Exploring the Phase Behavior and State of Wildfire BBOA

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October 4, 2023

Introduction

Wildfires are a major source of organic aerosols, which can affect the climate and our health.

Wildfire frequency and intensity is increasing in many parts of the world due to climate change.[1]

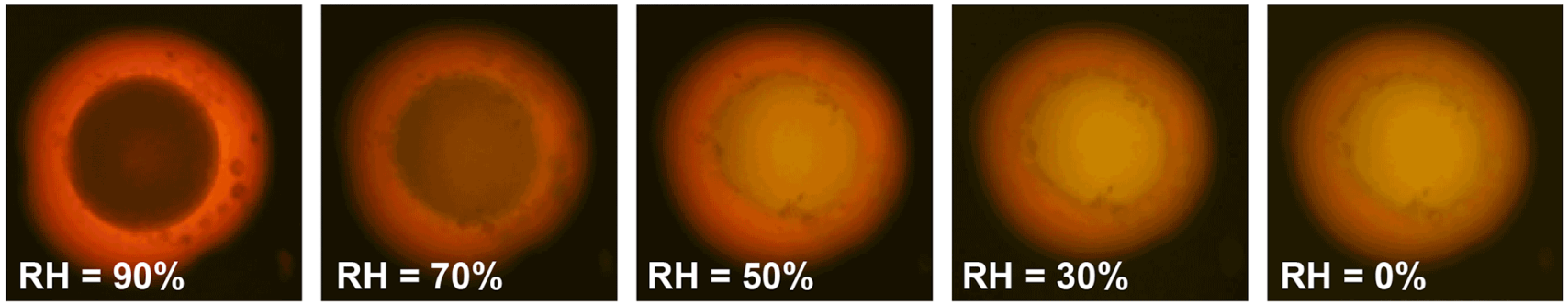
The amount of land burned by extreme fires is expected to increase by 50% by 2100.[2]

We need to understand the physical properties of BBOA to model them properly and get accurate predictions of air quality and climate.

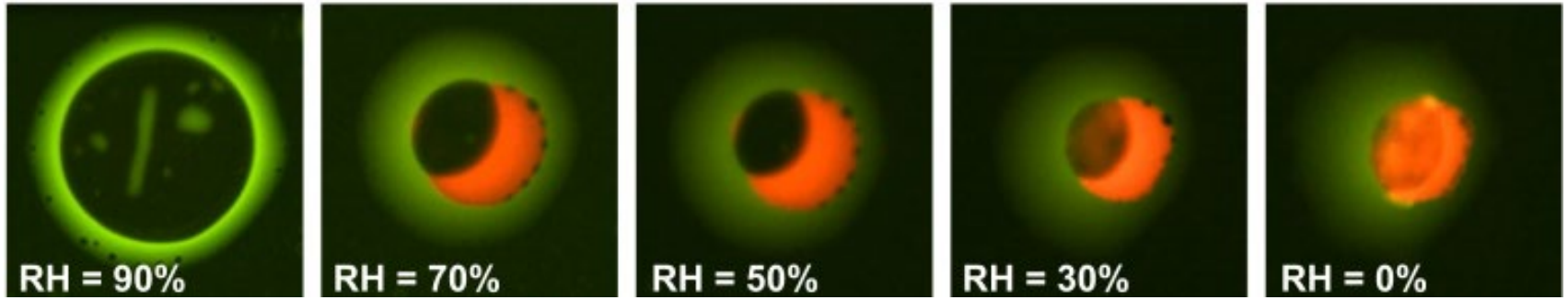
[1] IPCC AR6, 2021
[2] UN Environment Programme report, 2022

Phase Separation in Organic Aerosols

Organic aerosols can separate into two (or three) distinct phases in one particle if large differences in polarity exist.



2 phase SOA mixtures, Mahrt et al. (Atmos. Chem. Phys., 2022)



3 phase SOA + POA + inorganic, Huang et al. (PNAS, 2021)

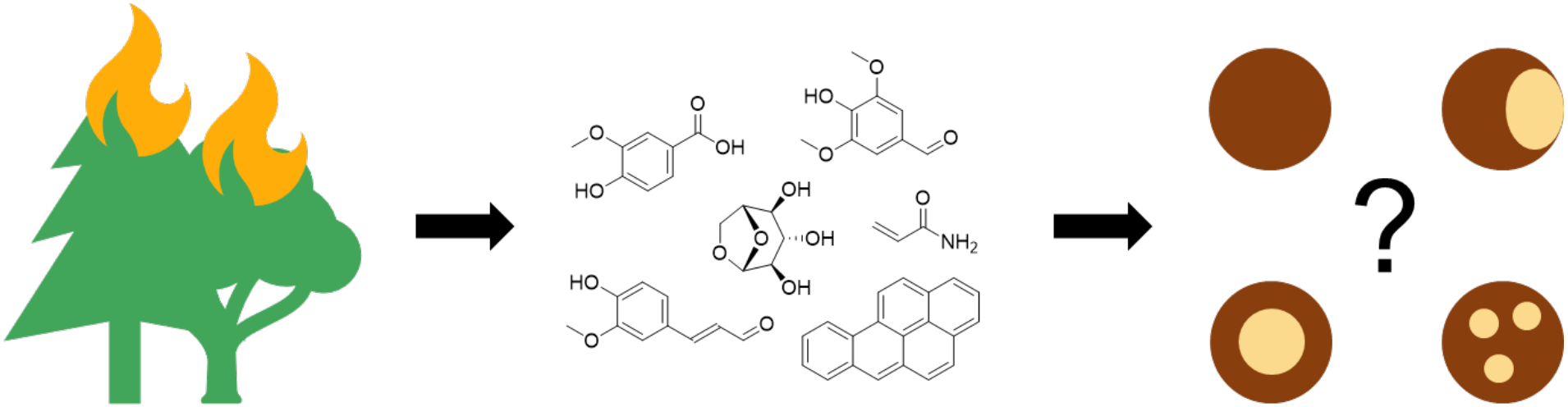
Phase separation can influence:*

- Gas/particle partitioning
- Reaction rates
- Cloud condensation
- Optical properties

*Reid et al., Phys. Chem. Chem. Phys. 2011

Phase Separation in Biomass Burning Aerosols?

Biomass burning generates a wide range of compounds with varying polarities, which might not mix.



Jahn et al. showed BBA with 2 organic phases on TEM (*ACS Earth Space Chem.* 2021)

Li et al. separated wood-tar into polar and non-polar phases (*Atmos. Chem. Phys.* 2019)

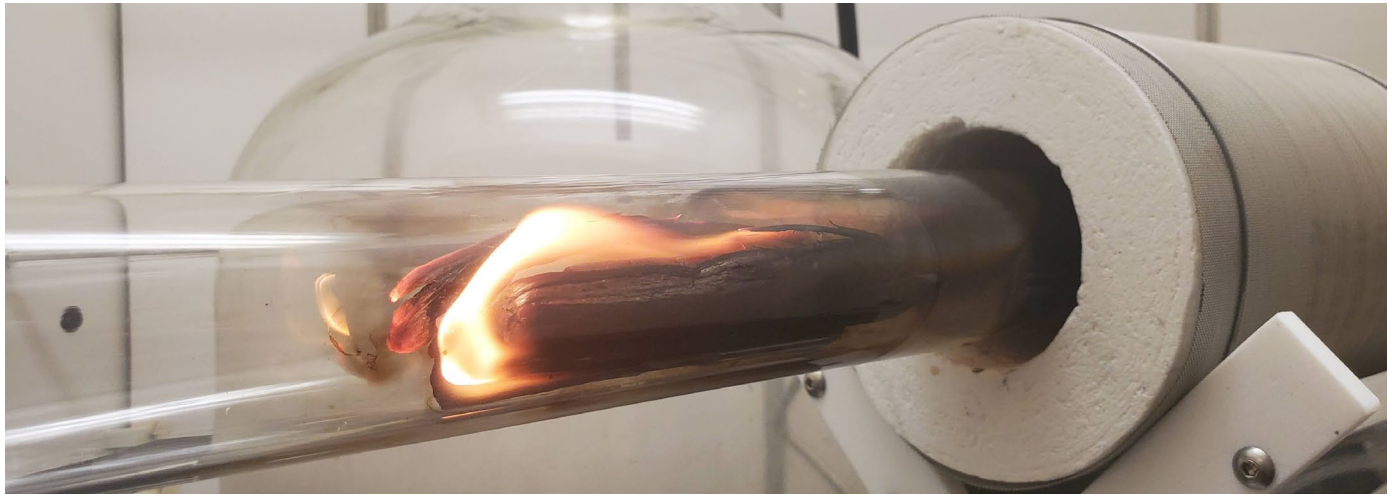
Lab Generated smoke

Pine chips lined up in flow tube, heater moves down the track at 1 cm min^{-1}

Flow rate of 2 L/min through tube, and 30 L/min into the dilution volume.

