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In-situ characterization of gas-liquid precipitation reaction in a spray using rainbow refractometry

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Key words: Rainbow refractometry; In-situ characterization; Refractive index; Gas-liquid precipitation reaction

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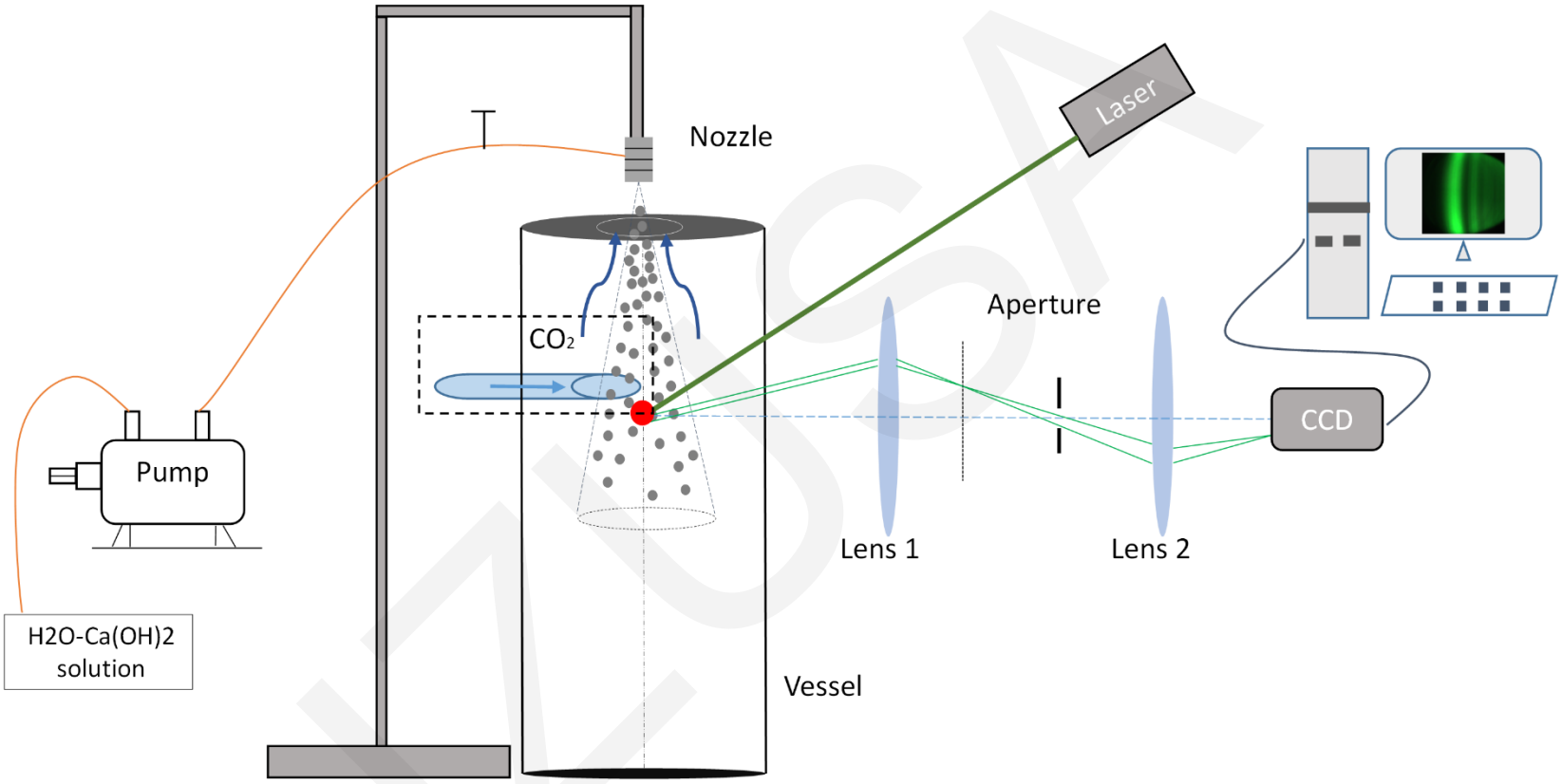
Highlights

- A rainbow refractometry-based method is used to measure the reaction process of these spray-based gas-liquid precipitation reactions in a non-intrusive way for the first time.
- Experiments and heat transfer analyses, respectively, demonstrate the possibility and effectiveness of the method.

