SURFACE EFFECTS ON THE SORPTION KINETICS AND NANOSTRUCTURE OF CO2 CAPTURE SOLVENT THIN FILMS

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ABOUT ME

- Name: Muriel M. Sandoval Vázquez
- School: University of Texas at El Paso (UTEP)
- Major: BS in Geological Sciences
- Classification: Going into my last year (senior)

- Time in UTEP:
  - CHRES Program
    - Surface Effects on the Sorption Kinetics and Nanostructure of CO2 Capture Solvent Thin Films
  - Undergrad Research:
    - Timing and origin of Y + HREE-enriched magmatism at the eastern shoulder of Rio-Grande rift, Sierra Blanca, Hudspeth, Texas
  - Officer and member of:
    - Association for Women Geoscientist (AWG) Sun City Chapter – Treasurer
    - Geology Club/ Sigma Gamma Epsilon – Treasurer
    - Planetary Science Club (PSC) – Co-founder/President
    - Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) – Member

PROJECT IMPORTANCE

- This project was developed to find possible methods that will cost less then \$100 per ton to capture CO_2 from the atmosphere.
- Water lean solvents (WLS) are known to be very good at capturing CO_2 from power plants.
- We also want to understand more properties of this WLS such as rate of absorption at the nanomolecular level.
- Findings of this study will be able to help research into modifying the WLS to work as efficiently for the atmosphere as they are to power plants.

BACKGROUND

- Global warming, a pressing and intricate environmental issue, refers to the gradual rise in Earth's average temperature caused primarily by human activities.
- The emission of greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, traps heat in the atmosphere, leading to the intensification of the greenhouse effect.
- The consequences of global warming are far-reaching and alarming.
  - Melting polar ice caps
  - Rising sea levels
  - Extreme weather events

