Review of Sensors for In-Situ Amine Degradation Monitoring in Post-Combustion Carbon Capture

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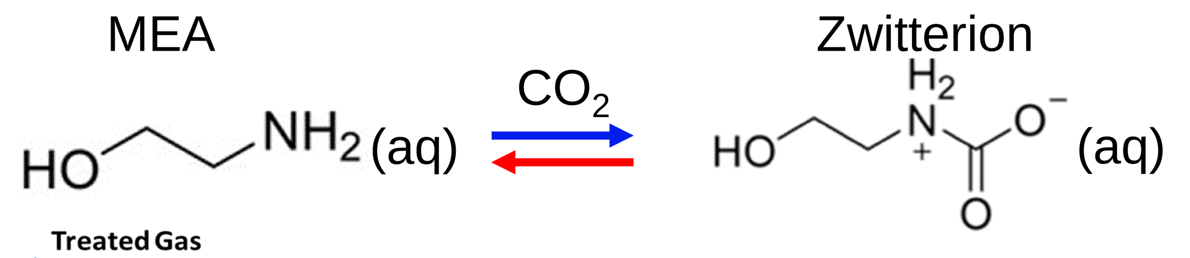
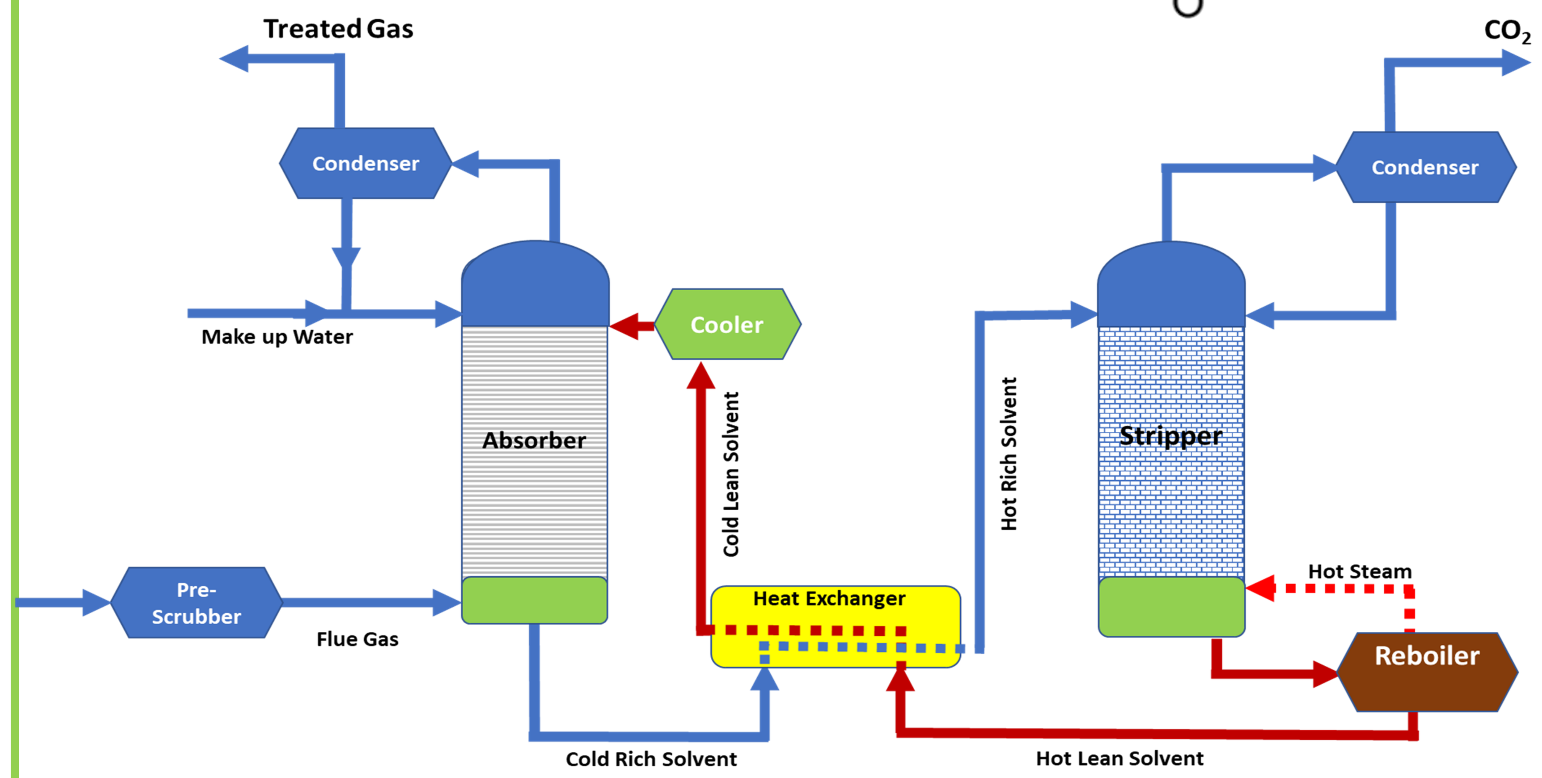
Introduction

