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Optimizing the Tier 2 Carbon Capture Process

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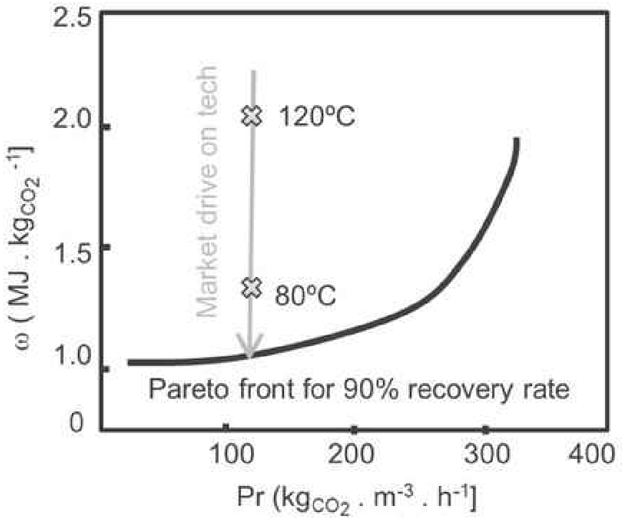
BATTELLE

Tier 2 Carbon Capture is critical to Climate Resilience

- Tier 2 sources comprise ~90% of the addressable CCUS sources
  - Fossil-fuel power generation
  - Cement, steel, chemical, … production
  - Hydrogen generation
- DOE Industrial Carbonization Roadmap:
  - "Industrial CO2 capture capacity needs to increase substantially and at an unprecedented rate in a future with CCUS as a meaningful decarbonization approach."
  - "CCUS technology could also benefit from … better process designs to bring higher efficiency levels, lower costs, and lower material consumption or waste production."

Opportunities to make Tier 2 Capture viable

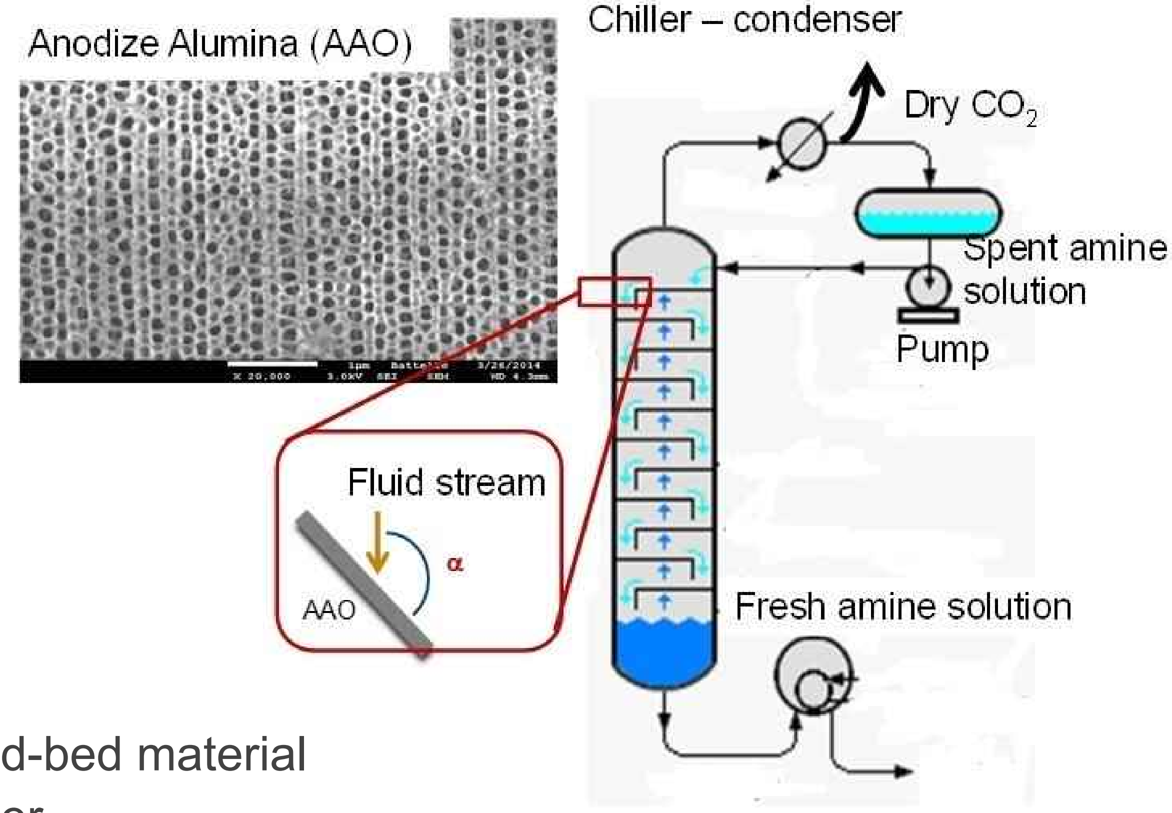
- Current process for **CO_2 capture at industrial sites**
  - **Amine absorption**: Absorbing column > desorption of CO_2 > amine regeneration
  - High temperature (~120^{o}C) for desorption results in **excessive energy cost**.
- Alternative processes have inherent disadvantages
  - Adsorption – Low sorption energy materials reduce regeneration temp but also CO_2 capture efficiency
  - Membrane – Low pressure of flue gas (~1atm) and relatively low CO_2 concentration (~15%) limits effectiveness
  - Both require flue gas drying prior to capture
- Amine Absorption Process Improvements
  - Implement design features to improve regeneration efficiency
  - Alternative sorbent solutions reduce regeneration temperature but capture efficiency is a challenge



