The Massachusetts Institute of Technology:
Taking Charge of Carbon Capture

E-MAR
(Electrochemically-Mediated Amine Regeneration)

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What Does E-MAR Do?

E-MAR, or **E**lectrochemically-**M**ediated **A**mine **R**egeneration, is an entirely new way of performing the desorption and regeneration steps for amine scrubber systems that remove carbon dioxide, CO_2, from industrial flue gases.

Traditionally, desorption has been achieved through heating the amine working solution with steam until the CO_2 is released. The solution's CO_2 sorption capacity is regenerated in a heat exchanger before the solution returns to the absorber.

The heart of the E-MAR system is an electrochemical cell, which performs both the desorption and regeneration of the loaded amine solution under isothermal conditions using targeted electrical energy instead of heat.

Why Do We Need E-MAR?

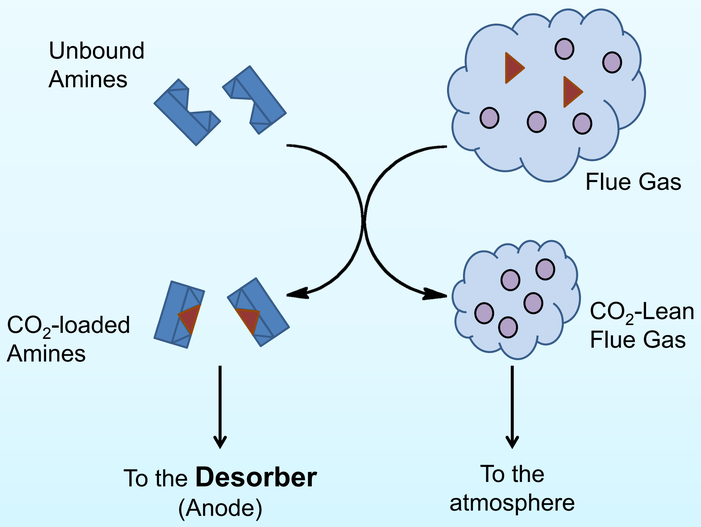
Thermal-swing absorption systems have been unable to meet the efficiency required for carbon capture and sequestration (CCS) to be an economical method of mitigating CO_2 emissions. **E-MAR** has several advantages over traditional thermal scrubbing systems:

- **Direct application of energy for CO_2 release**
  - *No energy used to heat water*
- **High desorption partial pressures of CO_2**
  - *Compressor duty can be reduced by 50%*
- **Drop-in downstream configuration for easy retrofitting**
  - *No rearrangement of the steam turbine chain*
- **Double the per cycle utilization of amines**
  - *Novel desorption strategy allows for near zero loading in lean stream*

E-MAR offers the advantages of an advanced amine scrubbing system with the flexibility of an electrically-based system.

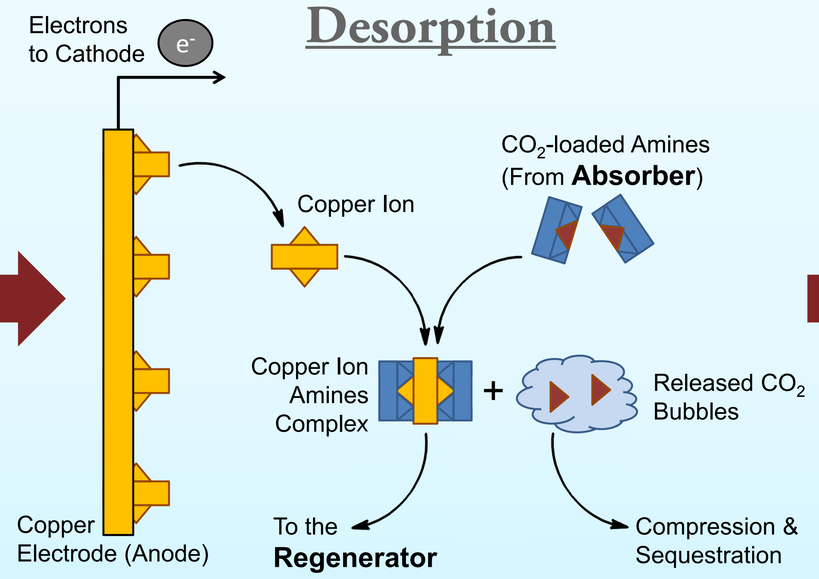
How Does E-MAR Work?

Absorption



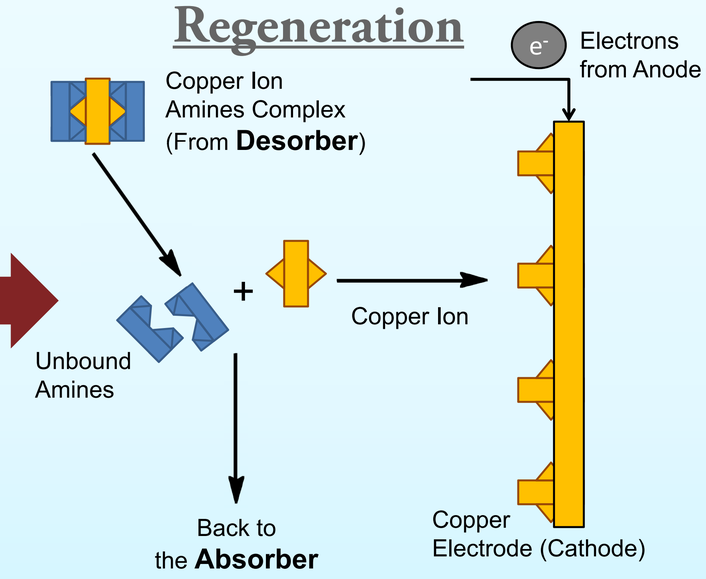
In the absorber, unbound amine molecules contact the flue gas and remove about 90% of the CO_2 before releasing the lean flue gas out the stack to the atmosphere. The CO_2 loaded amine solution then goes to the desorber.