Smoldered at 300 °C

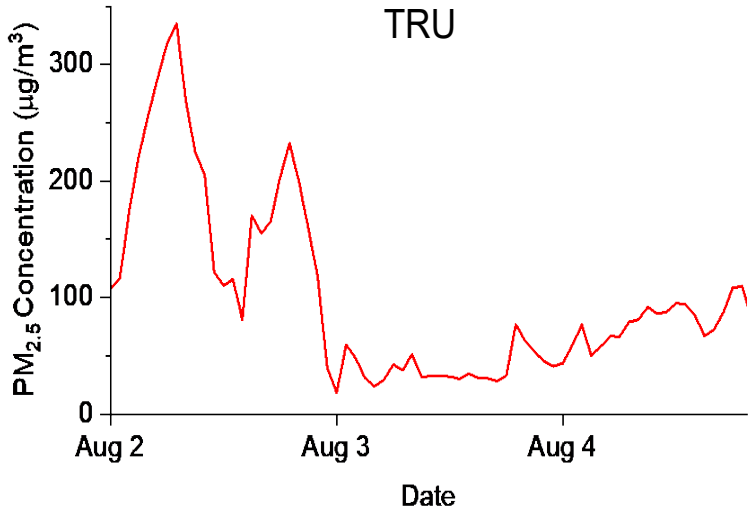
Collected on PTFE filters.

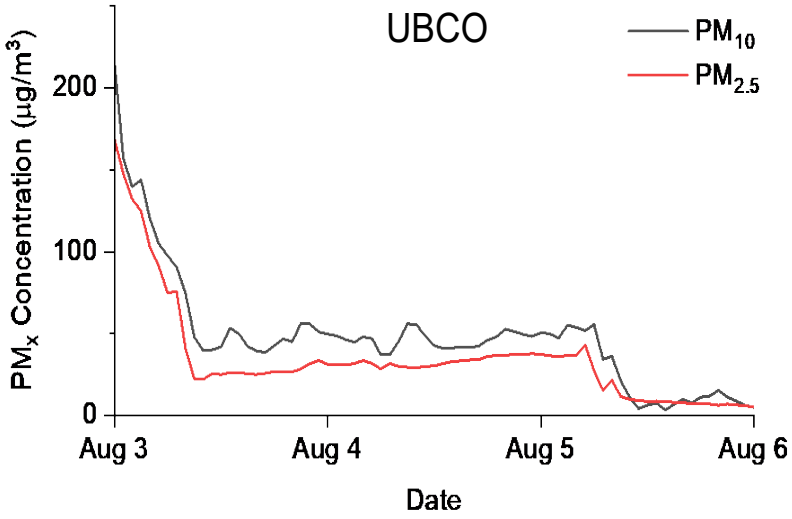


Flow tube with flames for dramatic effect

Field Sampling

Collected air from UBC-Okanagan (UBCO) in Kelowna and Thompsons Rivers University (TRU) in Kamloops during heavily wildfire-influenced days.





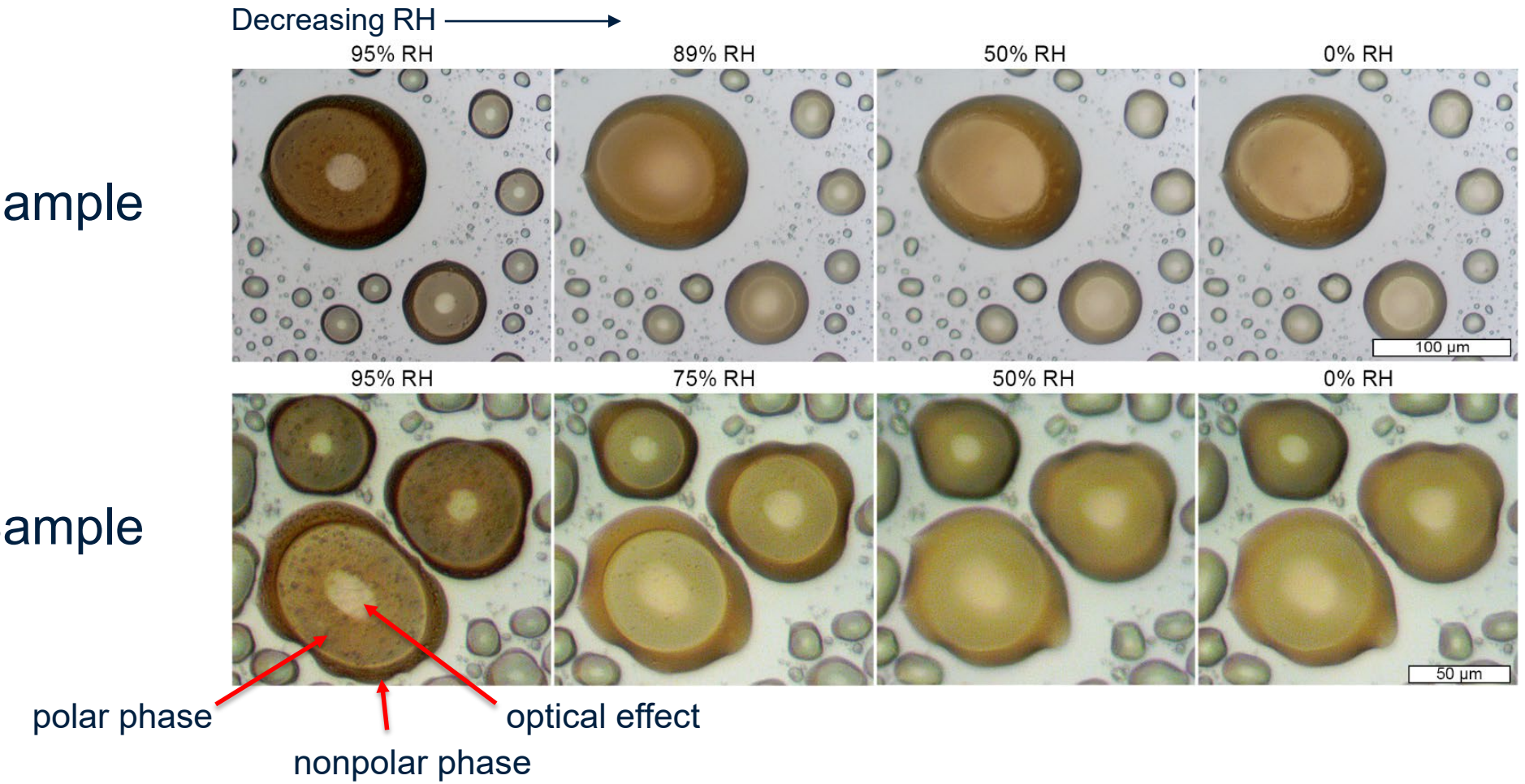
BBOA Extraction

- Extracted in 50% methanol, 50% water.
- Extract filtered to remove black carbon and other insoluble materials.
- BBOA extracts were nebulized and collected on microscope slides in an impactor
    - Droplets 1~100 um in diameter.
    - Larger than most aerosols in the atmosphere, but necessary for viewing on the microscope.
- Placed in humidity-controlled flow cell and viewed at RHs from 0 to 100% on a microscope.

Phase Separation

All samples showed 2 phases at all RHs.

The inner phase changes at high RH, suggesting it is the more polar/hygroscopic phase.

