Calcium Looping tests with SiC/Limestone Mixtures to Improve Solar Adsorption in a Directly Irradiated Fluidized Bed for thermochemical energy storage

F. Di Lauro[*], C. Tregambi[**], G. Marotta[***], R. Arena[***], F. Montagnaro[***], P. Salatino[*], R. Solimene[****]
*roberto.solimene@cnr.it

[*]Università degli Studi di Napoli Federico II, Dipartimento di Ingegneria Chimica e dei Materiali e della Produzione Industriale (DICMaPI), Naples, 80125, Italy
[**]Università degli Studi del Sannio, Dipartimento di Ingegneria, Benevento, 82100, Italy
[***]Università degli Studi di Napoli Federico II, Dipartimento di Scienze Chimiche, Naples, 80126, Italy
[****]Consiglio Nazionale delle Ricerche, Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili (STEMS), Naples, 80125, Italy

Concentrated Solar Power (CSP) systems traditionally rely on molten-salts heat transfer fluids, whose operational window (290–565°C) limits overall efficiency. Several reversible reactions using dense solid suspensions were investigated to overcome this barrier and enable thermochemical energy storage (TCES), safely operating above 1000°C. In TCES, a reversible chemical reaction, usually gas-solid for an easy products separation, is cyclically performed in the endothermic way for solar energy collection, and in the exothermic way for energy release/retrieval. Calcium Looping (CaL) exploits the reversible calcination/carbonation of limestone ($CaCO_3$/CaO), offering high reaction enthalpy (~178 kJ mol^{-1}), abundant low-cost feedstock, and minimal environmental impact. However, in directly irradiated fluidized-bed reactors, CaL faces a poor solar adsorption, due to the whitish color of limestone, and sintering phenomena of CaO by localized overheating, which decreases reactivity over cycles. In this work, physical mixtures of limestone and silicon carbide (SiC), the latter characterized by a dark color and a high solar adsorption, were investigated to both enhance optical absorption and thermally shield limestone grains. Preliminary tests were conducted to optimize SiC particle size and limestone/SiC mixing ratio, before performing 20 reactive cycles (carbonation: 650–850°C; calcination: 750–950°C). Results demonstrate that even a $10\%_{vol.}$ of SiC markedly increases the fraction of radiation absorbed, while preventing excessive thermal spikes at the CaO surface. Moreover, when compared to commercial molten-salt TCES, the CaL–SiC system achieves higher energy storage density for at least the first ten cycles. These findings suggest that the use of SiC as an inert is a promising strategy to enhance the viability of directly irradiated TCES systems.