SILCO Project: Waste-derived SIlica-based porous solids for Carbon diOxide capture, storage and re-use catalytic technology

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Significance and Relevance.

SILCO Project exhibits the potential to address both environmental and industrial challenges through innovative resource utilization. By transforming a hazardous industrial by-product hexafluorosilicic acid (FSA) into high-value silica, it advances the circular economy by converting waste into functional porous support for adsorption and heterogeneous catalysis applications. Waste-derived Silica produced as such, showing tunable porosity and surface area, are functionalized and tested as Dual-Function Materials (DFMs). DFMs integrate CO_2 adsorption and catalytic methanation functionalities, contributing to decarbonization strategies by enabling CO_2 capture and conversion into renewable methane, thus offering a sustainable and economically viable solution for CO_2 mitigation.
Preferred and 2nd choice for the topic: CO_2 Utilization and Recycling
Preferred presentation: Poster

Introduction and Motivations

Carbon dioxide remains one of the major responsible for the ongoing climate change, and the need to take urgent action to face this threat has motivated the scientific community efforts to develop efficient and cost-effective decarbonization strategies such as CO_2 Capture, Storage and Utilization (CCSU) systems. Among various technologies that have been developed to capture CO_2, adsorption and conversion by solid porous materials and catalysts is presented as a promising sustainable solution[1]. On the other side, there is a growing focus on developing sustainable processes that promote resource efficiency, prevent waste generation, and encourage the re-utilization of industrial waste by-products. Indeed, a hazardous by-product of aluminum fluoride and hydrofluoric acid industrial production is hexafluorosilicic acid (FSA, H_2SiF_6). FSA, as a co-product with limited applications, could be recovered and reused as a silicon-source for the production of silica with defined morphological and structural properties for catalytic support or sorbent applications.

In this frame, SILCO Project (PRIN2022PNRR-P2022SZANL) aims to integrate a zero-waste, innovative, and sustainable technological solution to use FSA for the production of silica. The integration deals with the modification of the waste-derived silica recovering process to produce morphologically controlled SiO_2 supports, which would be functionalized for application in sorbent (CCSU) and/or catalytic (green-fuel production) routes (Fig. 1). Among the different CO_2 hydrogenation strategies, the catalytic route to renewable methane through Sabatier reaction ($CO_2+4H_2 \rightarrow CH_4+2H_2O$) is favorable due to its high efficiency. With all these concepts, Dual Functions Materials (DFM)[2] based technology, acting as both as solid adsorbents for capture CO_2 and as catalysts for fuel production upon H_2 exposure, is promising. DFMs operate in cyclic alternating conditions, schematized in Fig. 2: firstly, the material is exposed to CO_2-containing gas stream until saturation (carbon capture function due to alkaline and/or earth-alkaline catalytic material functionalization) and, secondly, a regeneration phase is carried out exposing the DFM to a H_2 stream to convert $CO_2^{adsorbed}$ into CH_4 (hydrogenation function typically exploited by the incorporation of Ru or Ni). In literature, successful DFM consist of Ru-dispersed and Alkaline-(-earth)doped Al_2O_3-supported materials[3].

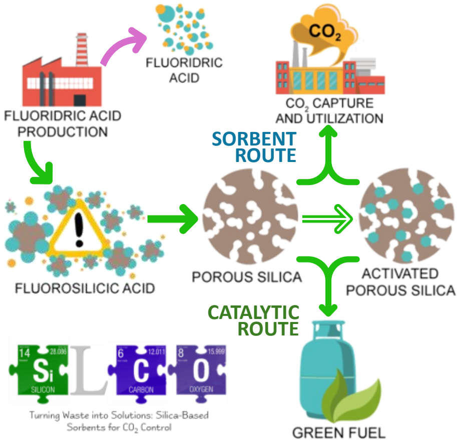

Figure 1. SILCO Project strategic development.

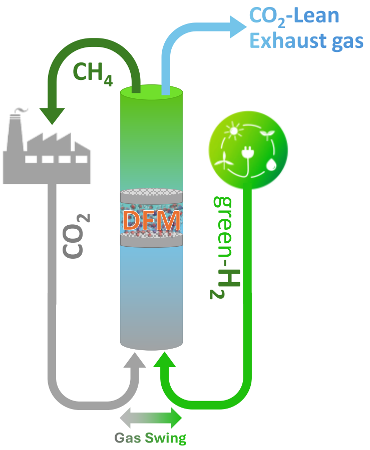

Figure 2. Schematic representation of alternating cycling condition process.

Results and discussion

Silica supports of controlled morphology, size, and porous structure, are synthesized in the presence of templates such as PEG, CTAB, and Pluronic-P123 and have been deeply characterized by FT IR spectroscopy, microscopies (SEM-EDX, HR-TEM-EDX), N_2-sorptometry, XRD, XPS, CO_2-TPD, inter alia. Acidity and surface properties have been also studied and compared to reference commercial materials. The supports will be then impregnated incorporating Ru (0.5% wt), and different Alkaline(-earth) oxides (i.e. Ba, Ca, K)[3]. The same preparation method has been used to obtain reference catalysts based on commercial SiO_2. FT-IR superficial characterization shows in case the presence of exposed silanol groups. Preliminary results obtained during the reduction of CO_2 with H_2, show that the CO_2 conversion over Ru-Ba catalysts does not depend on the support (Al_2O_3 or SiO_2); moreover, Ru-Ba/SiO_2 presents higher selectivity towards methane in respect of Ru-Ba/Al_2O_3 with the same composition (Fig. 3A,B).

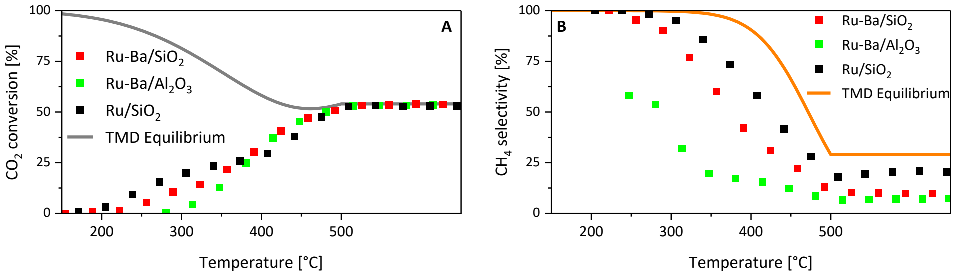

Figure 3. Results of TPR experiment: temperature ramp (from RT to 500°C @10°C/min) in CO_2 (1% v/v) + H_2 (4% v/v) balance He; A) CO_2 conversion; B) CH_4 selectivity.

Ru(0.5% wt)-Ba(16% wt)/SiO_2 has also been tested both in the adsorption of CO_2 and in its subsequent reduction. The catalyst at 150°C is able to adsorb near 230 $\mu mol/g_{cat}$, while during the reduction with H_2 only 63 $\mu mol/g_{cat}$ of CH_4 are produced. This suggests that some carbonates remain on the surface that doesn't participate to the methanation reaction.

References

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