Goal of this Research: Develop and implement novel desorption column media that **significantly reduces regeneration temperature**, and hence energy, of the desorption process; while **maintaining capture efficiency**

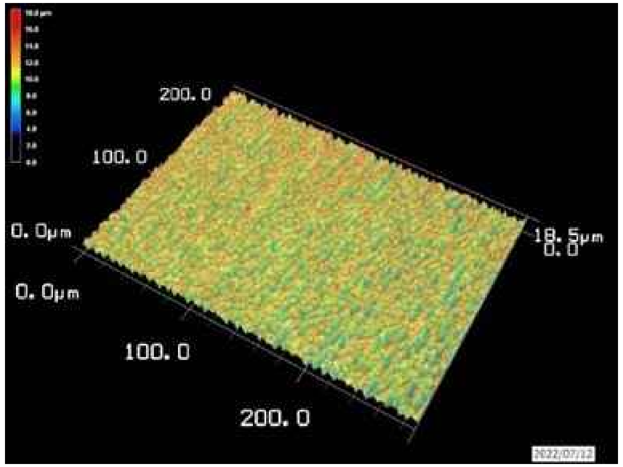
Battelle’s approach to reducing desorption energy

- Apply a multi-scale, nano-structure surface onto desorption column random packing material or regenerator trays
- Allows desorption temperature to be reduced to ~80°C.
- Benefits of reduced desorption temperature
  - Significant energy savings
  - Extended amine solution life
  - Reduced capital costs
- Critical Parameters
  - Interfacial Energy – affects nucleation as well as bubble growth and detachment
  - Surface Morphology (e.g. nano-pits, roughness) – affects nucleation
- Technical Challenges
  - Selection of the best architecture/media for the tower
  - Developing an effective anodization process for packed-bed material
  - Thermal effects of using aluminum in a desorption tower