Waggonwaybreen glacier in Svalbard, Norway

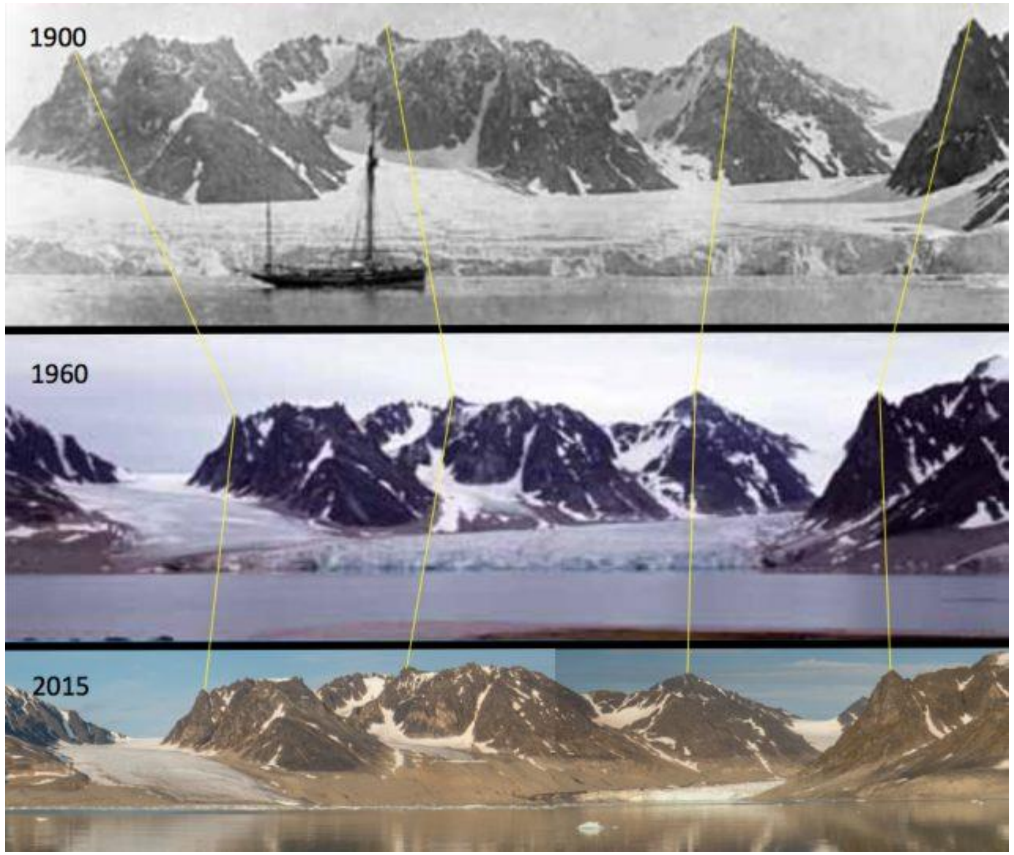


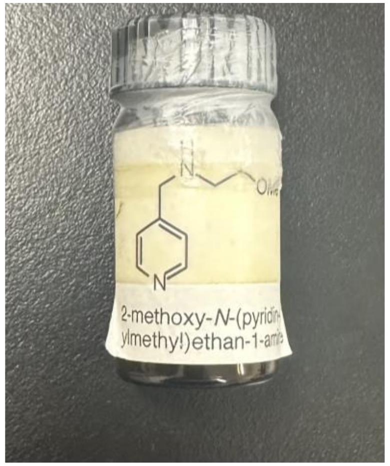
Photo: Andreas Weith

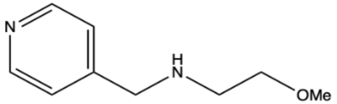
Houghton, J. (2005). Global warming. *Reports on Progress in Physics, 68*(6), 1343-1403. 10.1088/0034-4885/68/6/R02

BACKGROUND: WLS

- Water-lean solvents are a mixtures between an organic diluent and an amine. These solvents are known to enhanced mass transfer properties, increased absorption capacities, and lower regeneration heat duties.
- The Water Lean Solvents (WLS) solvents that have a similar density to that of water (approximately 1 g/cm^3) used in this experiment are:
  - N-(2-ethoxyethyl)-3-morpholinopropan-1-amine (2-EEMPA)
  - 2-methoxy-N-(pyridine-4-ylmethyl)ethan-1-amine (Para).
  - 2-methoxy-N-(pyridine-3-ylmethyl)ethan-1-amine (Meta)
  - 2-methoxy-N-(pyridine-2-ylmethyl)ethan-1-amine (Ortho)

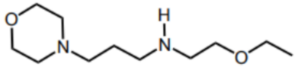
Para





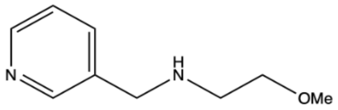
2-methoxy-*N*-(pyridin-4-ylmethyl)ethan-1-amine