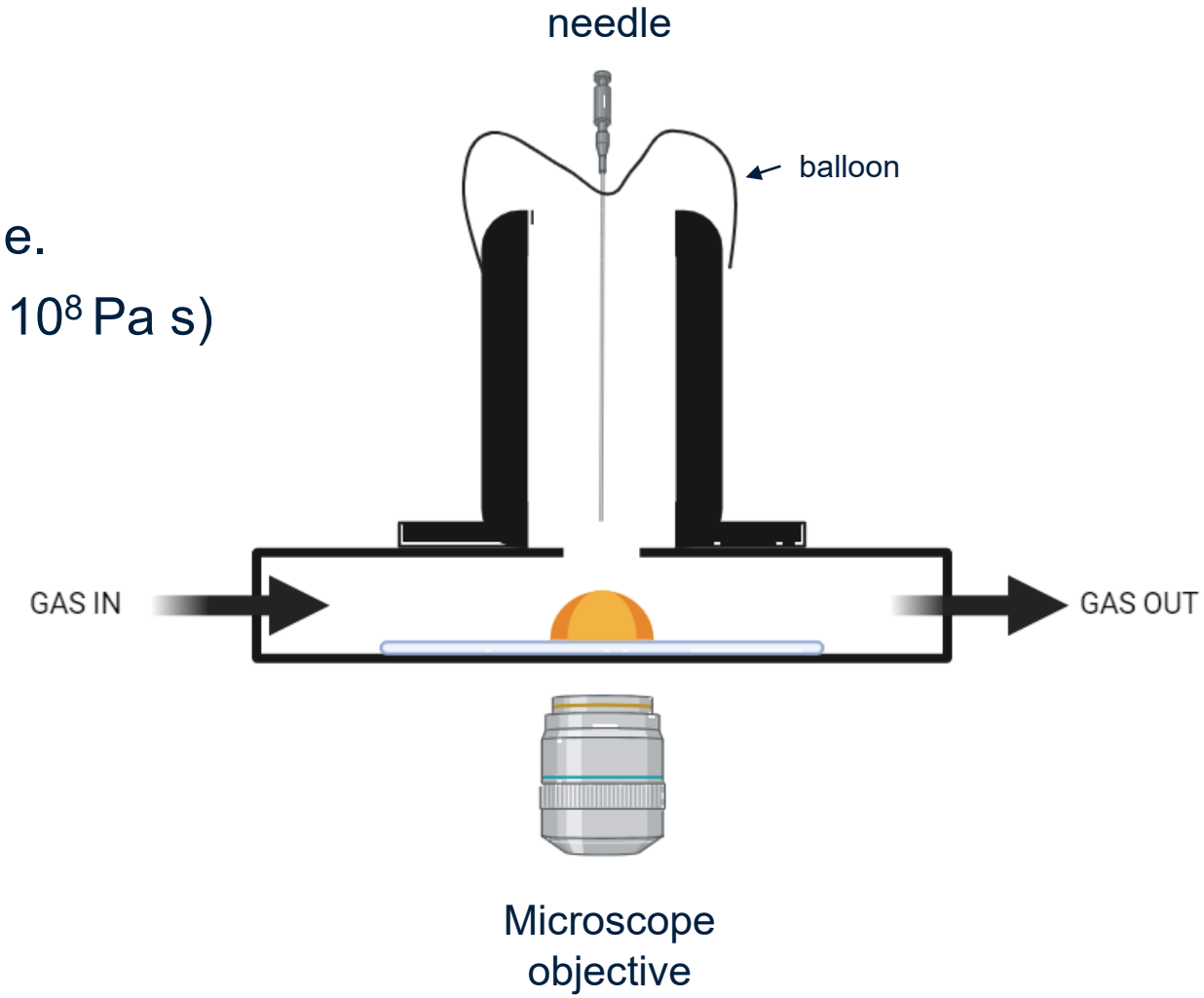


Viscosity

Viscosity impacts the rates of many aerosol processes by slowing down or halting diffusion.

Viscosity was investigated with the poke-flow method:

- Particles are poked with a fine needle.
  - Highly viscous particles (>2.5×10^8 Pa s) shatter
  - Liquids flow



Lab sample at 30% RH

Results from recent paper
(lab BBOA, diffusion measured with FRAP)

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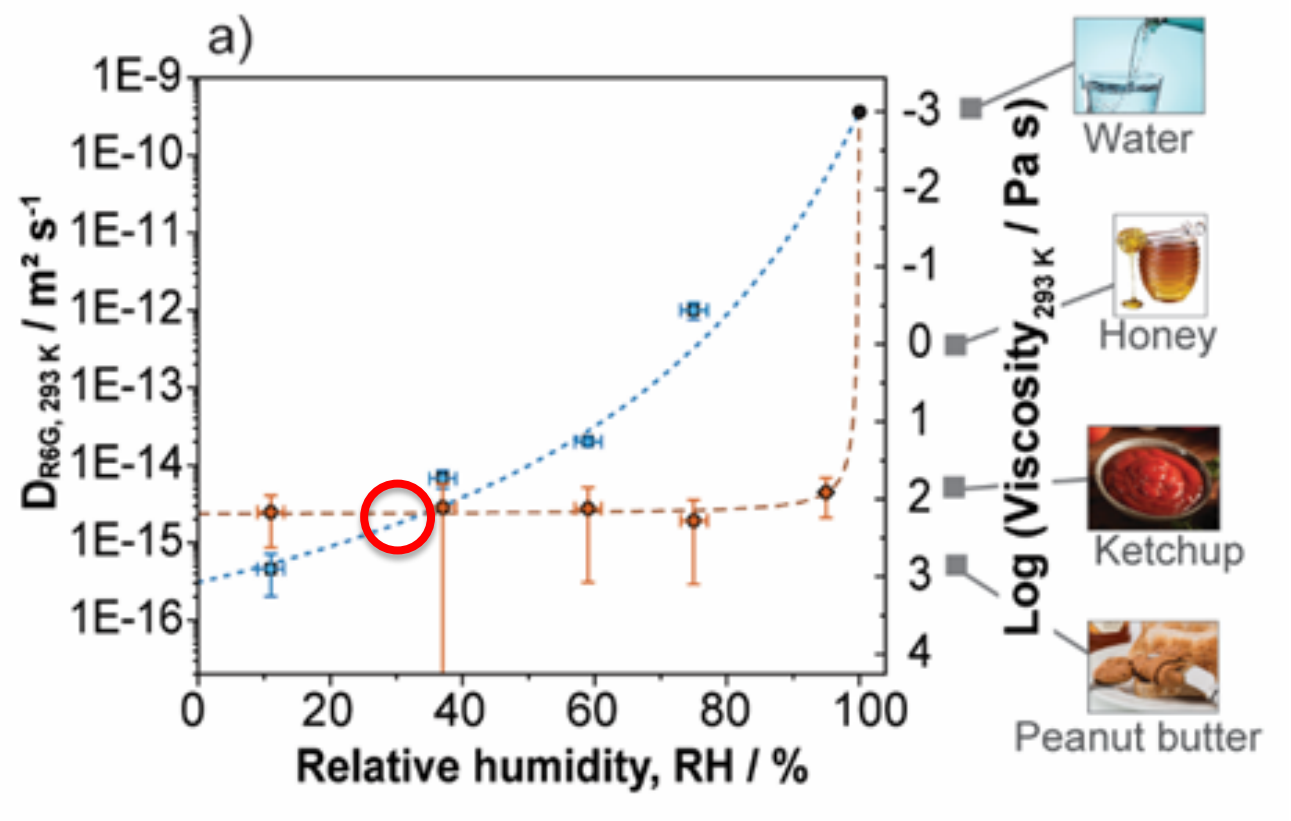
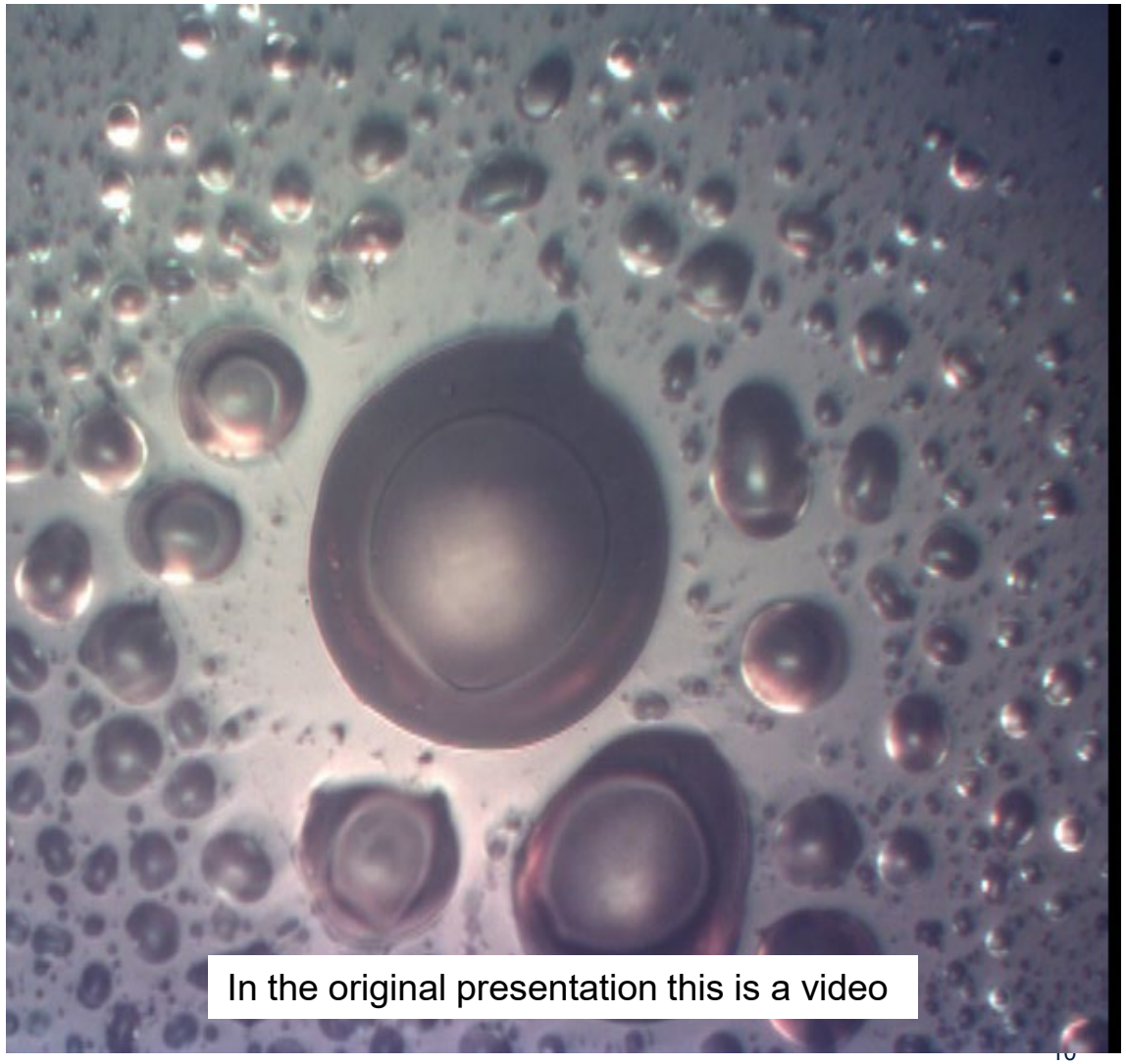