Desorption



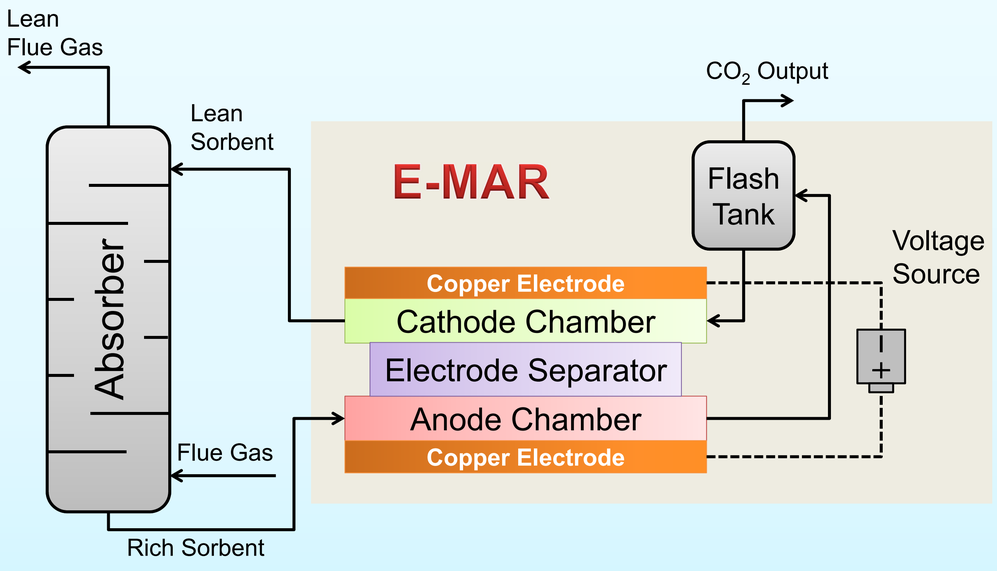
In the desorber, the copper cathode is oxidized dissolving copper ions into the working solution. These ions then bind with the CO_2 loaded amines and release the CO_2. The complexed amine solution then goes to the regenerator.

Regeneration



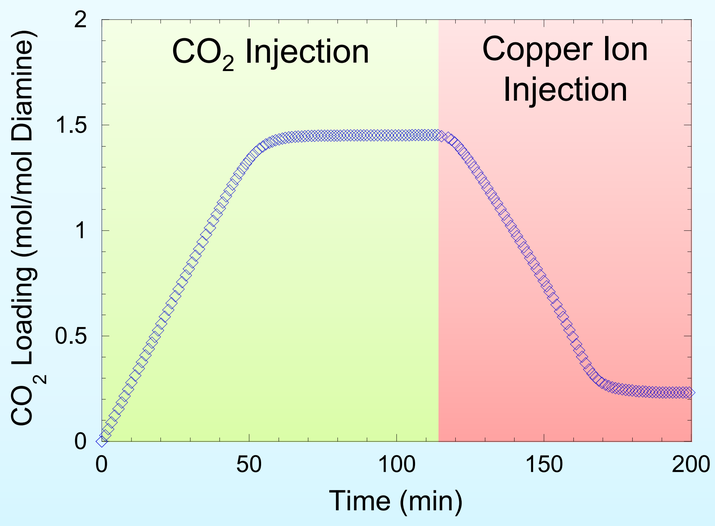
In the regenerator, the complexed amine solution contacts the copper anode. The anode is reduced causing the copper ions to electroplate onto the surface. The unbound amines then return to the absorber to capture more CO_2.

CO_2 Removal Using E-MAR

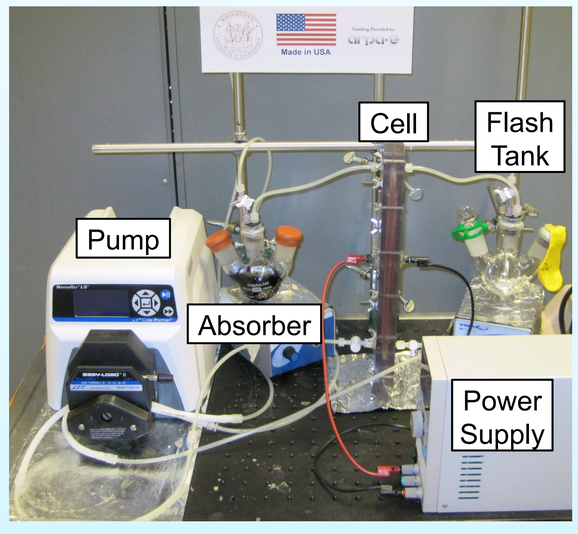


The full scrubbing process consists of a gas absorber in series with the **E-MAR** system. The amine-based working solution cycles between the two units. The main energy input comes from the voltage source powering the electrochemical cell. Pumps and other small auxiliaries are not shown.

E-MAR in the Real World



Carbon dioxide is bubbled through an amine solution until saturated. Over 93% desorption of the carbon dioxide is achieved through the injection of copper ions into the CO_2 saturated amine solution.



A bench-scale **E-MAR** system capable of capturing 40 sccm of carbon dioxide has been constructed and is being tested at MIT. Initial results have demonstrated proof of concept.