2-EEMPA



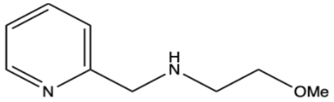
$C_{11}H_{24}N_2O_2$ 2-EEMPA

Meta



2-methoxy-*N*-(pyridin-3-ylmethyl)ethan-1-amine

Ortho

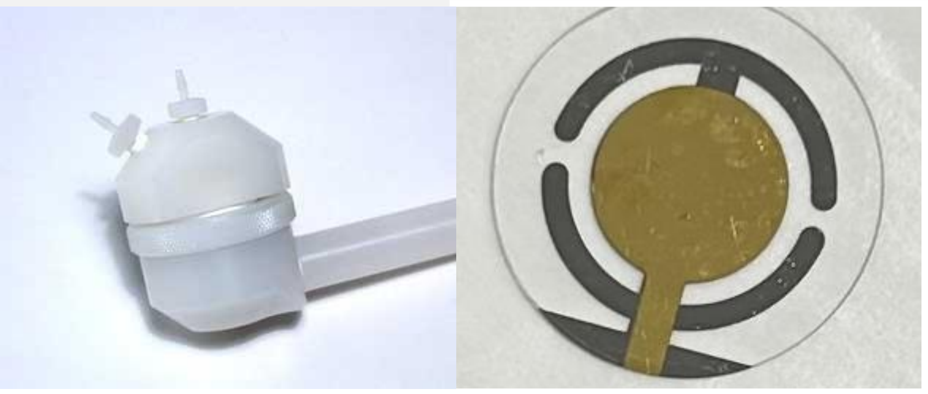


2-methoxy-*N*-(pyridin-2-ylmethyl)ethan-1-amine

Wanderley, R. R., & Knuutila, H. K. (2020). Mapping Diluents for Water-Lean Solvents: A Parametric Study. *Industrial & Engineering Chemistry Research*, *59*(25), 11656-11680. 10.1021/acs.iecr.0c00940

BACKGROUND: QCM

- Quartz Crystal Microbalance (QCM) uses piezoelectric effect to vibrate at a certain frequency
  - In this experiment it vibrates around 5MHz.
- The piezoelectric effect is a phenomenon where specific types of material like quartz produce an electric charge proportional to the mechanical stress applied to them, the geometric strain of these materials is proportional to changes in the applied electric field.
- If mass is added or taken away the frequency of the crystal changes.
- We can observe how a thin layer of certain water lean solvents that are known to capture CO_2, can absorb CO_2 depending on the thickness of this layer.



SRS

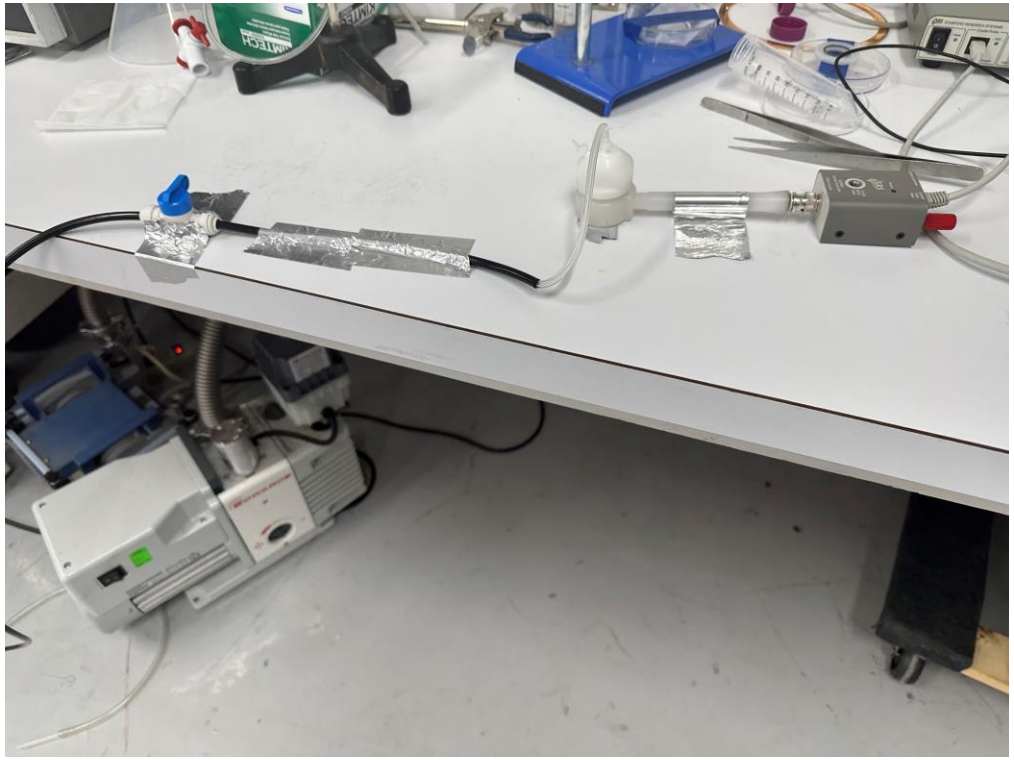
Guler, U., Tufan, T. B., Chakravarti, A., Jin, Y., & Ghovanloo, M. (2015). Implantable and Wearable Sensors for Assistive Technologies. *Reference Module in Biomedical Research* (pp. 449). Elsevier Inc. 10.1016/B978-0-12-822548-6.00072-8

METHODS: QCM EXPERIMENT

- The crystal was placed on the QCM flow cell holder, which is then attached to a hose that lets a flow of gases (CO2 and Nitrogen).
- The QCM then gives a relation between change in frequency over time, which allow us to determine the change in mass absorbed or released from the crystal using the Sauerbrey equation:

$$\Delta F = - C_f \times \Delta m$$

- where C_f is a constant (56.6Hzug-1cm^2 for a 5MHz crystal).

