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MONITORING THERMAL PHENOMENA IN CO_2 CAPTURE BY BRUCITE

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ABSTRACT

Infrared and thermography technology provides countless applications in different research and applied fields. The analysis of thermal changes and their monitoring is one of the popular usages of infrared technology which equally applies for long-term specimen observations or in contexts where chemical reactions are responsible for thermal changes.
The proposed approach addresses thermal change-tracking of CO_2 capture by brucite, a highly reactive magnesium dihydroxide mineral, in laboratory controlled conditions. Capture of CO_2 by brucite is accompanied with thermal generation which commonly occurs in natural environments. An experiment was conducted in a carbonation cell at room temperature (22-23ºC) where gaseous CO_2 is contacted with brucite while the process is monitored by means of a thermal camera positioned perpendicularly atop of reactor. Moreover, these thermal changes are recorded by thermocouples inserted at different locations in the carbonation cell. The slow reaction takes place over several hours during which the acquired data are stored to be post- processed after completion of the experiment. For the purpose of tracking spatially-resolved temperatures, thermal regions of interest from the infrared image were segmented first into several different sub-regions to represent local averaged zone temperatures. Then their corresponding changes were tracked over time. A color-based clustering was implemented for the segmentation in thermal images and for the smoothing of thermal fluctuations, namely, the Savitzky-Golay filter was used. Changes around 0.5ºC in amplitude were confirmed by the thermal sensors during the experiment.

KEYWORDS: *CO_2 storage, Infrared thermography, Passive thermography, Middle-wave infrared hyperspectral imaging, Clustering.*

SUMMARY

Infrared technology has been receiving an increasing attention through the large scope of application extending from medical field to in quality control and monitoring system. Based on the objectives of the research and test material, 2 types of infrared thermography (IRT) can be distinguished: active and passive. Unlike active thermography, passive one does not require any external excitation source and is used mostly in quantitative analyses [1]. Chemical engineering is one of the fields where passive IRT can be successfully applied due to the importance of precise temperature measurements during experiment or industrial process where heat effects are legion. Generally, temperature variations in chemical processes are caused by the heat release during chemical reaction and can be monitored by using high-speed cooled infrared camera with a high sensibility [2]. The infrared camera (Phoenix FLIR SC7000-mid-wavelength infrared (MWIR)) was placed above the chemical reactor at room temperature and atmospheric pressure. A mixture of 10% mineral brucite (powder, 060659A, Cimbar) with crystalline silica (50-70 mesh, 274739, Sigma Aldrich) was reacted with gaseous CO_2 in the middle section of the cell. This reaction (1) is exothermic providing heat following the stoichiometry of Eq.1 by converting brucite into nesquehonite:

$$\underbrace{Mg(OH)_2(s)}_{\text{brucite}} + CO_2(g) + 2H_2O(l) = \underbrace{Mg(HCO_3)OH \cdot 2H_2O(s)}_{\text{nesquehonite}} + (-86\ \text{kJ/mol}\ CO_2) \qquad (1)$$