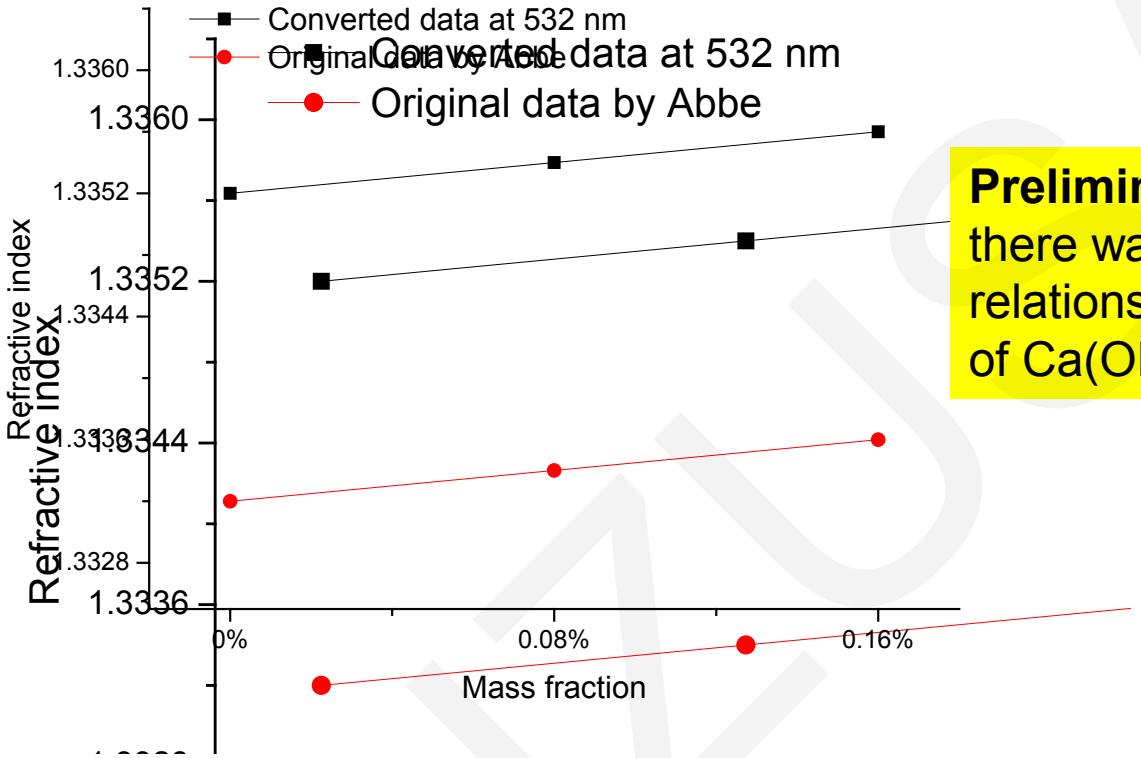
Experimental set up



Consists of

1. Spray generation and reaction parts
2. Optical measurement system

Results and discussion



Preliminary experiment illustrated: there was obviously a corresponding relationship between the concentration of $Ca(OH)_2$ solutions and its RI

$$n_T^{\lambda} = 1.31405 - 2.02\times10^{-6}T^2 + (15.868 - 0.00423T)\lambda^{-1} - 4382\lambda^{-2} + 1.1455\times10^{6}\lambda^{-3},$$

$$n_T^{532} - n_T^{589.3} = \left(20.46106762 - 7.731200136\times10^{-3}T\right)\times10^{-4} \approx 2\times10^{-3}.$$