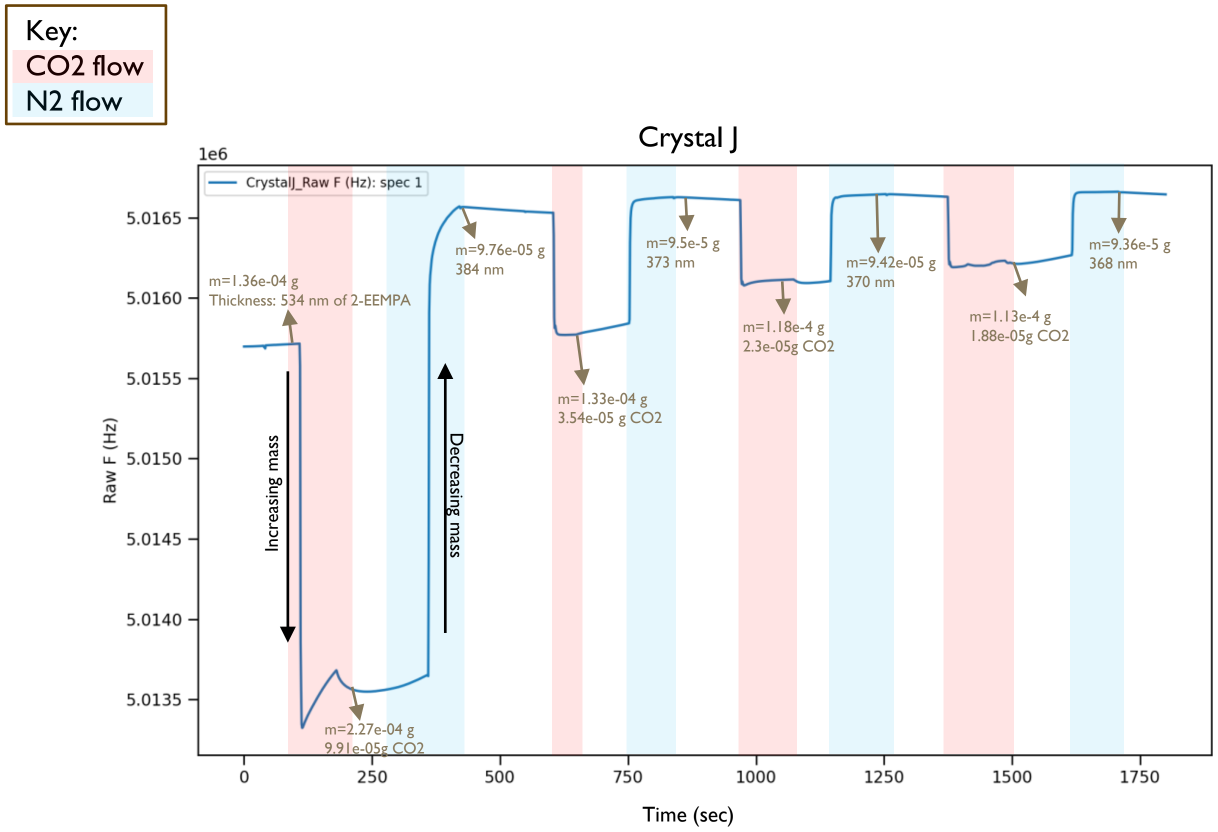


METHODS: SAMPLE PREPARATION

- Using a Laurell Technologies Corporation spin coater to coat the quartz crystals with the water lean solvents at 5000 rpm for 30 seconds.
- The masses before and after coating were calculated to determine the amount of WLS on the surface of the crystals.
- Crystals that were coated in 2EEMPA the average mass was 0.2 mg.
- Crystals that were coated with Para the average mass was around 0.4 mg.

