Solid Oxide Fuel Cells (SOFCs) are among the most promising technologies for the production of electricity and heat from traditional and renewable energy sources. The symmetrical SOFCs (S-SOFC) with the same electrode, are very promising, due to reduced cell components, simplified manufacturing process and alleviated chemical stability problems, consequently decreasing production costs and ensuring a long-term stable operation. S-SOFCs can also address carbon deposition and sulfur poisoning problems by simply reversing the gas flows (oxidizing the deposited product). In addition, S-SOFC facilitates a reversible operation between fuel cell and electrolysis mode. To be economically competitive, the commercial application of S-SOFCs and SOFCs will require lowering the temperature to a low temperature range (≤600 °C) while still maintaining a high-power output. Therefore, new redox stable electrode materials with enhanced electrocatalytic properties are indispensable for boosting the performance of S-SOFCs.

The scientific aim of the proposal is to design novel redox stable electrode materials $(Ln, Ba/Sr)_{2-\alpha}(Fe, M)_{2-x}(NiCo)_xO_{6-\delta}$ (Ln = selected lanthanides; M = Mn, Ti, Cr, Mo, W) with the ability of *in situ* exsolution of nanocatalysts for significantly boosting the electrode performance of S-SOFCs. In this project, the following materials design strategy will be applied, allowing to obtain functional redox stable electrode materials with unique and required physicochemical and electrochemical properties:

- ✓ The introduction of A-site deficiency will favor the improvement of the electrocatalytic properties of electrode materials with the formation of additional highly mobile oxygen vacancies.
- ✓ A-site deficiency design with the presence of a controlled amount of Ni, Co cations at B-site shall facilitate the control of *in situ* growth of catalytically active nanoparticles decorated on the anode for boosting the electrochemical performance of S-SOFCs.
- ✓ The *in situ* exsolved nanoparticles can be socketed to the parent oxide, enhancing the stability and hydrocarbon coking tolerance, making the S-SOFCs fueled by cheaper and available non-hydrogen fuels feasible. Moreover, the possible reversible exsolution/dissolution of nanoparticles can potentially resolve the particle agglomeration and coke formation during usage of non-hydrogen fuels.
- ✓ The A-site cations design with substitution of Ba^{2+}/Sr^{2+} by Ln^{3+} cations will allow the formation of double perovskite structure that favors fast oxygen ion transport.
- ✓ The cheap and commonly available Fe with a variable oxidation state doped into the B-site together with M (M = Mn, Ti, Cr, Mo, W) cations will introduce good mixed ionic-electronic conductivity with ensuring high phase stability both in oxidizing and reducing conditions.

The scarcity of systematic studies of redox stable A-site deficient perovskites with the ability of *in situ* growth of nanocatalysts in terms of utilization of these materials as electrode materials for S-SOFCs makes the proposal especially of interest. In this project, fundamental challenges related to the determination and understanding of critical issues of electrode materials for S-SOFCs, based on the proposed A-site deficient double perovskites will be undertaken. The *in situ* exsolution/dissolution of socketed nanocatalysts mechanism and carbon deposition tolerance in S-SOFCs will be elaborated, and the reversible operation between fuel cell and electrolysis mode in S-SOFCs will be conducted for the studies of degradation mechanism of the electrode. The scientific methodology with an interdisciplinary approach characterized by the synergetic use of the solid state physiochemistry, electrochemistry and materials engineering will be done, especially including the high temperature XRD and Raman analysis, XPS, EIS method, SEM, EDS and TEM techniques. With the knowledge going to be acquired, it will be possible to establish general rules in the design of functional redox stable electrode materials with unique and required physicochemical and electrochemical properties, and as high-performance electrode materials in S-SOFCs for power generation and energy storage operation with enhanced operational parameters.

The successful accomplishment of the proposed project will have major impact on the development and commercial adoption step of S-SOFCs technology in power generation and energy storage, and generally, in clean and renewable power applications. The progress of solid state chemistry and physics in terms of understanding the *in situ* exsolution/dissolution of nanocatalysts in anode and cathode operation conditions and the relation between the physicochemical properties and the electrochemical properties of redox stable electrode materials will also be made. The implementation of this project will provide both a new fundamental understanding and an applied R&D approach with significant importance on new-generation fuel cell materials and technologies.