- Carbon dioxide emission comes from the chemical combustion process
  - A human-made source is produced in fossil-fuel power plants
- Reducing the CO_2 emissions is paramount
  - Post-combustion carbon capture offers a variety of advantages:
    1. Retrofitted to existing coal fired power plants
    2. Suitable natural gas fired power plants
    3. Power generation can be achieved even if the carbon capture process is down for maintenance
- Chemical absorption is a widely used post-combustion method[1–4]
  - The most common chemical absorbers are amine-based solvent
    - Monoethanolamine (MEA) being the most studied
- Solvent system degrades losing its carbon capture efficiency over time
  - Identifying key indicators of amine solvent degradation will optimize operational control and carbon capture efficiency

Point Source Carbon Capture (PSCC)





Amine Degradation Mechanisms

- Oxidative degradation
  - Absorber and heat exchanger
- Thermal degradation
  - Stripper
- Degradation can be caused by flue gas contaminants
- SOx, NOx, halogenated compounds, hydrocarbons, and other impurities

Amine Degradation Consequences

- Increase the solvent viscosity and surface tension
  - Lead to corrosion, fouling, and foaming
- Reduce capture capacity and efficiency
- Increase costs
  - Monitoring: send samples to laboratories
  - Replenishment of chemicals
  - Equipment and maintenance

Key Parameters for Degradation

Direct Monitoring

Amine Solvent Color Change

- Colorless
  - Pure amines
- Yellow coloration
  - Cyclization, dealkylation, oxidation, oligomerization or coupling
- Dark brown coloration
  - Heat stable salt formation

Figure 2. Examples of an amine solvent system degradation over time.[9]

Amine Concentration in Water

- Viscosity/flow rate, dielectric constant, electrical conductivity

pH Change

- Indicates CO_2 loading; CO_2 dissolution into water; heat stable salt neutralization
- Amine performance indication

Degradation Products Detection

- Nitrate, sulfate salts, nitrosamine, ammonia gas

Indirect Monitoring

Temperature Monitoring

- In the stripper, 100 °C – 160 °C are typical operation temperatures (T) for various amine absorbents
- Degradation increases significantly when T increases
- In the absorber, T changes at different CO_2 loading, and can be used for amine absorption efficiency indicator

O_2 Monitoring

- Oxidative: absorber, cross exchanger
- O_2 concentration: 5-10 ppm in solvents

Monitoring of Flue Gas Contaminants

- SOx, NOx, etc.

Toxic Trace Metal Ion Monitoring

- Trace Metal: Hg, As, Se, Cr

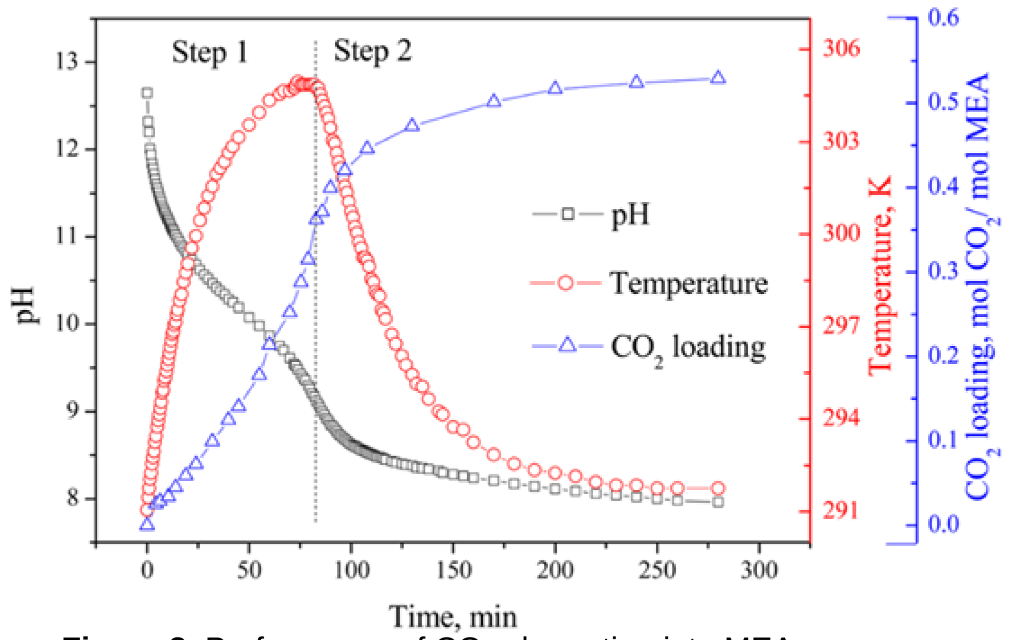


Figure 3. Performance of CO_2 absorption into MEA solution over time.[13]

pH Monitoring

- pH sensing optical fiber for distributed measurements
- Three current options for pH sensitive coatings based on conditions
- Oxides and calcined pH sensitive polymer coatings

