68/Issue 1	*The Electrochemical Society*	*United States*	2015	1889-1896	10.1149/06801.1889ecst	no
8	Evaluation of Performance and Degradation Profiles of a Metal Supported Solid Oxide Fuel Cell under Electrolysis Operation	Aziz Nechache, Feng Han, Robert Semerad, Guenter Schiller, Rémi Costa	ECS Transactions	Vol. 78/Issue 1	*The Electrochemical Society*	*United States*	2017	3039-3047	10.1149/07801.3039ecst	no
9	Evaluation of the Influence of Nickel	V. Yurkiv, G. Constantin, A.	ECS Transactio	Vol. 68/Issue	*The Electroche*	*United States*	2015	1517-1526	10.1149/06801.1517ecst	no

	Addition on LST-CGO Based Solid Oxide Fuel Cell Anodes Performance	Gondolini, E. Mercadelli, A. Sanson, L. Dessemond, R. Costa	ns	1	*mical Society*					
10	Modelling and Prediction of Deformation during Sintering of a Metal Foam Based SOFC (EVOLVE)	M. Xu, D. Masson, D. Ryckelynck, A. Chesnaud, A. Thorel	ECS Transactions	Vol. 68/Issue 1	*The Electrochemical Society*	*United States*	2015	2971-2980	10.1149/06801.2971ecst	no
11	Morphological Modelling of a Metal Foam Supported SOFC Configuration	D. Masson, B. Abdallah, F. Willot, D. Jeulin, E. Mercadelli, A. Sanson, A. Chesnaud, A. Thorel	ECS Transactions	Vol. 68/Issue 1	*The Electrochemical Society*	*United States*	2015	2951-2960	2951-2960	no
12	Performances and Limitations of Metal Supported Cells with Strontium Titanate based Fuel Electrode	R.Costa, F. Han, P. Szabo, V. Yurkiv□, R. Semerad, S.K. Cheah, L. Dessemond	Fuel cells	Submitted (June 2017)	*Wiley*	*Weinheim, Germany*	Submitted (June 2017)	Submitted (June 2017)	Submitted (June 2017)	no

This table reflect the status of published or submitted publication at the date of August 2017 and does not consider publication to be submitted in the future based on the foreground generated by the project EVOLVE.

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[8]	Main leader	Title	Date/Period	Place	Type of audience[9]	Size of audience	Countries addressed
1	Presentation	D. Masson, A. Chesnaud, A. Thorel	GDR PACS-ACTHYF	May 13 – 16, 2013	Montpellier, France	*Scientific Community*		France
2	Poster	D. Masson, A. Chesnaud, A. Thorel	Symposium "L'énergie demain"	May 30 – 31, 2013	Paris, France	*Scientific Community + Industry*		France
3	Presentation	R. Costa, A. Ansar	SOFC XIII	October 6 – 11, 2013	Okinawa, Japan	*Scientific Community*		international
4	Poster	R. Costa	EFC Technology & Applications Piero Lunghi Conference. Side Event: Dissemination of European Projects	December 11 – 13, 2013	Rome, Italy	*Scientific Community*		international
5	Presentation	B. Abdallah, F. Willot,	11th German	March 4 – 7, 2014	Ulm,	*Scientific Community*		international

8 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.

9 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).

