Investigation into Carbon Capture Through Gallium-Based Liquid Metals

Graduate

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Initial Situation: Climate change is one of the greatest challenges facing the world, with anthropogenic carbon dioxide emissions being a major contribution to the greenhouse effect. Even with a transition to renewable energy sources, carbon dioxide emissions must be removed from industrial exhaust gas emissions to stop this increase. Most current carbon capture technologies require high temperatures or pressure to separate carbon dioxide. The focus has also been on gas phase isolation with long-term underground storage. Gallium-based liquid metal alloys have demonstrated the ability to extract carbon dioxide from gas streams and convert it into solid carbon at modest temperatures. This emerging technology has the potential as a more efficient carbon capture process, by providing fast phase-change carbon conversion and mild operation conditions.

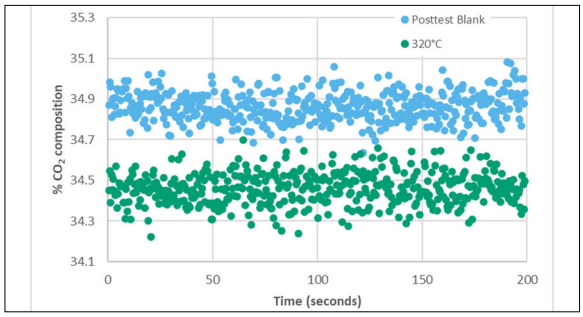
Objective: This project studied the potential for carbon capture through gallium-based liquid metals in a simple bubble column reactor. A comprehensive analysis of the technology and an experimental carbon capture plant were used to understand the process of carbon capture through gallium-based liquid metals. Research and analysis of existing studies provided a basis of understanding for the mechanisms. Experimental data provided insights into the process effectivity and the operational mechanics. The analyses and experiments also provide insight into the challenges and opportunities related to implementation of this novel technology.

Result: A simple bubble column reactor was installed inside of a furnace with a heating capability of over 400°C and with an adjustable inlet gas streams of carbon dioxide and argon. Through mass spectrometry, a reduction in carbon dioxide concentration was shown after passing through the liquid metal column. No other gaseous species, such as carbon monoxide, were detected in the outlet stream, which verifies that a portion of the carbon dioxide was fully removed from the gas stream. The gallium in the liquid metal alloy is oxidized and forms an amorphous gallium oxide layer around an agglomeration of unreacted liquid metal along with the solidified carbon. Separation and testing of reaction products by x-ray diffraction proved the presence of carbonaceous species and oxidized gallium, which confirms that the carbon dioxide has been converted to a solid form. A method for recovery of unreacted liquid metal in the laboratory is also presented in this paper, as well as methods for recovery and conversion of gallium oxide to metallic gallium in order to form a regenerative and cyclical carbon capture process with gallium-based liquid metals.

Droplet of the liquid metal used in project for carbon capture: the eutectic alloy of gallium, indium and tin
Own presentment

Image of liquid metal after reaction with carbon dioxide in bubble column reactor to form gallium oxide and solid carbon
Own presentment

Carbon dioxide removal by liquid metal from a CO2-Argon gas stream in a laboratory bubble column reactor
Own presentment



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Subject Area
Energy and Environment