RESULTS

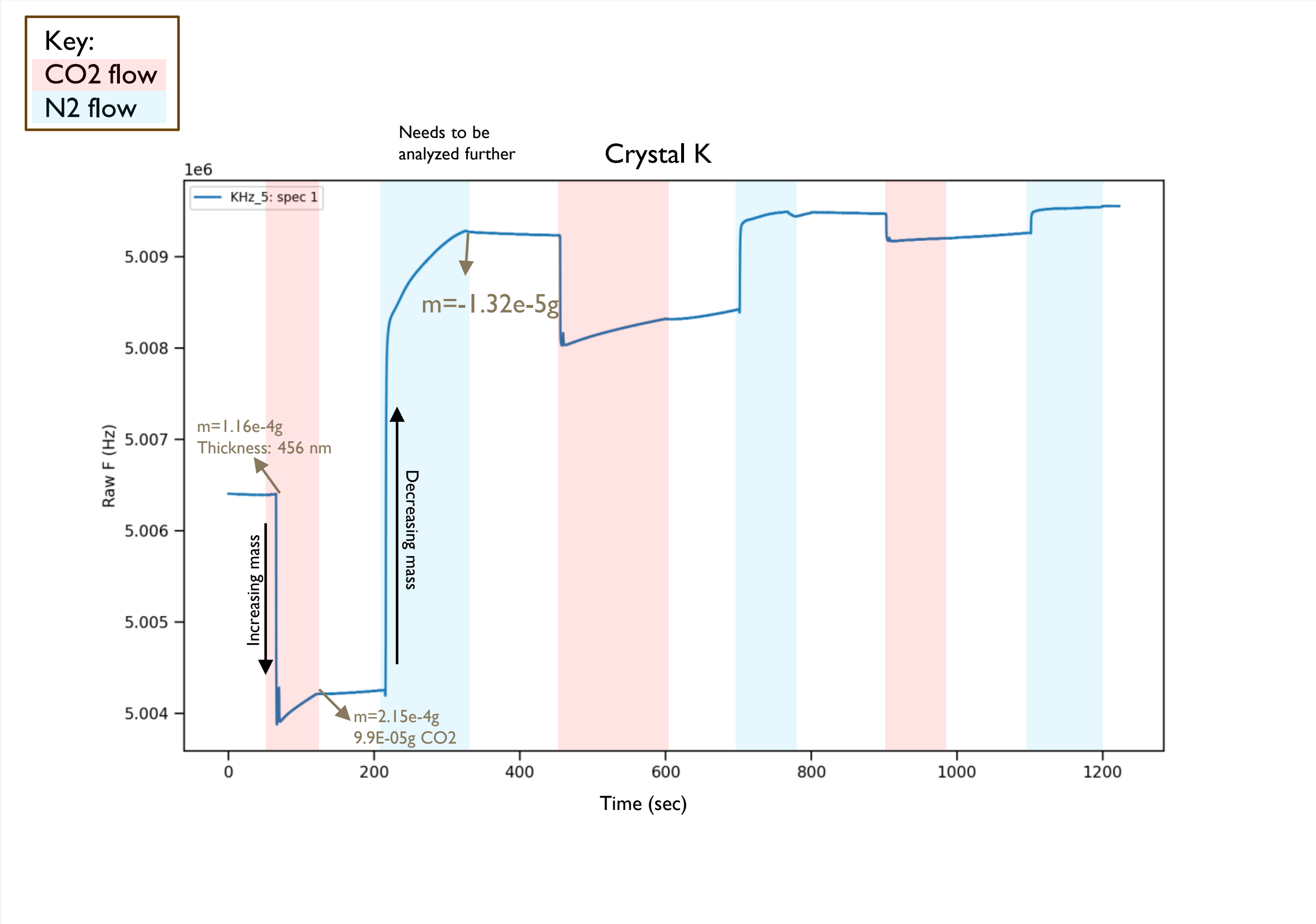
- When the frequency shifts down that indicates a mass increase.
- Frequency shifts up indicates a mass decrease.
- Solvents evaporation needs to be accounted for.
  - Evaporation is minimal