How it looks with poke-flow



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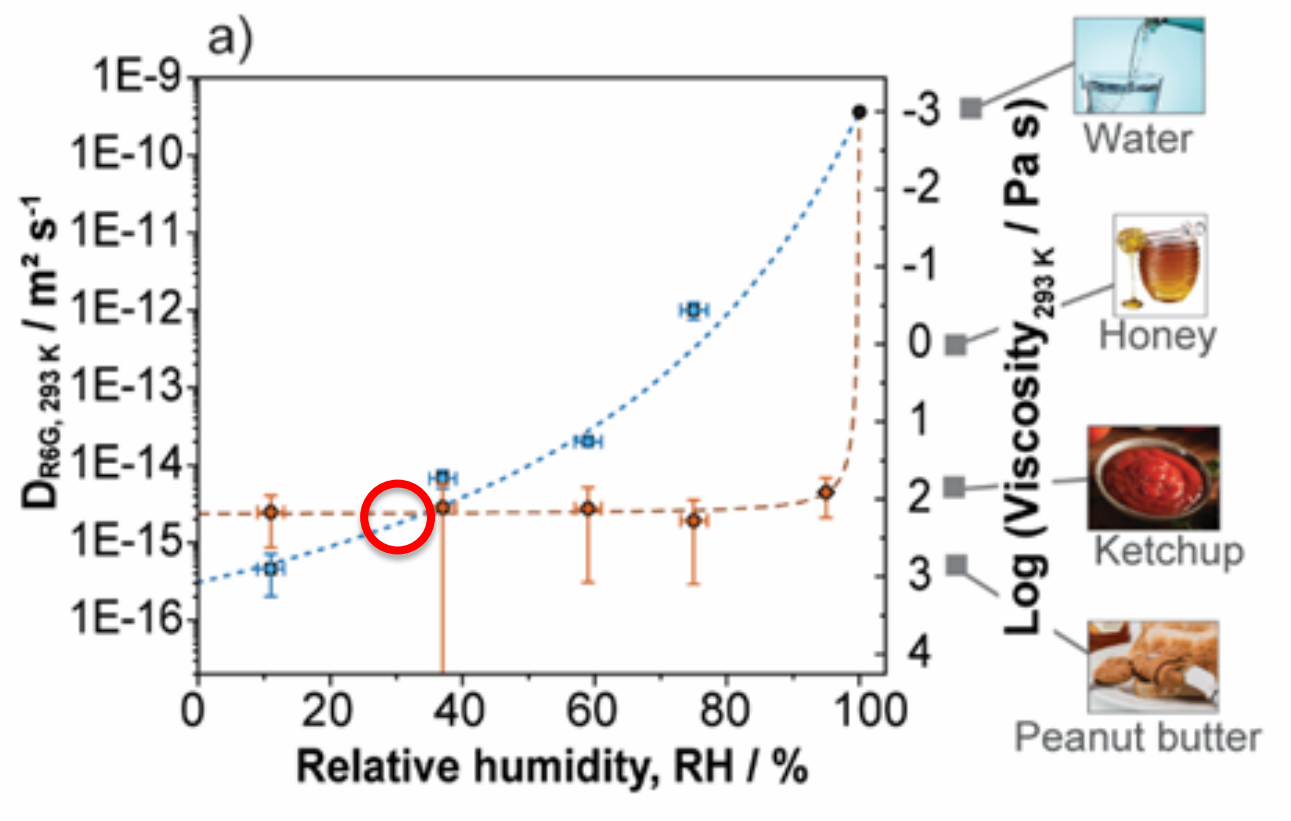

