Publishable Summary for Project LASER-CELL

Project full title: Innovative cell and stack design for stationary industrial applications using novel laser processing techniques

Project LASER-CELL has brought together experts in advanced manufacturing, carbon technology, laser processing, computational modelling, life-cycle analysis, hydrogen and fuel cells in order to investigate the production of laser processed substrates for alkaline fuel cell electrodes. Within Project LASER-CELL, a novel alkaline fuel cell (AFC) and stack was proposed, delivering competitive performance and economical volume production for large scale stationary applications. In order to achieve this, the project partners set out the following objectives:

1. Designing a novel alkaline fuel cell based on laser-processed substrates that provide optimised technical and commercial characteristics.
2. Assessing and adapting state-of-the-art laser manufacturing techniques and incorporating their benefits (while taking account of their restrictions) in the fuel-cell design.
3. Designing an innovative fuel-cell stack to operate in industrial stationary settings, which delivers safety, mass manufacture, ease of assembly, recyclability, serviceability and optimal performance.
4. Combining the above objectives in order to establish the cost-competitiveness of the AFC technology in comparison with all competing technologies – confirming for the first time the commercial viability of AFCs in large-scale stationary applications.

To achieve these project objectives, the partners investigated an additive and a subtractive manufacturing route and two different material sets.

Laser sintering and laser drilling were compared with significant advances being made in each. In laser drilling multi-spot optics and drilling on the fly were used to great effect with drilling speeds exceeding those projected at the outset. Laser sintering was used to produce substrates with highly tailorable porosity characteristics and vastly increased sintering speeds were achieved.

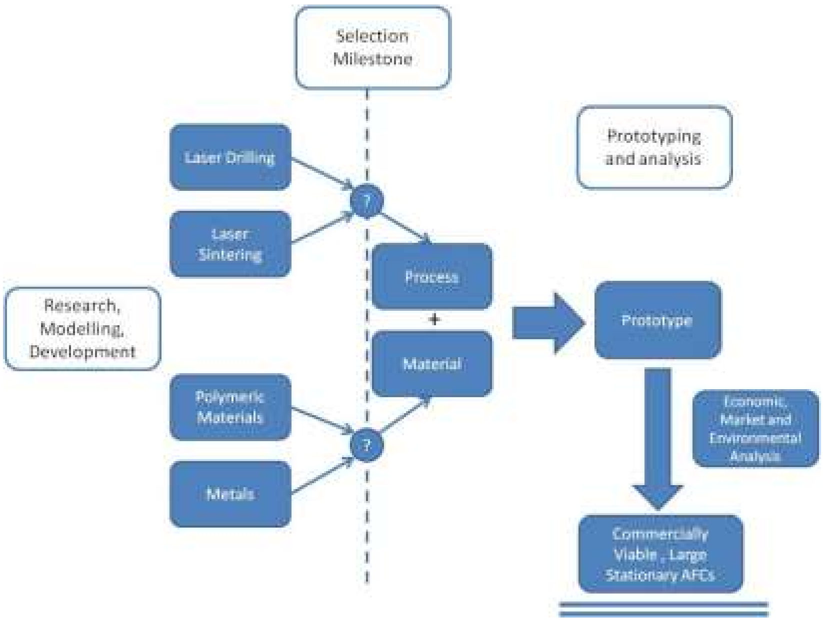

Figure 1. Project structure showing the research phase (left) and the Prototyping and analysis phase (right)

In addition to two laser processing techniques, the project also investigated two distinct material sets for the substrates. Metals were investigated due to their high electrical conductivity and chemical resistance. Polymer matrices were combined with conductive carbons and metal powders to provide substrate materials which were more responsive to laser excitation thus allowing faster manufacturing speeds.