		D. Jeulin	Probability and Statistics Days		Germany			
6	Presentation	R. Costa	Metal Supported Cells Development	May 22, 2014	Bordeaux, France	*Scientific Community* *+ Industry*		international
7	Presentation	G. Syvertsen-Wiig, S. Weber, M.L. Tarot, R.A. Strøm	Metal Supported Cells Development	May 22, 2014	Bordeaux, France	*Scientific Community* *+ Industry*		international
8	Poster	S. Presto, F. Perrozzi, G. Canu, M. T. Buscaglia, V. Buscaglia, M. Viviani	Electroceramics XIV	June 16 – 20, 2014	Bucharest, Romania	*Scientific Community*		international
9	Presentation	F. Han, R. Semerad, R. Costa	11th European SOFC & SOE Forum 2014	July 1 – 4, 2014	Lucerne, Switzerland	*Scientific Community*		international
10	Poster	R. Costa, A. Ansar	11th European SOFC & SOE Forum 2014	July 1 – 4, 2014	Lucerne, Switzerland	*Scientific Community*		international
11	Poster	A. Hornes, M. Torchietto, G. Syvertsen-Wiig, R. Costa	11th European SOFC & SOE Forum 2014	July 1 – 4, 2014	Lucerne, Switzerland	*Scientific Community*		international
12	Poster	V. Yurkiv, G. Constantin, A. Hornes, A. Gondolini, E. Mercadelli, A. Sanson, L.	11th European SOFC & SOE Forum 2014	July 1 – 4, 2014	Lucerne, Switzerland	*Scientific Community*		international

		Dessemond, R. Costa						
13	Poster	F. Perrozzi, S. Presto, R. Spotorno, M. Viviani, P. Piccardo	11th European SOFC & SOE Forum 2014	July 1 – 4, 2014	Lucerne, Switzerland	*Scientific Community*		international
14	Poster	A. Gondolini, E. Mercadelli, A. Sanson	CISM-Advanced Professional Training School (APTS), Advances in Medium and High Temperature Solid Oxide Fuel Cells Technology	July 14 – 18, 2014	Udine, Italy	*Scientific Community*		International
15	Presentation	F. Willot, B. Abdallah, Y.-P. Pellegrini	14th European Mechanics of Materials Conference - EMMC14	August 27 – 29, 2014	Göteborg, Sweden	*Scientific Community*		international
16	Poster	A. Gondolini, E. Mercadelli, A. Sanson	Towards the Next Generation SOFC	October 6 – 7, 2014	Stuttgart, Germany	*Scientific Community* *+ Industry*		International
17	Presentation	R.Costa	Towards the Next Generation SOFC 1st EVOLVE Workshop	October 6 – 7, 2014	Stuttgart, Germany	*Scientific Community* *+ Industry*		International
18	Presentation	G. Syvertsen-Wiig	Towards the Next Generation SOFC	October 6 – 7, 2014	Stuttgart, Germany	*Scientific Community* *+ Industry*		International

			1st EVOLVE Workshop					
19	Presentation	A. Ansar	Towards the Next Generation SOFC 1st EVOLVE Workshop	October 6 – 7, 2014	Stuttgart, Germany	*Scientific Community* *+ Industry*		International
20	Presentation	F. Han, R. Semerad, R. Costa	Towards the Next Generation SOFC 1st EVOLVE Workshop	October 6 – 7, 2014	Stuttgart, Germany	*Scientific Community* *+ Industry*		International
21	Presentation	B. Abdallah, F. Willot, D. Jeulin	12e Journée d'étude des milieux poreux 2014	October 9 – 10, 2014	Toulouse, France	*Scientific Community*		France
22	Presentation	B. Abdallah, F. Willot, D. Jeulin	Matériaux 2014	November 24 – 28, 2014	Montpellier, France	*Scientific Community*		France
23	Presentation	F. Han, R. Semerad, G. Constantin, L. Dessemond, R. Costa	ICACC 15 Symposia - 12th Internatioal Symposium on Solid Oxide Fuel Cells (SOFC): Materials, Scienc and Technology	January 25 – 30, 2015	Daytona beach, USA	*Scientific Community*		international
24	Presentation	R. Costa, R. Poss, F. Willot, A. Chesnaud,	ICACC 15 Symposia - 12th	January 25 – 30, 2015	Daytona Beach, USA	*Scientific Community*		international