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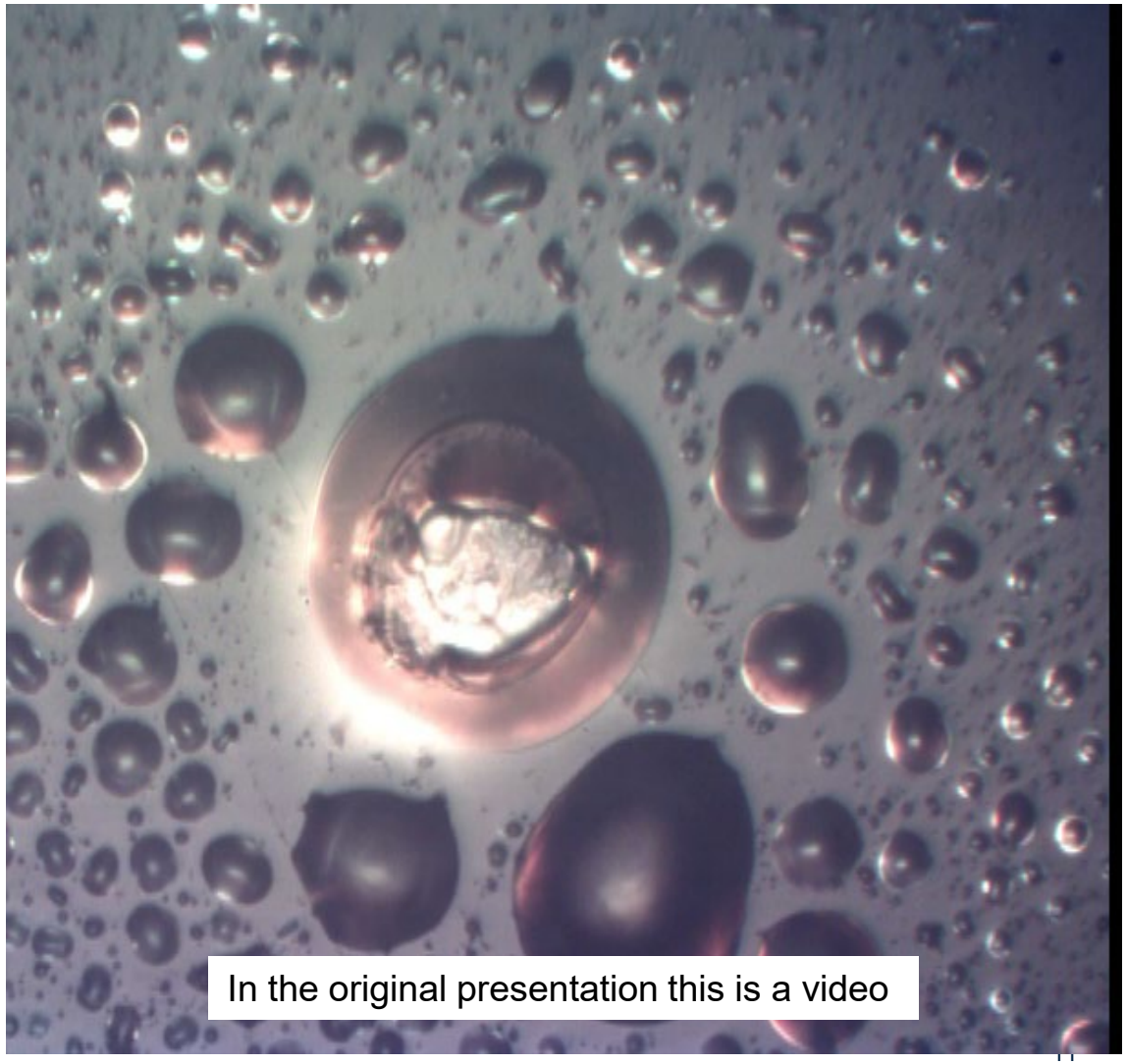

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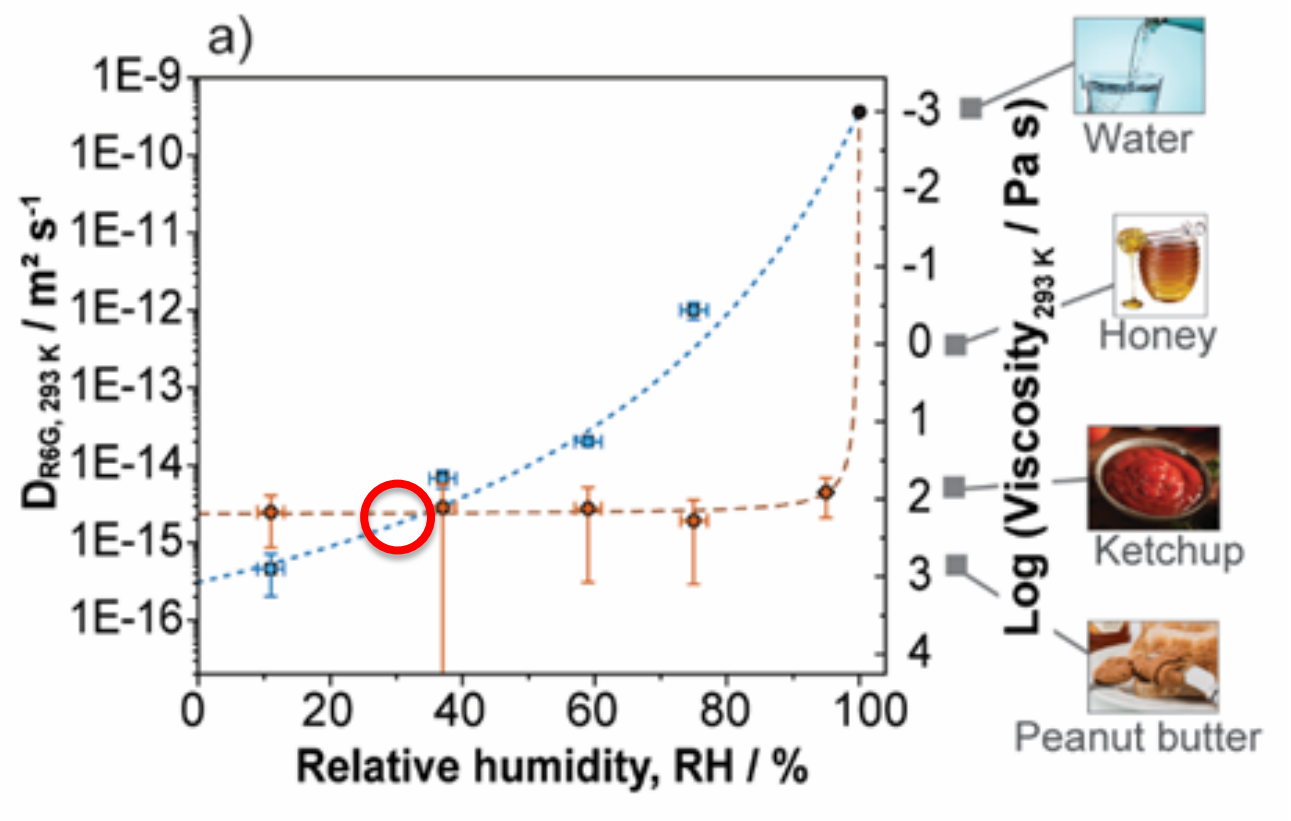