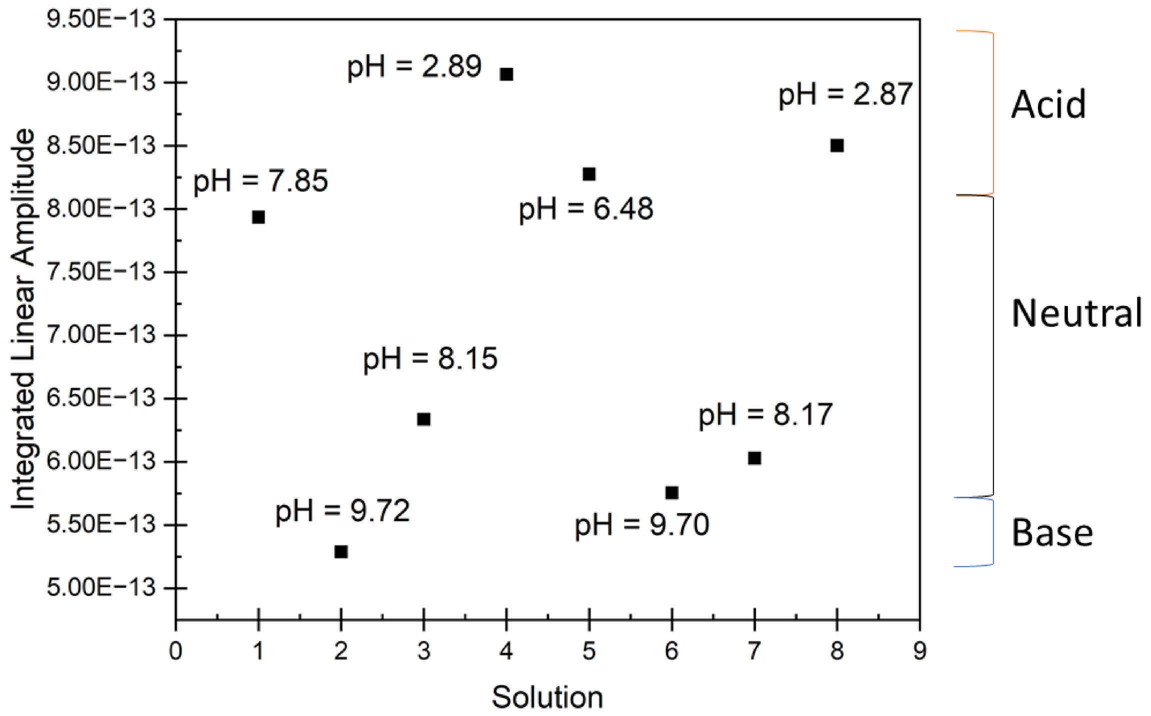


Figure 4. Distributed pH Monitoring at 80 °C.

Colorimetric Analysis

30% v/v MEA

- CO_2 bubbled for two days and heated at 40 °C
- Heated for two days at 120 °C
- 300-600 nm changes in reflection

- Colorimeter operates on reflected light through a bifurcated fiber bundle
- Glass fiber sensor tip is heat and chemically resistant at capture system conditions