		G. Syvertsen Wiig, M. Viviani, A. Sanson, L. Dessemond, R. Semerad, A. Ansar	Internatioal Symposium on Solid Oxide Fuel Cells (SOFC): Materials, Scienc and Technology					
25	Poster	F. Willot, B. Abdallah, Y.-P. Pellegrini	Euromech Colloquium 559 - Multi-scale computational methods for bridging scales in materials and structures	February 23 – 25, 2015	Eindhoven, The Netherlands	*Scientific Community*		international
26	Flyer	DLR	Hannover Messe 2015	April 13 – 17, 2015	Hannover, Germany	*Industry*		
27	Presentation	V. Yurkiv, G. Constantin, A. Hornes, A. Gondolini, E. Mercadelli, A. Sanson, L. Dessemond, R. Costa	227th ECS Meeting	May 24 – 28, 2015	Chicago, Illinois, USA	*Scientific Community*		international
28	Presentation	E. Mercadelli, A. Gondolini, G. Constantin, L. Dessemond, V. Yurkiv, R. Costa, A. Sanson	14^{th} International Conference European Ceramic Society	June 21 – 25, 2015	Toledo, Spain	*Scientific Community*		international
29	Presentation	D. Masson, B. Abdallah, F. Willot, D. Jeulin, E. Mercadelli, A. Sanson, A. Chesnaud, A. Thorel	SOFC-XIV	July 26 – 31, 2015	Glasgow	*Scientific Community*		international
30	Presentation	F. Han, R Semerad, G	SOFC-XIV	July 26 – 31, 2015	Glasgow,	*Scientific*		international

		Constantin, L Dessemond, R Costa			Scotland, UK	*Community*		
31	Poster	V. Yurkiv, G. Constantin, A. Gondolini, E. Mercadelli, A. Sanson, L. Dessemond, R. Costa	SOFC-XIV	July 26 – 31, 2015	Glasgow, Scotland, UK	*Scientific Community*		international
32	Poster	A. Richter, G. Syvertsen-Wiig	KIFEE-Kyoto International Forum for Environment and Energy	September 22, 2015	Trondheim, Norway	*Scientific Community*		international
33	Poster	A. Richter, G. Syvertsen-Wiig	Summer school on "Ionic and protonic conducting ceramic membranes for green energy applications"	September 25, 2015	Valencia, Spain	*Scientific Community*		international
34	Presentation	M. Viviani, S. Presto, F. Perrozzi	FisMat 2015	September 28 – October 2, 2015	Palermo, Italy	*Scientific Community*		international
35	Presentation (invited)	A. Sanson	ICACC 40th International Conference and Expo on Advanced Ceramics and Composites	January 24 – 29, 2016	Daytona Beach, Florida, USA	*Scientific Community*		international
36	Poster	F. Han, R. Semerad, P. Szabo and R. Costa	18th ISE topical meeting	March 8 – 11 of 2016	Gwangju, South Korea	*Scientific Community*		international

37	exhibition	DLR	Hannover Messe 2016	April 25 – 29, 2016	Hannover, Germany	*Industry*		International
38	Presentation	F. Han, R. Semerad, P. Szabo, V. Yurkiv, L. Dessemond, R. Costa	12th EUROPEAN SOFC and SOE FORUM	July 4 – 8, 2016	Lucerne, Switzerland	*Scientific Community*		international
39	Poster	V. Yurkiv, L. Dessemond, F. Han, P. Szabo, R. Semerad, R. Costa	12th EUROPEAN SOFC and SOE FORUM	July 4 – 8, 2016	Lucerne, Switzerland	*Scientific Community*		international
40	Presentation	F. Han, R. Semerad, P. Szabo and R. Costa	ICC6	August 21 – 25, 2016	Dresden, Germany			international
41	Poster	F. Willot, B. Abdallah, D. Jeulin,	Euromech EMMC 15	September 7 – 9, 2016	Brussels, Belgium	*Scientific Community*		international
42	exhibition	DLR	World-of-energy-solutions 2016	October 10 – 12, 2016	Stuttgart, Germany	*Industry*		International
43	Presentation	A. Gondolini, E. Mercadelli, A. Sanson	Towards the next generation Metal Supported Cell 2nd EVOLVE workshop	October 10-12	Stuttgart, Germany	*Scientific Community*		International
44	Presentation	F. Han, R. Semerad, V. Yurkiv, L. Dessemond, P. Szabo, R. Costa	Towards the next generation Metal Supported Cell	October 12, 2016	Stuttgart, Germany	*Scientific Community*		International