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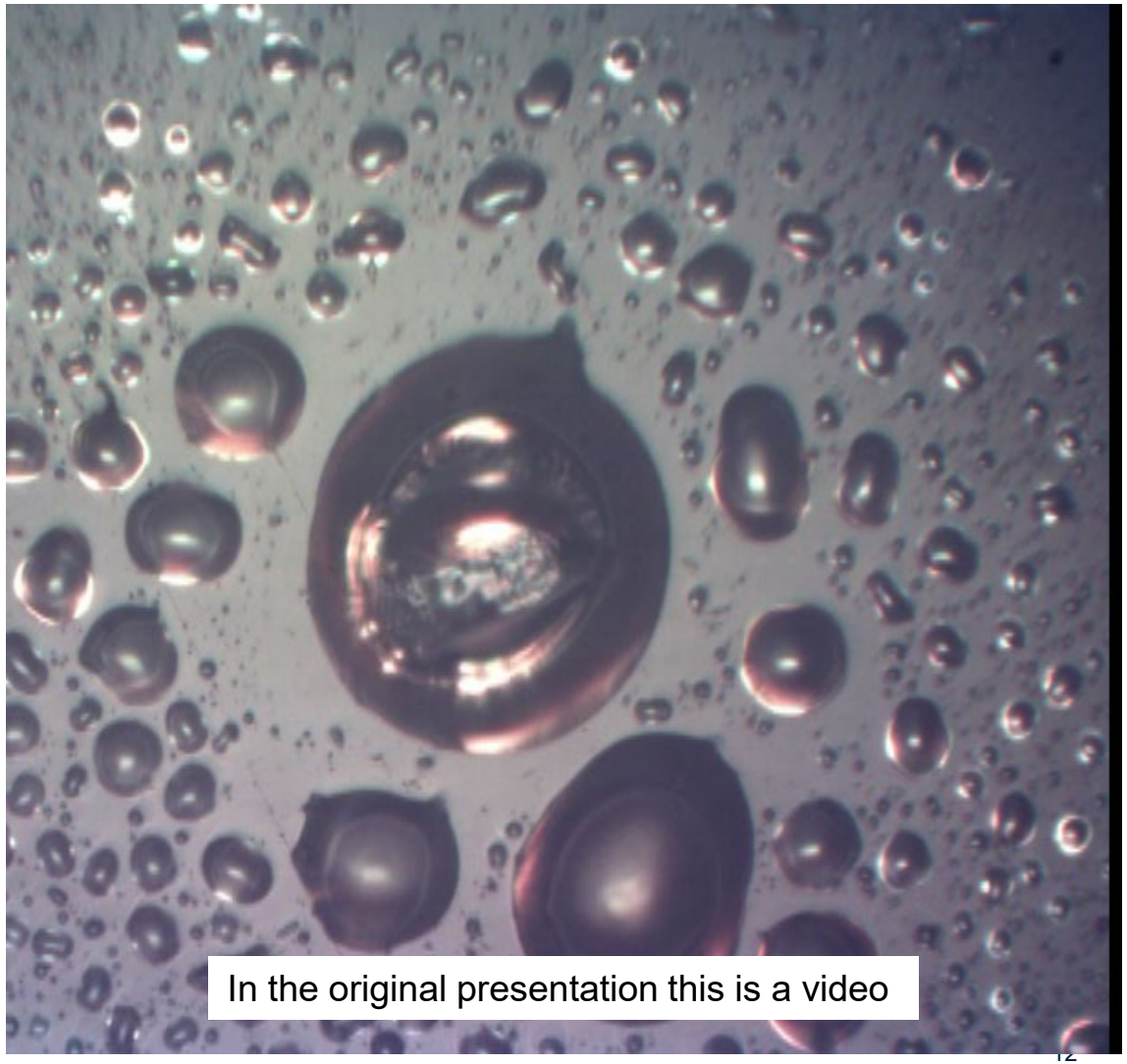
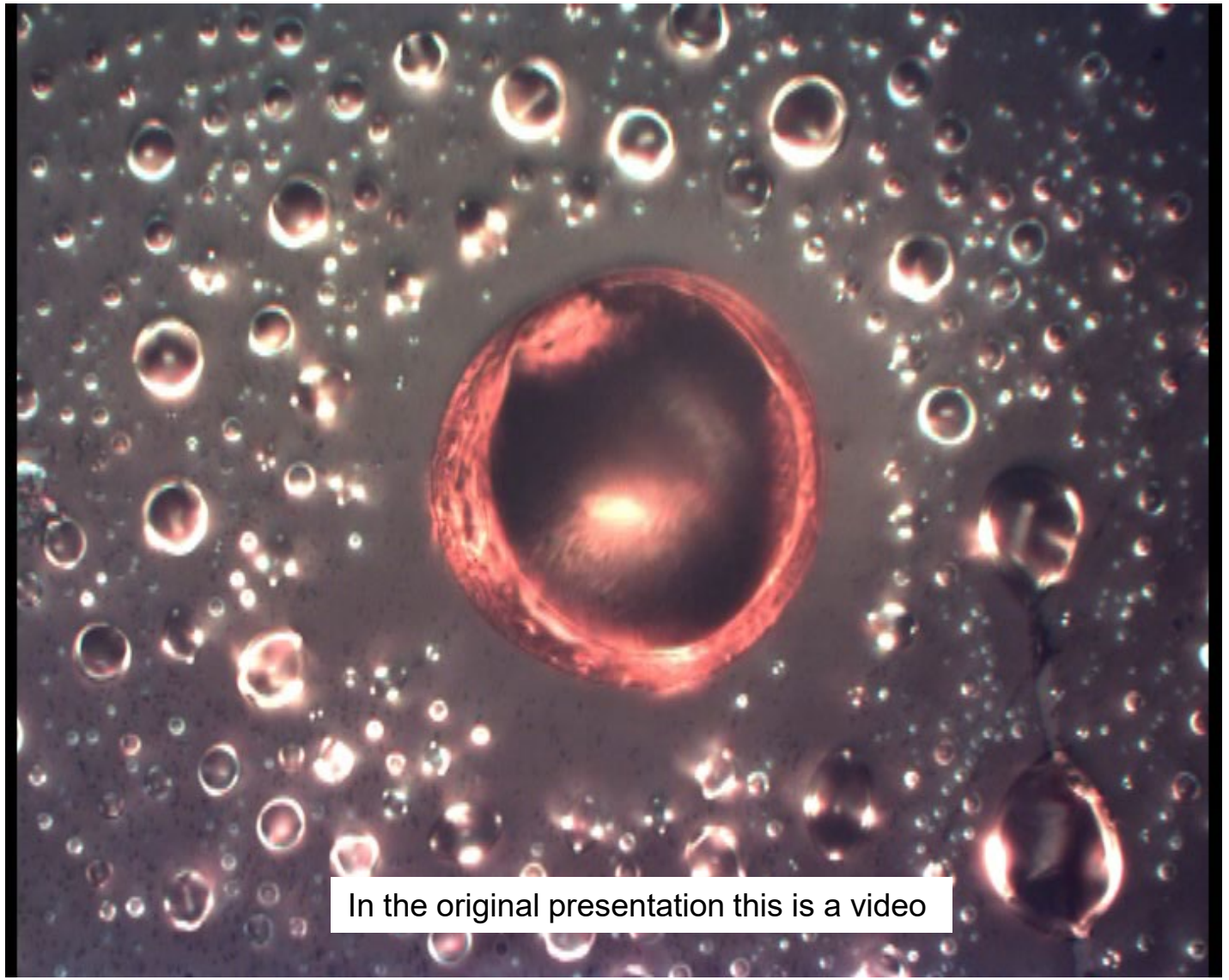


Field sample at 30% RH



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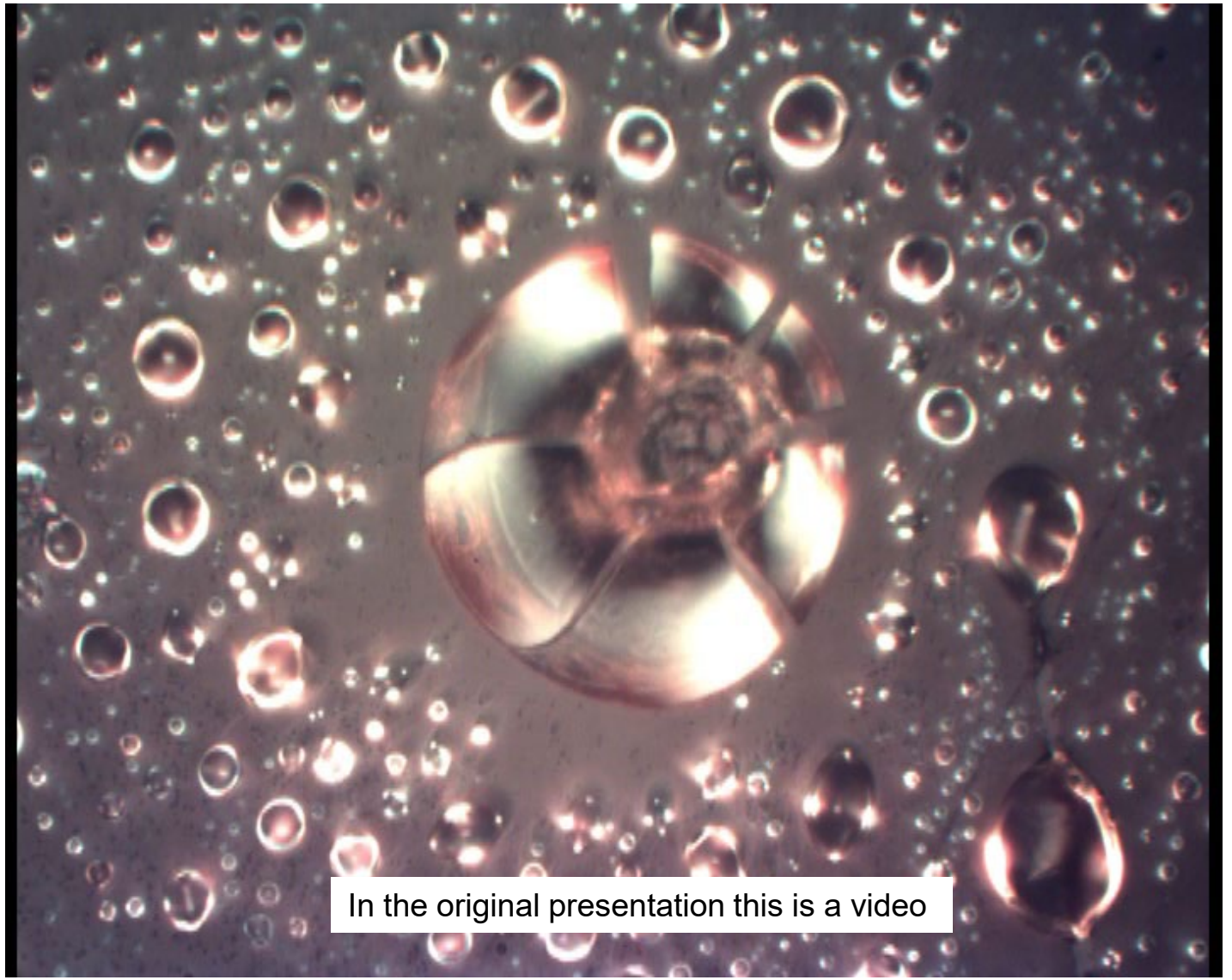
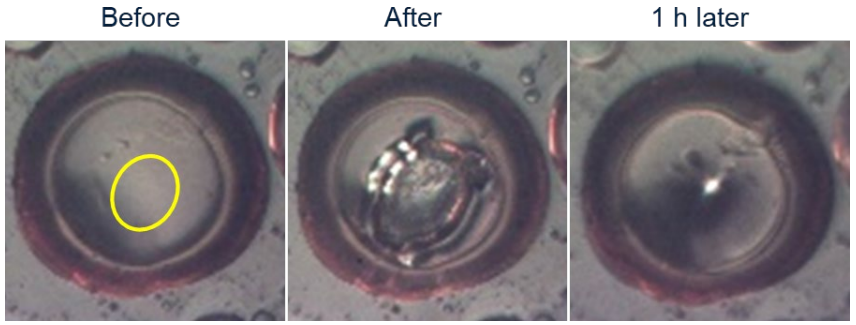