RESULTS OF CRYSTALS WITH 2EEMPA

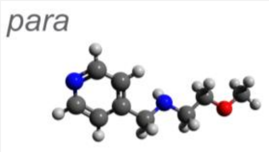
- Crystal J
  - Mass of crystal with no solvent: 439.08 mg
  - Mass of crystal with solvent: 439.35 mg
  - Mass of solvent: 0.27 mg over an area of 5.067cm2
  - Exposed area is 2.54469cm2
  - Exposed mass is 0.136mg or 1.36e-04 g
  - To Find the thickness we used the fact that the density of 2-EEMPA is roughly 1 g/cm3
  - So using d = mass/volume = mass/height*Area and d ~1 then height or thickness ~ mass/area

RESULTS OF CRYSTALS WITH 2EEMPA



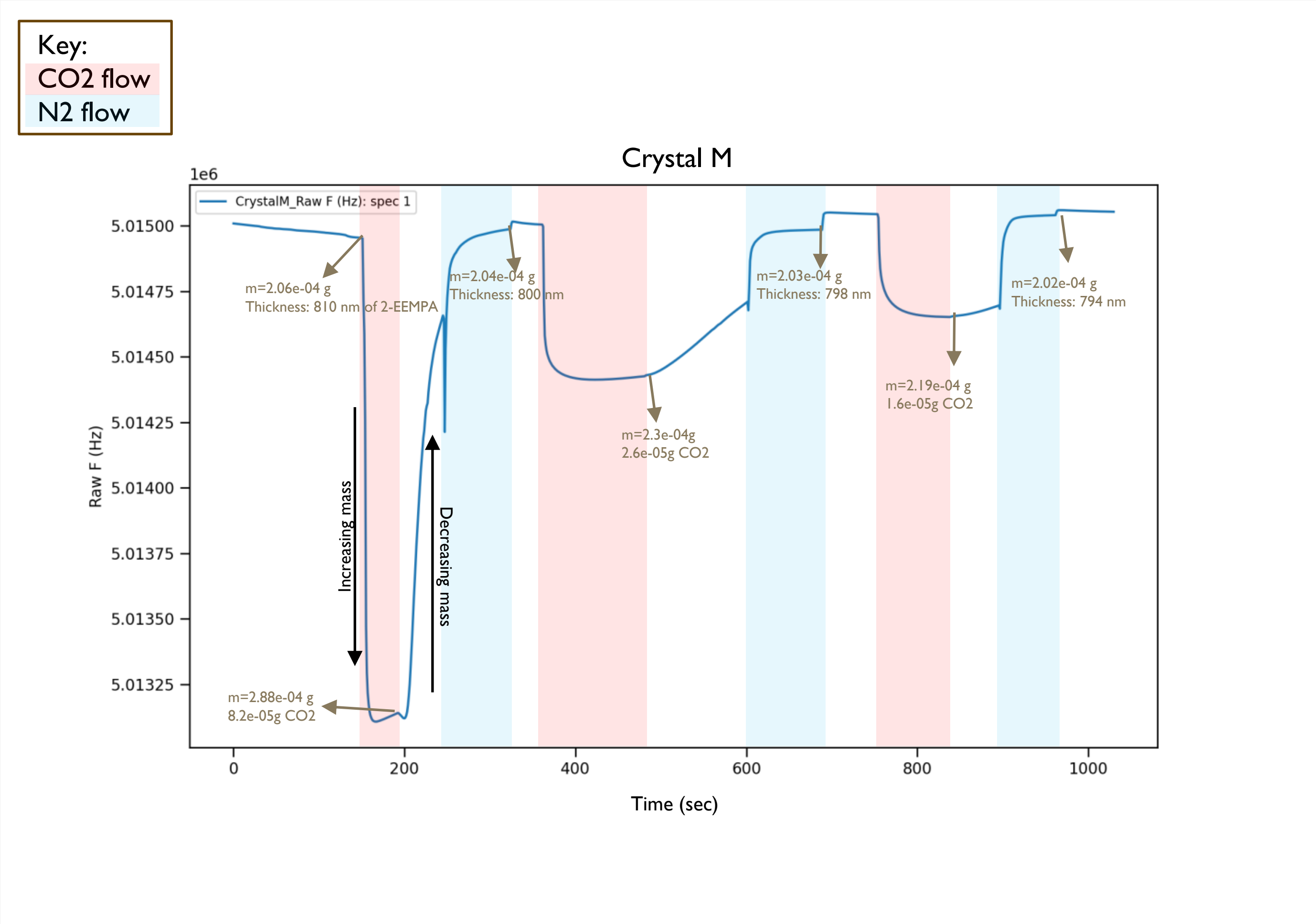
- Crystal K
  - Mass of crystal with no solvent: 439.02 mg
  - Mass of crystal with solvent: 439.31 mg
  - Mass of solvent: 0.29 mg
  - Mass of crystal with solvent after 3 hours: 439.25 mg
  - Mass of solvent: 0.23 mg over an area of 5.067cm2
  - Lost 0.06 mg in 3 hours
  - Exposed area is 2.54469cm2
  - Exposed mass is 0.116mg or 1.16e-04 g