Results and discussion

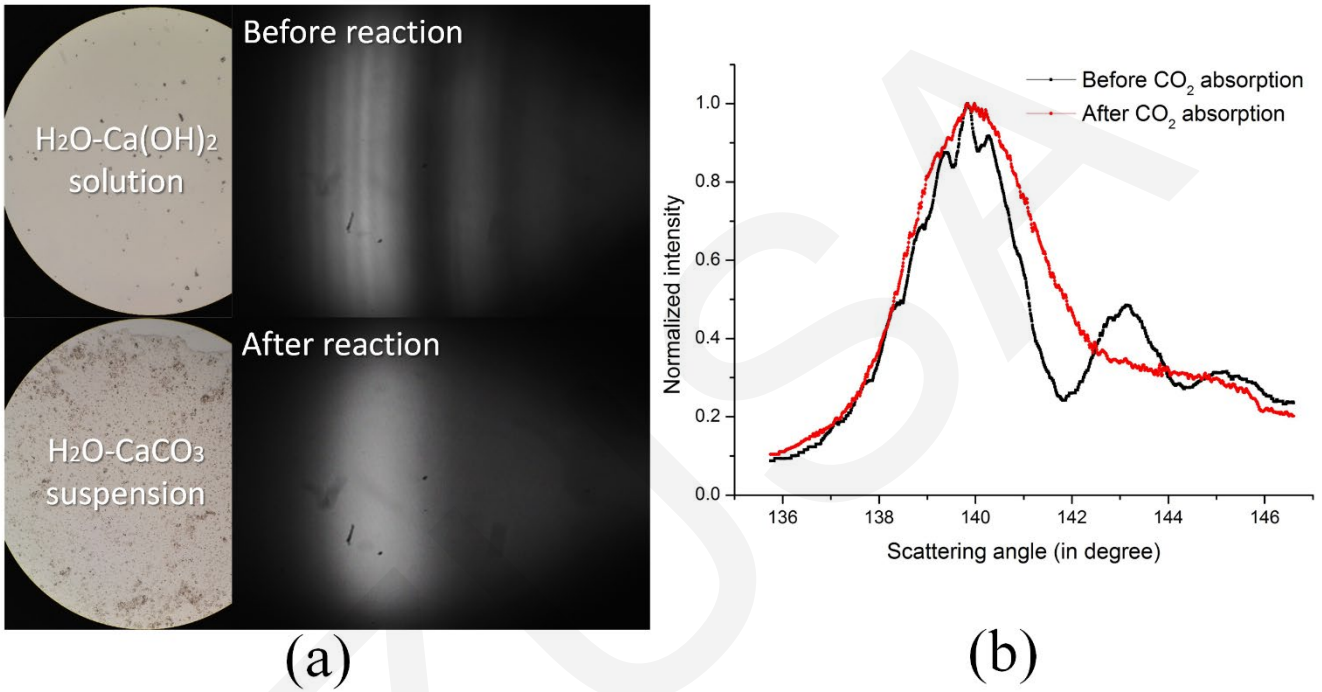


Fig. (a) Rainbow signals for H_2O-$Ca(OH)_2$ solution before and after CO_2 absorption; (b) intensity curves of the rainbow signals

1. Seen from the micrograph that lots of small $CaCO_3$ solid particles of size 1–3 μm appear after the absorption reaction