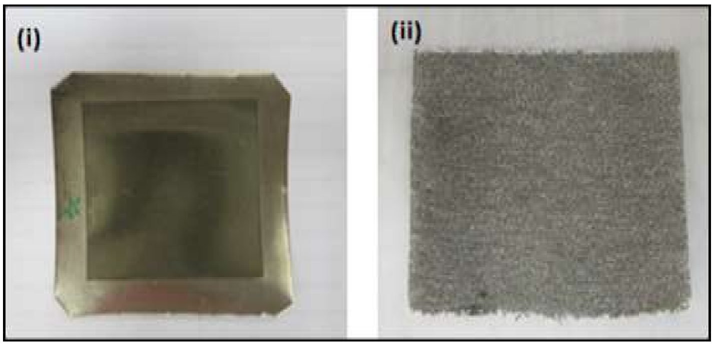

Figure 2. Test-scale coupons of (i) Laser-drilled substrate. (ii) Laser-sintered substrate.

Significant computer modelling activities were also undertaken in order to evaluate the relationship between alkaline fuel cell performance and substrate type. An added benefit of this work was a substantial increase in understanding of the fundamental science driving the alkaline fuel cell, applying modern modelling techniques to this technology in novel ways.

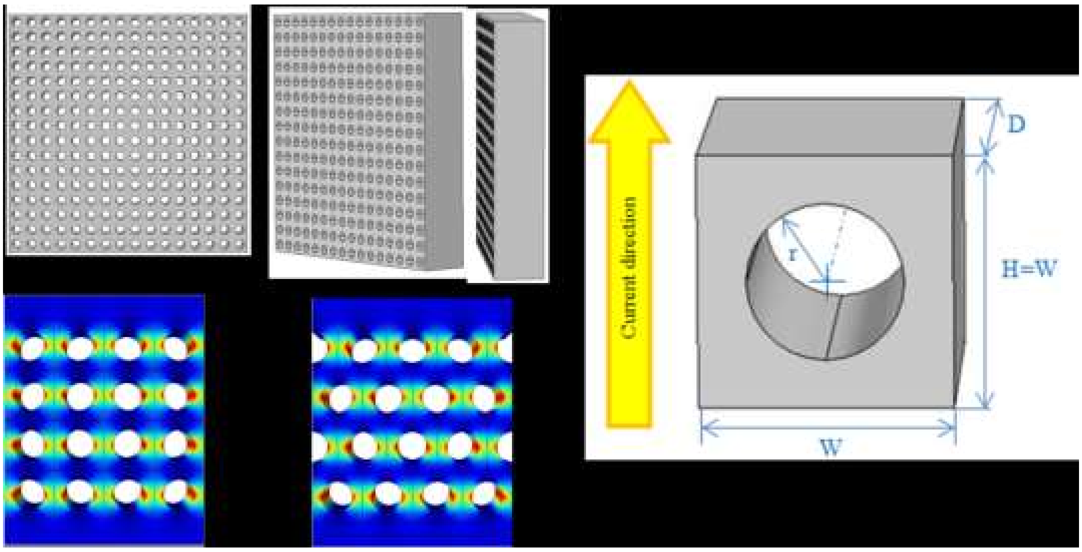

Figure 3. Geometric substrate model and current distributions

At the end of the second year of the project, a manufacturing method and a material were selected in order to build a prototype fuel cell stack. After the technological advances made in the project were weighed up, technology readiness proved to be the deciding factor. More mature technologies were chosen leading to laser drilling of metal substrates for the prototype system. It is noteworthy however that the partners obtained outstanding results with the other two technology areas investigated and carried out further work on these during the final year of the project.

Figure 4. Laser sintering (left) and laser drilling (right)

In order that these prototype electrodes had the best chance of fulfilling all of the project objectives modifications were made to the design and function of the fuel cell technology, most notably by reducing shunt currents in the electrolyte circuit using an ingenious, ionic decoupling method.

