Final Report

Project acronym: *NanoElMem*

Project number*: 4228*

M-ERA.NET Call 2016

Period covered: 1/6/2017 to 31/8/2020

Publishable project summary

Project results are providing novel scientific and technological concepts and efficient solutions in the development of fuel cells, which have been identified as the key technology in a global effort to secure clean energy industry of the future. Fuel cells directly convert chemical energy stored in fuels into electrical energy through electrochemical reactions, and as such hold a great potential for the development of alternative and sustainable energy systems. The *NanoElMem* project presents an innovative approach towards the design and fabrication of materials for the creation of direct alkaline ethanol fuel cells (DAEFC). Emphasis was put on the **development of platinum (Pt)-free anode catalysts and nano-composite membranes**, where environmentally friendly and sustainable polysaccharides and inorganic materials were employed. The vast potential of graphene, from a scientific and applied point of view, was harnessed as an active component in polysaccharide-based nanocomposite membranes. Partners in the project consortium (i.e. Norwegian University of Science and Technology and Abalonyx an SME, the Slovenian Universities of Maribor and of Nova Gorica, and the Taiwan Chang Gung University) have devised a systematic work-plan consisting of R&D activities that fully encompassed the entire development procedure of the novel fuel cell, from design to the actual fabrication of the prototype. Even more so, in order to arrive at an innovative and efficient product by the end of the project's run, the work-plan has been constructed around the current technical obstacles, that limit full implementation of fuel cells in a commercial scale; by directly addressing these limitations, i.e. **cost**, **performance** and **durability**.

Reducing the costs of existing fuel cells was achieved by development of highly active 30%Pt/CNF, 40%Pd/KB and 40%PdNi/KB ethanol oxidation reaction (EOR) catalysts and noble metal free oxygen reduction reaction (ORR) catalysts (Fe-NPC). All three EOR catalysts showed better performance (lower onset potential and higher current density) in EOR than commercial Pt/C in cyclic voltammetry. The 30%Pt/CNF is the most promising one. The highly efficient EOR catalyst could reduce the used of Pt without influence the electrochemcial performance. While the metal free ORR catalyst could eliminate the use of Pt catalyst for cathod. Therefore, the cost of the fuel cell could be significatnly reduced combing efficient EOR and noble metal free ORR catalyst.

In terms of performance, DAEFCs struggle mainly with relatively low power density. This major technical problem was tackled by the design of ion-exchange membranes with enhanced efficiency and durability while maintaining low costs; here, bio-based polysaccharide polymers were used, which served as the matrix for newly synthesized (N)-doped and quaternized graphene oxide (GO) nano-fillers, which improved membrane ion conductivity, thermal and mechanical stability, and prevented ethanol crossover through cross-linked membranes. The highest value for hydroxide conductivity, 142.5 ± 4.0 mS cm^{-1} at 40 °C, was achieved for the chitosan-$Mg(OH)_2$ based composite anion exchange membranes (AEMs) with ethanol permeability value of 6.17 × 10-7 ± 1.17 × 10-7 cm2 s-1 in spite of its relative high KOH uptake (1.43 g KOH/g membrane). Chitosan-Mg(OH)2 based AEMs with 0.01 wt.% N-doped GO filler have achieved a maximum power density of 149 ± 2.2 mW
cm-2 at 80 °C, which is significantly higher than that of the benchmark commercial FAA Fumapem® and polybenzimidazole with values of 11 and 60 mW cm-2, respectively. This is the highest reported power density value for chitosan based membranes. Obtained results demonstrate that the obtained membranes are promising AEM candidates for direct alkaline alcohol fuel cell applications.