2. The absorption of CO_2 brings about a significant leftward shift in the increase part of the main peak

Results and discussion

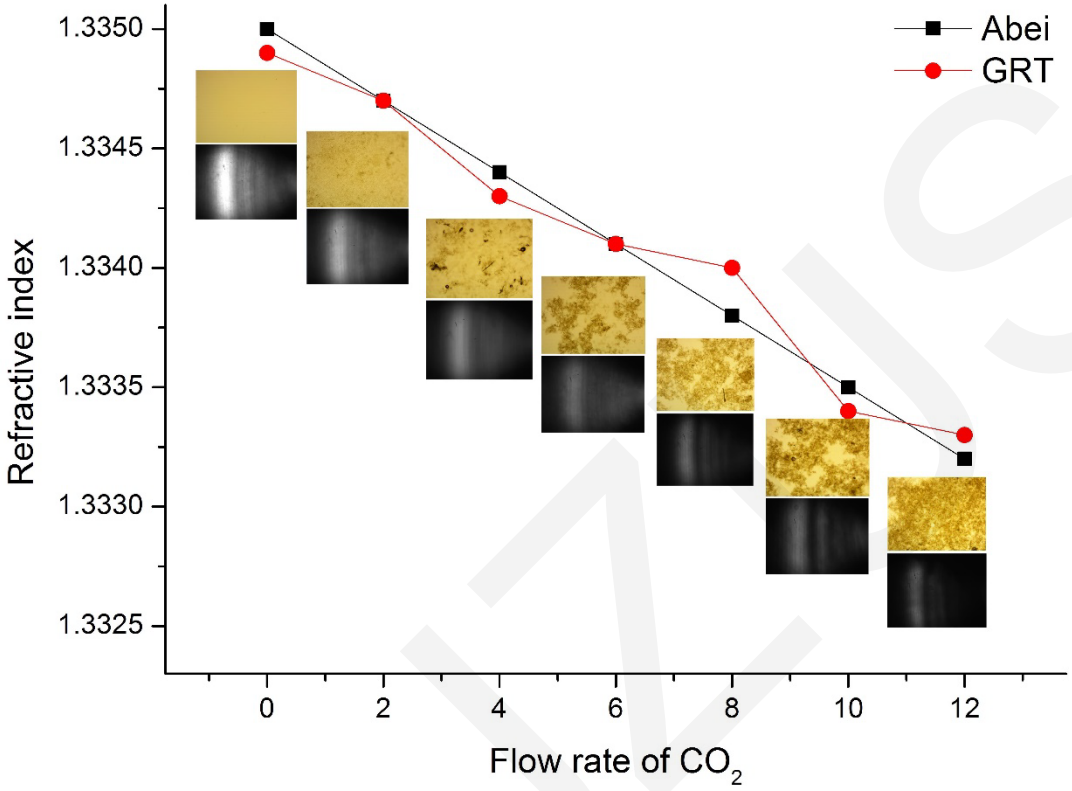


Fig. Rainbow characterization of CO_2 absorption reaction in different processes

2. Refractive index of droplets decreased with the reaction process (CO_2 absorbed by $Ba(OH)_2$), which acted well as an evolution indicator of the reaction

Heat transfer analysis

The heat transfer between a droplet in the falling state and air could be classified as forced convection heat transfer for flow in a single sphere

$$Nu = 2 + \left(0.4Re^{1/2} + 0.06Re^{2/3}\right) Pr^{0.4} \left(\frac{\eta_\infty}{\eta_w}\right)^{1/4},$$

$$\Delta T < \frac{Q_r}{\left(C_V m + h\frac{3m}{\rho d}\Delta t\right)},$$

$$Re = \frac{VD}{\nu}, \quad h = Nu \cdot \frac{\lambda}{D},$$

$$Q_d = h \cdot A \cdot \overline{\Delta T} \cdot \Delta t,$$

$$Q_r - Q_d = C_V m \Delta T,$$

$$A = N \cdot 4\pi d^2 = \frac{m}{\rho\frac{4}{3}\pi d^3} \cdot 4\pi d^2 = \frac{3m}{\rho d},$$

Considering the convection heat transfer between the droplets and the test environment, the temperature increase is less than **0.05 K**. The heat transfer of reaction between $Ba(OH)_2$ solutions and CO_2 can be analyzed in the same way, with a maximum ΔT of less than **0.61 K**.

Conclusions

- ✓ Rainbow refractometry was used to measure the reaction process of a gas-liquid absorption precipitation reaction.
- ✓ A global rainbow experimental measurement system was built for in-situ characterization of the CO2 absorption reaction. A preliminary experiment illustrated the feasibility of characterization of the concentration of Ca(OH)2 solutions by refractive index.
- ✓ After a heat transfer analysis based on a flow in single sphere model, the temperature increase in the measurement volume was estimated to be less than 0.61 K, which was within the measurement accuracy of rainbow refractometry and could be ignored.