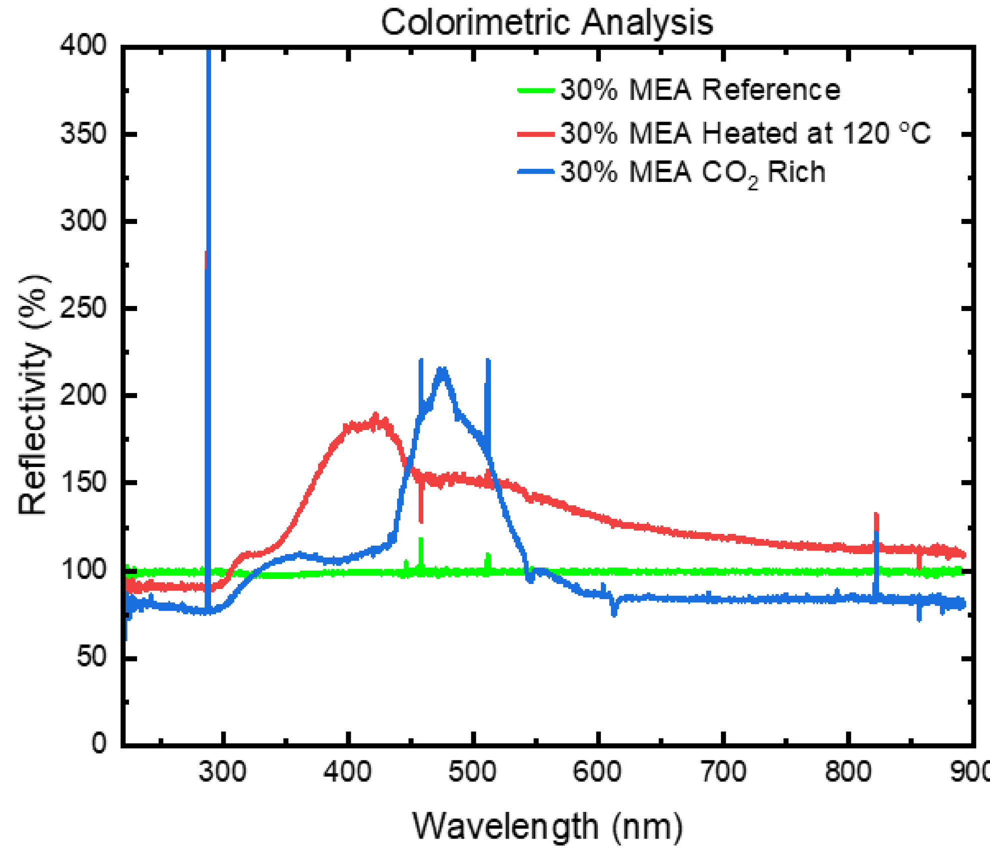


Figure 5. Colorimetric analysis of 30% MEA.

CO_2 Monitoring

- Sorbent matrix coated optical fiber gas sensor
- Good selectivity of CO_2 over other atmospheric gases
- Reversible sensing with rapid response time

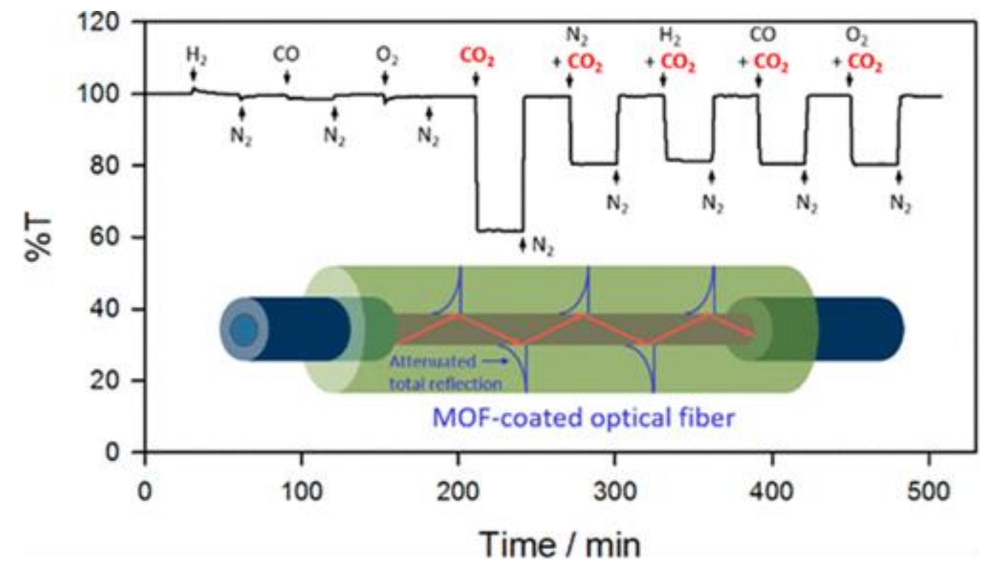


Figure 6. Pictorial representation of a coated MOF optic fiber sensing for carbon dioxide.[10]

Summary

In-situ monitoring with fiber optic sensors can be developed for deployment into the post-combustion carbon capture streams (CO_2 Monitoring, Colorimetric Analysis, and pH Monitoring)

- These sensors will:
  - Reduce operational costs
  - Provide feedback on the carbon capture efficiency and solvent health through:
    - Monitoring the CO_2 capture efficiency in multiple location both in aqueous and gas phase
    - Evaluation of the degradation of the amine solvent system as the color changes
    - Monitoring the loading and unloading of CO_2 for the amine solvent system as the pH changes through cyclization between the absorber and stripper

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