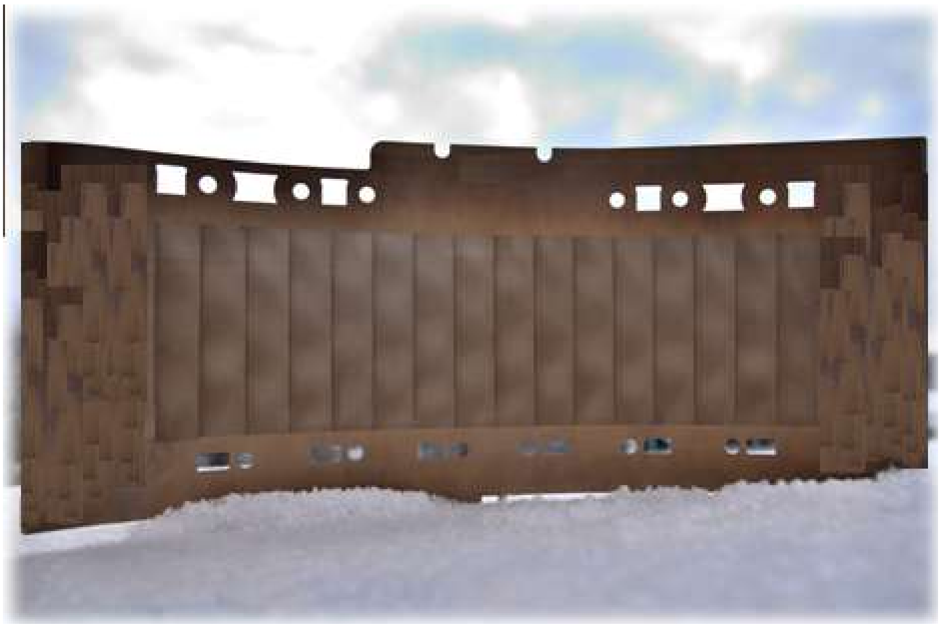

Figure 5. A prototype electrode substrate made during the second phase of the project

A prototype stack was built from selected technological advances resulting from the project and was found to have performance and longevity equivalent to AFC Energy plc contemporary technology.

Significant modelling and analysis was carried out to evaluate the environmental, economic and market implications of the project's results. Significant improvement in global warming score and cost of cartridge are reported. The cost reduction and improved environmental impact shown through this analysis add to the successes of the project. Market penetration within the EU was also assessed and, although highlighting the requirement for regulatory incentives in order to target the use of by-product Hydrogen, shows real potential for these technological advances to be capitalised upon.

The key outcomes of each phase of the project are summarised in the table below.

Key project outcomes	
Primary outcomes	
Research phase	**Prototyping phase**
Laser Drilling selected as most appropriate processing method	**Fully functioning stack prototype tested**
Metal selected as most appropriate substrate material	
Highlighted outcomes	
Research phase	Prototyping phase
Significantly increased Laser drilling speeds	Shunt current reduction (by ionic decoupling) prototyped and tested
Significantly improved Laser Sintering process	Technology shown to provide Environmental benefit over current Alkaline Fuel cells in stationary applications
Alkaline Fuel Cell model developed, refined and tested	Technology shown to significantly reduce the cost of Alkaline fuel cells in this application
Fuel cell electrode evaluation methods and test quality significantly improved	Priorities for market adoption using by-product Hydrogen identified
Production process for carbon/metal/polymer composites refined	
Conductivity of carbon/metal/polymer composites significantly increased	

The consortium partners have improved and assessed the manufacturability and cost of alkaline fuel cells by combining improvements to manufacturing processes, refinement of materials and stack design modifications with economic analysis, life cycle analysis and computational modelling. Furthermore, scientific knowledge has also been increased by the project. The consortium partners have further increased the impact of the project by sharing results in scientific papers and conferences and by running workshops for interested parties.

Looking forward, the co-ordinator of the project has already taken learning from project LASER-CELL into projects ALKAMMONIA and POWER-UP in order to demonstrate the technology on larger scales, in a product system and with alternative fuels.

Despite being focussed on one component of an electrode for an alkaline fuel cell, the advances made during this project show promise for a wide variety of applications. Consortium partners are seeking to exploit advances made during this project in other types of fuel cell, redox flow batteries, other battery electrodes, filtration applications, noise reduction/absorption, electromagnetic shielding, fire proofing and others.

The information and improvements made during this project have gone beyond fulfilling the consortium's objectives and have provided, not only an improved fuel cell system, but also solid platforms on which many other technologies will be built.