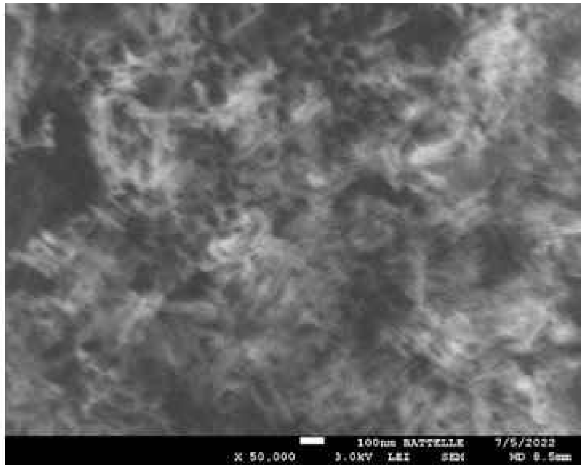


Experimental Results - Surface characterization

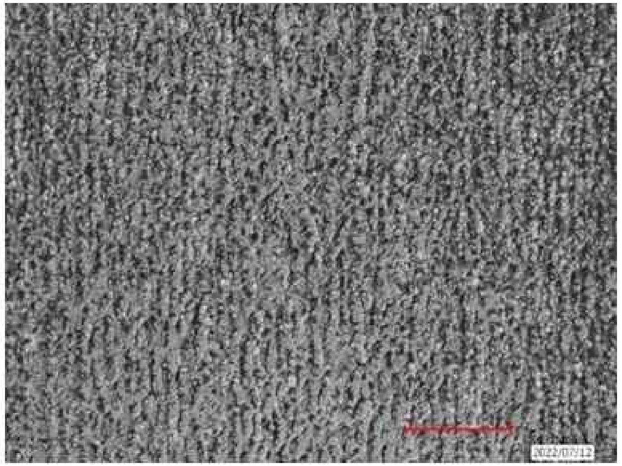
- “Porous anodized aluminum surface” (aka AAO) – oxide materials formed by anodizing aluminum in the presence of an acid create a uniquely structured surface identifiable by regular porosity
- Coating structures were assessed by
  i. Scanning electron microscopy (SEM)
  ii. Laser scanning microscopy (LSM)
  iii. Raman spectroscopy
- Surface properties of the AAO (see table) promote wicking and acceleration of the release of CO_2



3D optical profilometer



SEM images



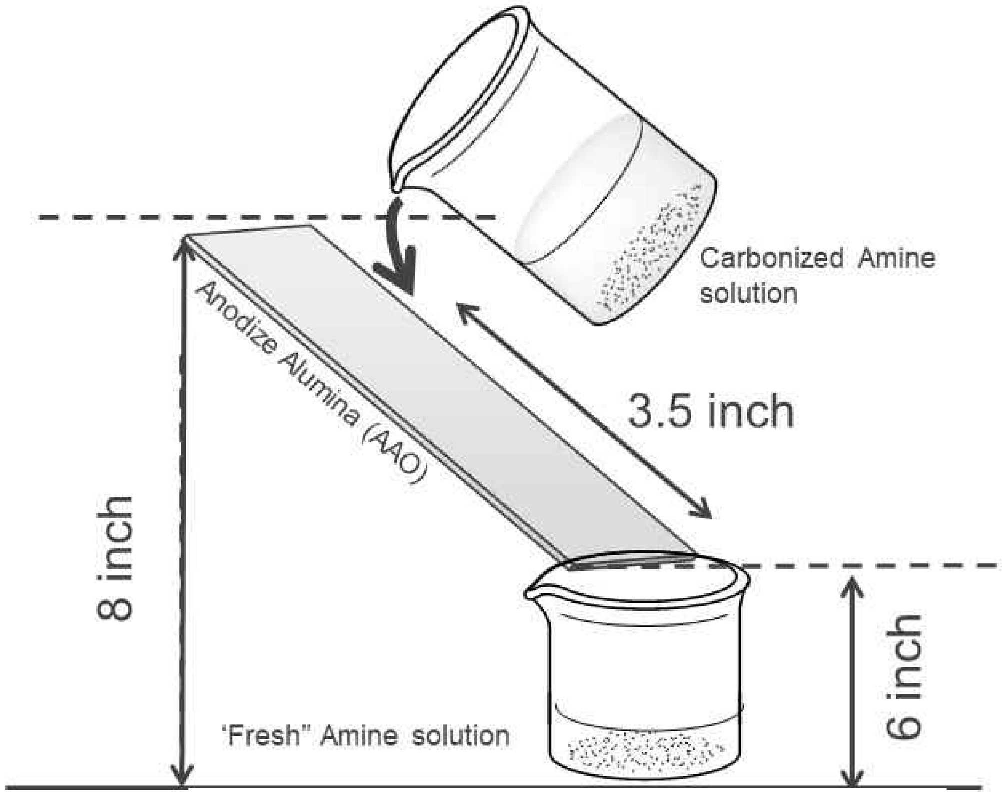
Optical Images

Properties	value
CA	< 5°
Ra (roughness)	2.8 um
Rz	27 um
Efficiency	87%

Experimental Results

- Pour tests conducted with AAO coupons to determine desorption efficiency at 40ºC, 80ºC, 100ºC
- Test coupon temperature maintained using heat tape
- CO_2 in amine solution measured with a Chittick apparatus

Coupon	Temp	Efficiency	CA (º)	Roughness
Bare 1xxx	80ºC	15 ± 10	95 ± 3	Ra < 0.4 um
AAO – 1xxx	100ºC	15 ± 10	< 5	Ra ≈ 2.8 Rz = 25 um
	80ºC	87 ± 10		
	40ºC	45± 10		
AAO – 6xxx	80ºC	78 ± 10		Rz = 19 um

