SOLSTICE	Name of the post doc: **Jean PUIG** Title of the post-doc: **Carbothermal reduction of metallic oxides using concentrated solar energy for the production of solid fuel** Dates (start/end): 01/12/2014 – 31/05/2016
Supervisors	M. Balat-Pichelin (PROMES-CNRS)
Other contributor	PSA-Peugeot Citroen

Context and objectives

The combustion of metal powders is a new energy process envisaged for the propulsion of future vehicles (long-term). Abundant and light metals with high energy densities such as Si, Al, Mg can be used and the unique products of combustion are solid metal oxides. Metals regenerated from their oxide with a good efficiency can enable a sustainable use of these resources. In this work, Concentrated Solar Energy (CSE) has been employed to properly reduce metal oxides formed after a combustion process.

Approach

After a study of the scientific literature on the topic, thermodynamic calculations were realized in order to evaluate which metal oxides could be industrially reduced and the operating conditions of this operation. Experimental reductions of the selected oxides were carried out using CSE.

Main results

Thermodynamic calculations have allowed to select MgO and Al_2O_3 due to their low reduction temperature in the presence of carbon: 1800 K under 100 and 0.1 mbar respectively. MgO:C or Al_2O_3:C pellets (8 mm Ø ; 2 mm thick) were positioned adjacent to the focus of a 2 kW solar furnace in the "Héliotron" batch reactor under argon at 10 mbar. Condensates from the reaction were recovered on a water-cooled metal finger and a microporous ceramic filter (Fig. 1a; black and green squares). Optimization of the reaction parameters was conducted (stoichiometric ratio of reagents, grain size, varieties of carbon). The influence of a pre-grinding, of the experiment time, of the concentrated solar flux... were also studied. Metal contents from 60 to 80 %wt. were determined in the collected powders and global conversion efficiencies of 50% were obtained. These powders are composed of agglomerates of nanoscale grains (Fig. 1b). The by-products are MgO (Fig. 1c) or Al_2O_3, Al_2OC & Al_4C_3.

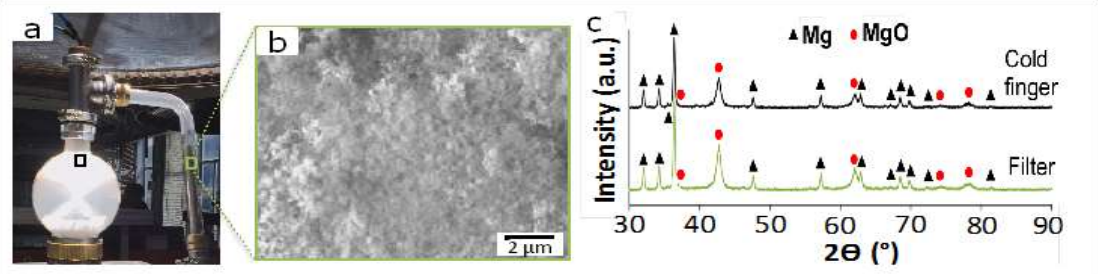

Figure 1. (a) "Héliotron" reactor during an experiment, (b) micrograph and (c) XRD patterns of the powder collected on the filter after a carbothermal reduction of MgO

A new reactor called Sol@rmet has been designed to optimize the carbothermal reduction process at the end of the post-doc. In this reactor, the temperature of the pellet and the outlet gases (CO, CO_2) from the reactor are monitored, which allows to better describe the by-products formation and the reaction kinetics. The optimized metal yields in the produced powders are larger than 90%.

Publications in scientific journals and international conferences

Scientific journals

Puig J., Balat-Pichelin M. « Production of metallic nanopowders (Mg, Al) by solar carbothermal reduction of their oxides at low pressure » Journal of Magnesium and Alloys (2016), 4, pp. 140-150
Puig J., Balat-Pichelin M., Experimental carbothermal reduction of MgO at low pressure using concentrated solar energy, J. Min. Metall. Sect. B-Metall. 54 (1), 2018, 39-50,DOI:10.2298/JMMB170215048P

International conferences

Puig J., Balat-Pichelin M., *High Temperature Materials Chemistry 15,* Orléans (France), 29 mar-1 april, 2016.
Puig J., Balat-Pichelin M., *9th European Metallurgical Conference*, Leipzig (Germany), june 25-28, 2017.
Puig J., Balat-Pichelin M., *SolarPaces 2017,* Santiago du Chili (Chili), sept 26-29, 2017.