Viscosity in Lab and Field Samples

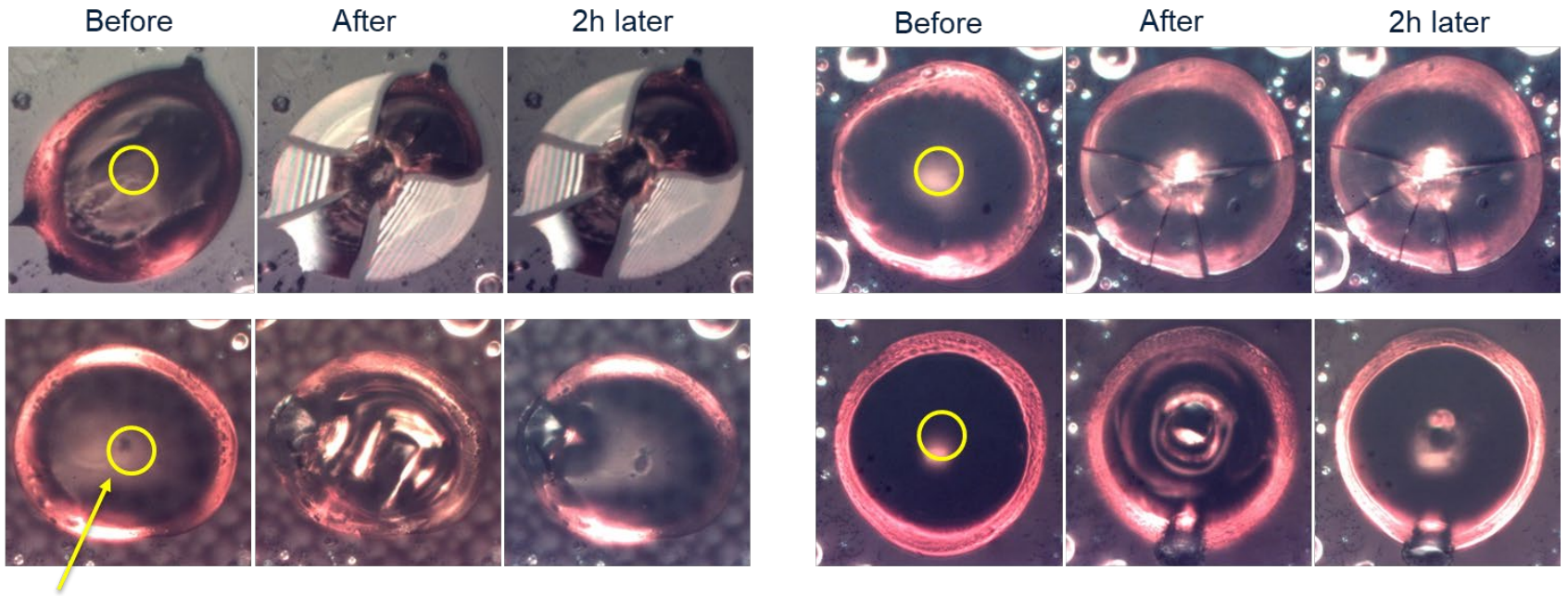
Lab Sample
0.5% RH



- Even when dry, the lab samples flow after an hour.
- Field samples *do not* flow until they reach 60% RH

Thompson Rivers sample

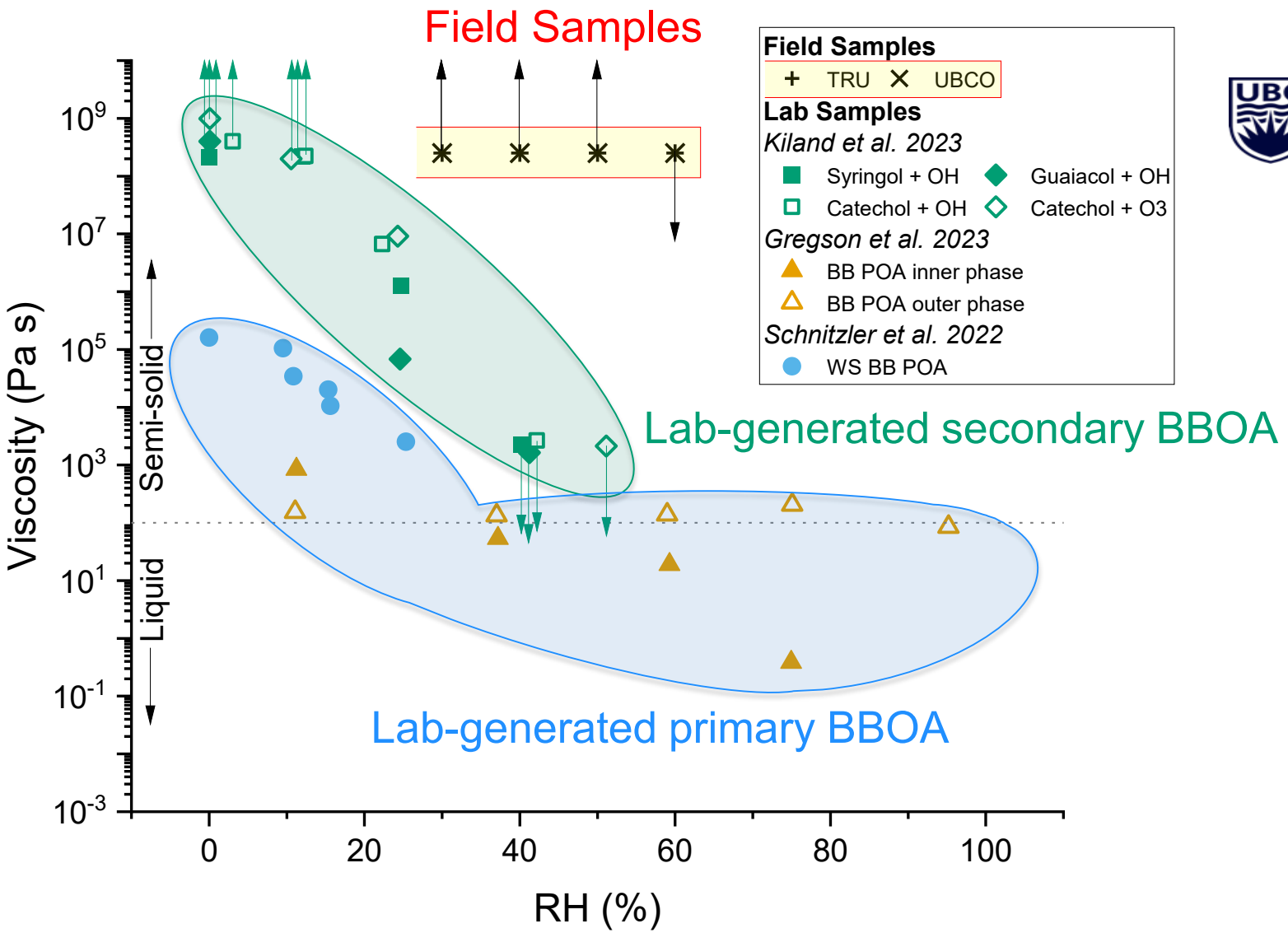
UBC Okanagan sample



Viscosity Comparisons

Our previous studies* on lab generated BBOA and BB-SOA proxies all showed lower viscosities than the field samples.