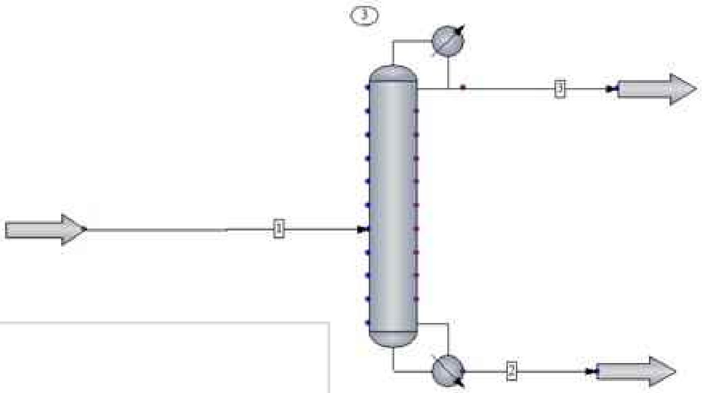


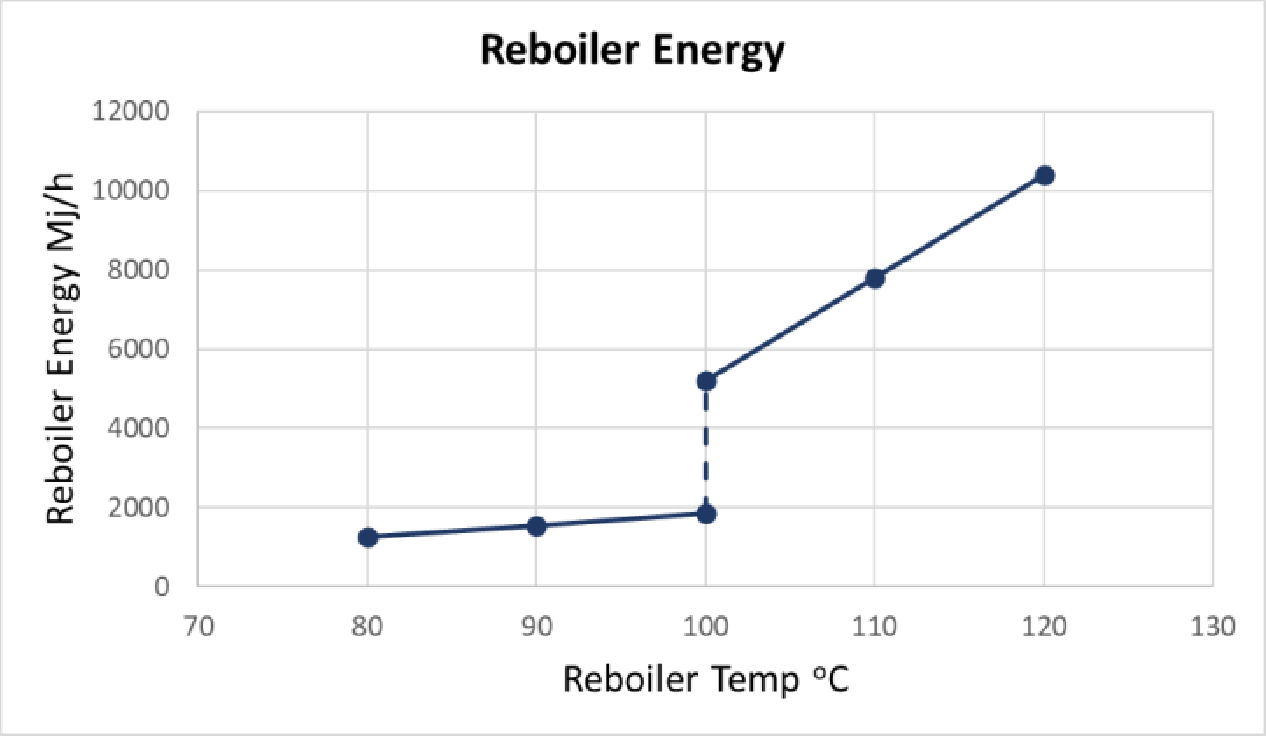
Direct pouring Setup

The multi-scale-structure obtained through anodization enables effective CO_2 desorption at 80ºC and atmospheric pressure.

Desorption Process Economic Analysis

- Modeled desorption process to determine reboiler energy for column operation at 120°C (current practice) and 80°C
- Analysis indicates that first-pass energy requirements are reduced by approximately 90% for the base system
- Planned enhanced modeling will include secondary cost savings:
  - Reduced capital costs
  - Extended amine lifetime





Future Work

- Prototype desorption column fabrication and testing – prove that we can desorb at low temperature
- Supporting analyses
  - Thermal FEA,
  - Enhanced performance and economic analysis
  - Scale-up requirements analysis
- Long-term stability of material
- Scale-up and design optimization