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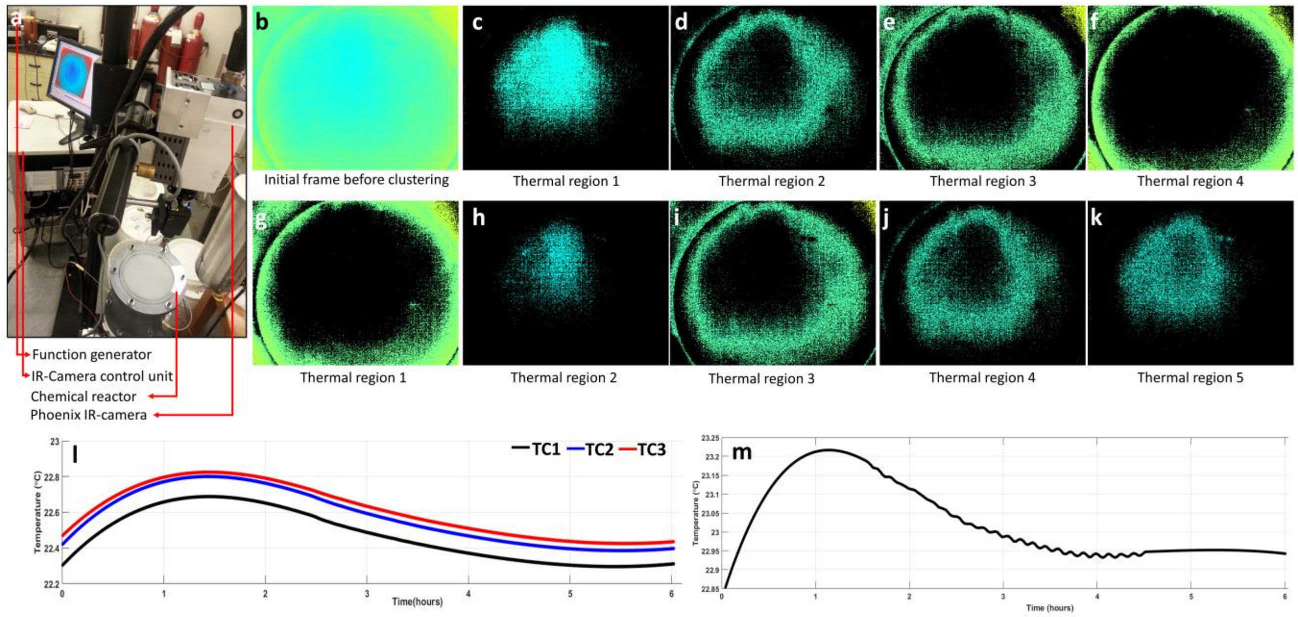

Figure 1. (a) Photograph of the experimental setup; (b) initial frame in a sequence; (c)-(f) segmentation into 4 ROIs; (g)-(k) segmentation into 5 ROIs; (l) General trend of thermal variation based on thermocouples; (m) Average thermal variation for k=5(clusters 2 and 5).

Fig1.a shows the experimental setup which includes IR-camera, function generator, and chemical reactor. Preliminary experiments conducted separately to verify the thermal transparency of the film and to calibrate the camera. Thermal camera monitored and recorded thermal changes during the carbonation experiment for thermal acquisition resolution over 640×512 pixels field-of-view at 16.6 mHz frequency (controlled by a pulse signal from a function generator).

To monitor temperature using IR thermography during the process of CO_2 uptake, a clustering method segmented the first frame (Fig.1.b) into several different regions of interests (ROIs) (for k=4, Fig1.c-f; for k=5, Fig1.g-k) whereby thermal variations are estimated separately in each frame. The best representatives of each segmentation (k=4, k=5) were allocated to track the thermal variation in the sample area (for k=4, Fig.1.c, d; for k=5, Fig.1.h, k). This approach provides considerable flexibility to locate extremal thermal points. Current work provides the first qualitative results of surface temperature fields for a partially-saturated brucite mineral powder during its reaction with CO_2 for the purpose of carbon mineralization. The general trend (Fig.1.l) from thermocouples (TC) data and the average thermal variation from IR camera data (Fig.1.m) observed in the experiment represent thermal changes occurring due to the chemical reaction which is the object of the infrared recording process. Both measurement methods yield similar results and show changes around 0.5ºC inside the sample and 0.2 ºC at the surface. Acquired signals are processed for smoothing using the Savitzky-Golay filter to improve the signal-to-noise ratio (SNR) while minimizing signal distortions [3]. It helps providing a smooth signal to inform about the general thermal trend over the entire field while getting rid of the spurious thermal fluctuations between frames. However, there are several issues that arise in connection with this work, which should be considered in future studies, for example, thermal insulation of the reactor, low thermal generation intensity, and the examination of alternative segmentation techniques.

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