			2nd EVOLVE workshop					
45	Presentation	M. Viviani	Seminar: “MERGELAB: materials and electrochemical processes for energy”	December 1, 2016	Department of Physics, Indian Institute of Technology, Banaras Hindu University, Varanasi – INDIA	*Scientific Community*		India
46	Presentation	R. Costa, F. Han, P. Szabo, R. Semerad, V. Yurkiv, L. Dessemond	FDFC2017	January 31 – February 2, 2017	Stuttgart, Germany	*Scientific Community*		international
47	Presentation	R. Costa, F. Han, P. Szabo, R. Semerad, V. Yurkiv, L. Dessemond	AMPEA workshop: "Materials for membranes in energy applications: gas separation membranes, electrolysers and fuel cells"	February 7 – 8, 2017	Oslo, Norway	*Scientific Community*		international
48	Presentation	F. Han, R. Semerad, P. Szabo, R. Costa	Materials and Challenges in Alternative and Renewable Energy MCARE2017	February 20 – 24, 2017	Jeju Island, Korea	*Scientific Community*		international
49	exhibition	DLR	Energy Storage	March 14 – 16,	Düsseldorf,	*Industry*		International

			Europe	2017	Germany			
50	Presentation	F. Han, A. Nechache, R. Semerad, R. Costa	ICE2017	June 12 – 15, 2017	Copenhagen, Denmark	*Scientific Community* *+ Industry*		International
51	Presentation	E. Mercadelli, A. Gondolini, A. Sangiorgi, D. Montaleone, R. Costa, G. Gautier, A. Sanson	ECERS2017	July 9 – 13, 2017	Budapest, Hungary	*Scientific Community*		International
52	Presentation	A. Nechache, F. Han, R. Semerad, G. Schiller, R. Costa	SOFC XV	July 23 – 28, 2017	Hollywood, Florida, USA	*Scientific Community*		International

This table reflect dissemination activities at the date of August 2017 and does not consider any activities that could take place in the future based on the foreground generated by the project EVOLVE.

4.2 Report on societal implications

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	303429
Title of Project:	EVOLVE
Name and Title of Coordinator:	DLR / Dr. Rémi Costa

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 : *Nota: based the information shared by the partners who answered the request.*

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		1
Work package leaders	1	6
Experienced researchers (i.e. PhD holders)	5 (ISTEC) 1 (DLR) 1 (CerPoTech)	1 (ISTEC) 5 (DLR) 2 (CerPotech) 1 (Grenoble INP) 2 (Alantum) 2 (Ceraco)
PhD Students		
Other	2 (CerPotech) 3 (DLR)	5 (CerPoTech) 1 (DLR)

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**2**
Of which, indicate the number of men:	1 (ISTEC), 1 (DLR)

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	○	○	○	○	○
X	Other:	No positive discrimination policy but equality of chance given independently from the gender				

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)?

○ Yes- please specify

X 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?

○ Main discipline[10]: 1.3, 2.3

○ Associated discipline[10]:1.1, 5.2 ○ Associated discipline[10]:

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.)?

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

13b If Yes, in which fields?

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

13c If Yes, at which level?

- ○ Local / regional levels
- X National level
- X European level
- X International level

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	
To how many of these is open access[11] provided?	
How many of these are published in open access journals?	
How many of these are published in open repositories?	
To how many of these is open access not provided?	
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]: ……………	

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).*	**2**

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	x	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:	*Indicate figure:*

[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	❑

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]