For this trial once we added nitrogen the first time, it is suggesting that we loss all of our CO_2, all of our 2EEMPA and some more mass. Thus, we are not considering this a reliable trial

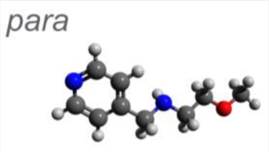


RESULTS OF CRYSTALS WITH PARA

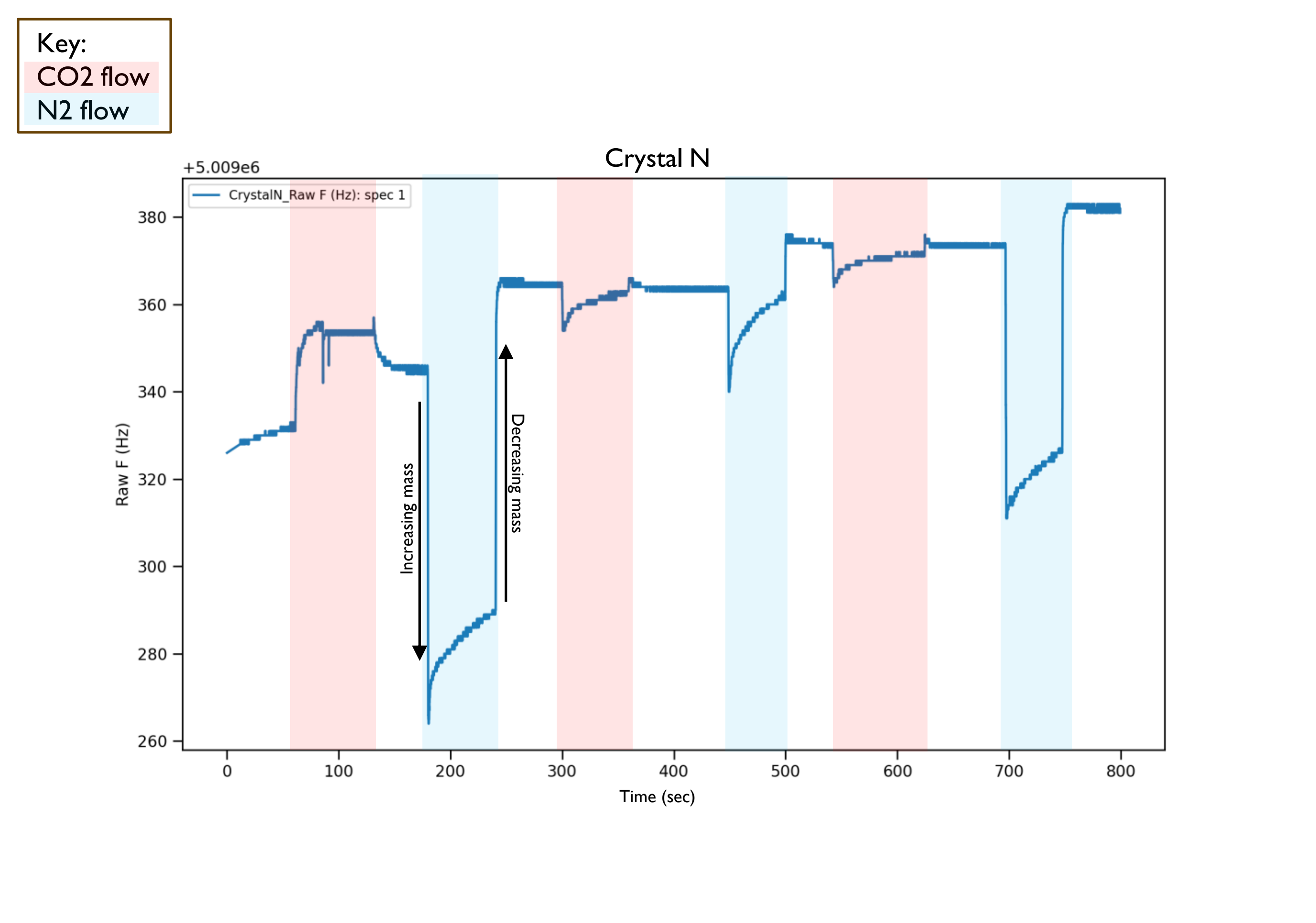
- Crystal M
  - Mass of crystal with no solvent: 439.06 mg
  - Mass of crystal with solvent: 439.47 mg
  - Mass of solvent: 0.41 mg over an area of 5.067cm2
  - Exposed area is 2.54469cm2
  - Exposed mass is 0.206mg or 2.06e-04g
- Has almost twice as much solvent compared to the 2-EEMPA crystals but acted the same.



RESULTS OF CRYSTALS WITH PARA



- Crystal N
  - Mass of crystal with no solvent: 439.01 mg
  - Mass of crystal with solvent: 439.43 mg
  - Mass of solvent: 0.42 mg
  - Mass of crystal with solvent after a day: 439.09 mg
  - Mass of solvent: 0.08 mg over an area of 5.067cm2
  - Lost 0.34 mg overnight
  - Exposed area is 2.54469cm2
  - Exposed mass is 0.04mgor 4e-05g
  - Max: 5009383 Hz
  - Min: 5009264 Hz
    - Diff: 119 Hz
- Rate of evaporation is higher than that of the 2-EEMPA
- Did the opposite of previous crystals.
  - Could be because there is not enough solvent on the crystal.
  - Perhaps the 0.08 mg that are on the crystal are from the air humidity.



CONCLUSION

- QCM shows that the 2EEMPA absorbs CO_2 much faster than Para.
- Even though Para has more mass of solvent the 2EEMPA gained more CO_2 mass.
- Working on analyzing and fitting models for the equilibration rates under both CO_2 exposure and Nitrogen exposure.
- Working on comparing results to see if there is an influence of having the different thickness films on the quartz crystal.
- Working on studying the 2EEMPA and the other solvents more and how to make a better set up for the study that will give us more precise results.

NEXT STEPS

- Further analyze the data to fully understand the differences between the solvents and the different thicknesses.
- Study the other WLS (meta and ortho) and compare them to the 2EEMPA and Para.
- See if results can be replicated.
- Try new set ups for the QCM to see if the results are more precise, since the QCM is very sensitive.

ACKNOWLEDGMENTS

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U.S. DEPARTMENT OF ENERGY | Office of Science

THANK YOU!

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DE-NA0003982

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