Politecnico di Torino

ENERGETICS

SHELL/DENERG - Study of the conversion of H2O/CO2 to chemicals of interest to the chemical industry by means of SOC by means of a hybrid solar-assisted thermal cathodic reduction + night-driven PCC electrolysis

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Context of the research activity	TITLE: Study of the conversion of H2O/CO2 to chemicals of interest to the chemical industry by means of SOC by means of a hybrid solar-assisted thermal cathodic reduction + night-driven PCC electrolysis. The issue of climate change and consequently the reduction of carbon impact is of fundamental importance for the chemical industry, considered a "hard to abate" production sector, especially following the significant energy intensity of the production processes. CO2 is also a possible feedstock for the chemical production chain, to be used as an alternative to traditional feedstocks of fossil origin - above all virgin naphtha - as a source of carbon, but the main difficulty to face is its poor reactivity, which makes its conversion is therefore a scientific and technological challenge. In particular, it is necessary to orient conversion processes towards energetically favorable approaches, such as to have a low carbon impact. Among the many technologies being studied today, electrochemical processes are certainly of particular interest, which - using electricity from renewable or nuclear sources - can guarantee this last requirement - low carbon impact. In particular, electrochemical processes are implementers of the trend towards the electrification of end uses (consistently with the growing electrification of primary sources) which can also be considered of growing interest for the chemistry sector. In these processes the CO2 is reduced to the cathodic section by reaction with the hydrogen of the water (or, preferably, with its ionic form deriving from the anodic oxidation reaction of the water), to give less oxygenated products, until reaching hydrocarbon compounds completely devoid of oxygen. The CO2 reduction reaction is thermodynamically unfavorable compared to the water reduction reaction, which occurs at lower potentials, and therefore it is necessary to use an appropriate catalytic system that overcomes this thermodynamic limit. Furthermore, also with regards to the technological structure of the electrolytic cell, there are various solutions under study, each with specific

	pros and cons, as is normal in these cases. Among the possible solutions, the one that is the subject of this doctoral thesis is solid oxide cell technology (Solid Oxides Electrolysis Cell - SOEC).

Objectives	The PhD activity will be carried out mainly at the HySyLab/CO2 Circle Lab of Politecnico di Torino. In particular, the scientific activity will be developed in close collaboration with the SHELL Energy Transition Campus Amsterdam (ETCA) in Amsterdam (co-funding the activity) that has recently signed a Cooperation Framework with Politecnico di Torino (in charge Prof. Massimo Santarelli). The activity is also developed in the framework of the EU PathFinder Project ECOLEFINS (DENERG-POLITO Partner). Finally, the activity is developed in the framework of a strong scientific collaboration with MIT (Boston, US) and University of Udine (Italy). Solar-to-Chemicals is a growing area devoted to the decarbonization of hard-to-abate sectors (chemical industry, long distance mobility). In this framework, dominated by e-chemicals, we are working on hybrid thermal-electrical process at higher efficiency compared to the e-driven processes. We have observed a good effect of solar driven reduction of perovskite SFNM, generating an exsolution process delivering exsolved core and shell grains of Ni-Fe (core) and SFNM (shell), good catalytic site for CO_2 reduction. The aim of the PhD studies is then: • include SFNM as cathodic material of a PCC cell • operate the cell in solar-assisted reduction mode, delivering O_2 from SFNM by thermal reduction and exsolving Ni-Fe (core) and SFNM (shell) • in the same time, operating the cell in PCC mode: H_2O sent at anode, H^+ migrating to cathode to SFNM catalytic sites already exsolved • CO_2 is sent to cathode, and it is reduced to CO at SFNM over the O_2 vacancies • H^+ and CO react at core&shell catalytic sites to produce light olefins: kinetic mechanism has to be defined • The process can be driven during the night in pure electrolysis mode (exploiting the already reduced cathode) through the continuous H^+ flux and partially re-oxidizing the SNFM through CO_2 • During sun day, SFNM is thermally reduced again, and the cycle re-start The PhD involves the design of the cathode electrode, the design, production and testing of an SRU (Single Repeating Unit), and especially the solar-fed receiver.

Skills and competencies for the development of the activity	• Solar concentrators • Solar fuels • Ceramic materials • Electro-catalysis • Kinetic • Thermodynamics • Heat transfer • Experimental capabilities on electrochemical technologies and processes • Modeling capabilities in terms of multi-physics phenomena (electrochemical, thermal, mass transport)