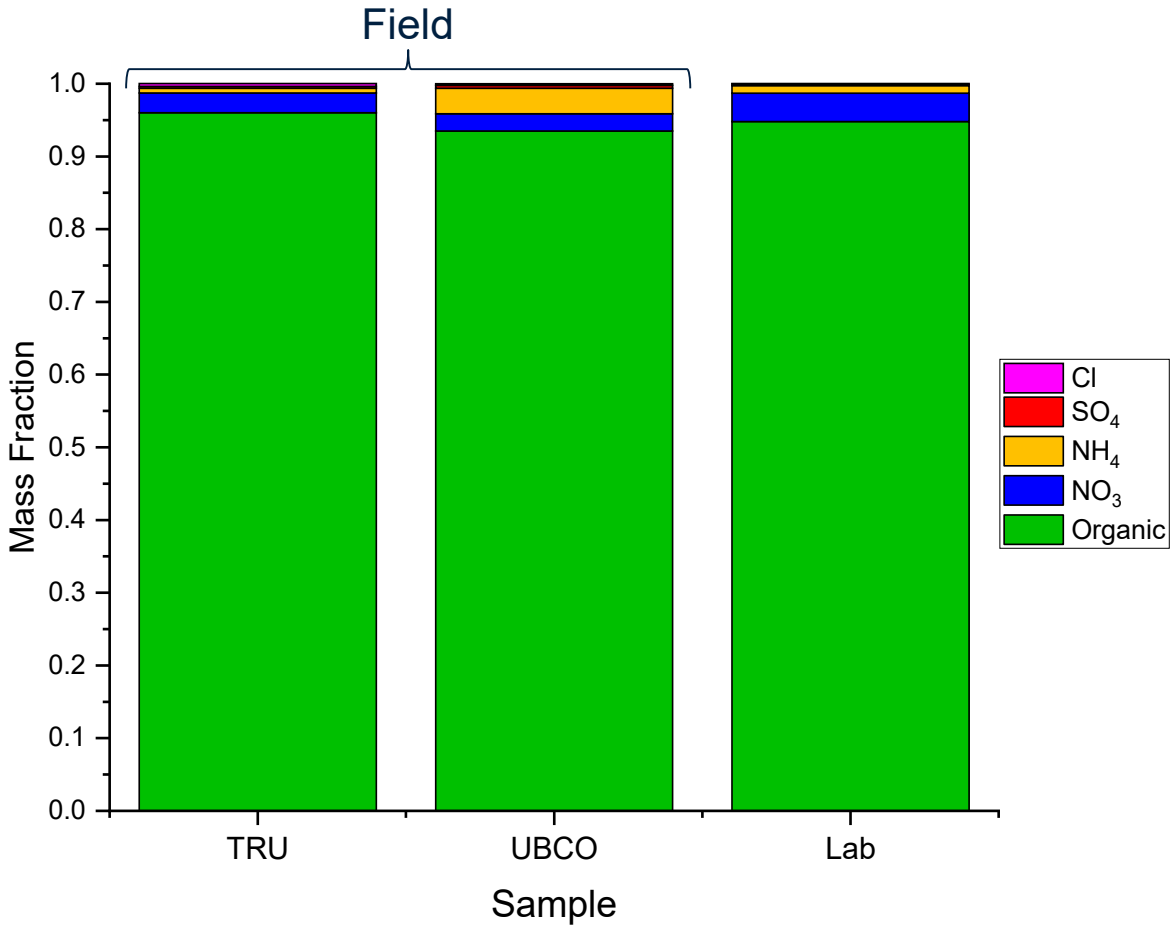
What is causing the difference?

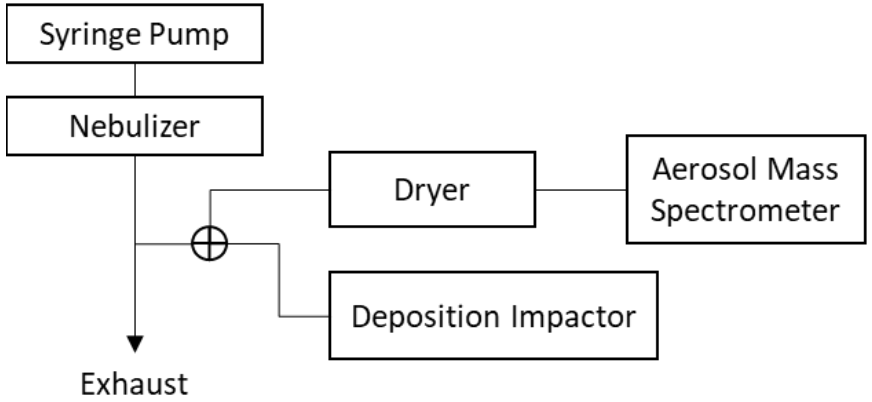


*Gregson et al.(ES&T 2023), Kiland et al. (ACS Earth Space Chem. 2023), Schnitzler et al. (PNAS, 2022)

Analysis with aerosol mass spectrometry

BBOA extracts nebulized, dried, and analyzed with AMS.

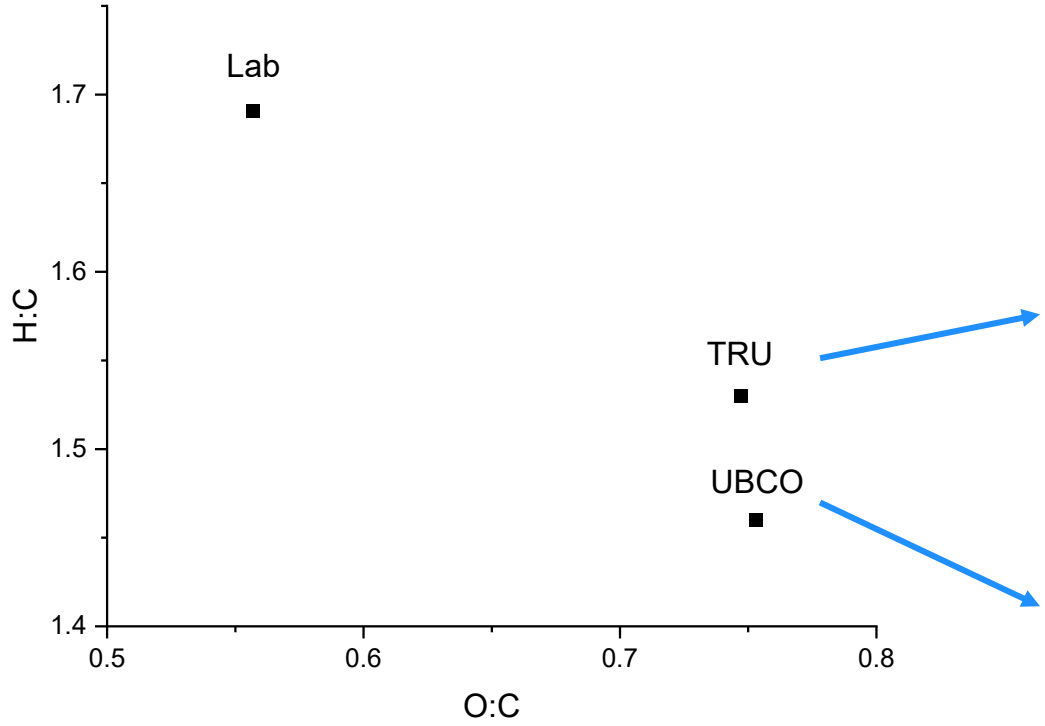


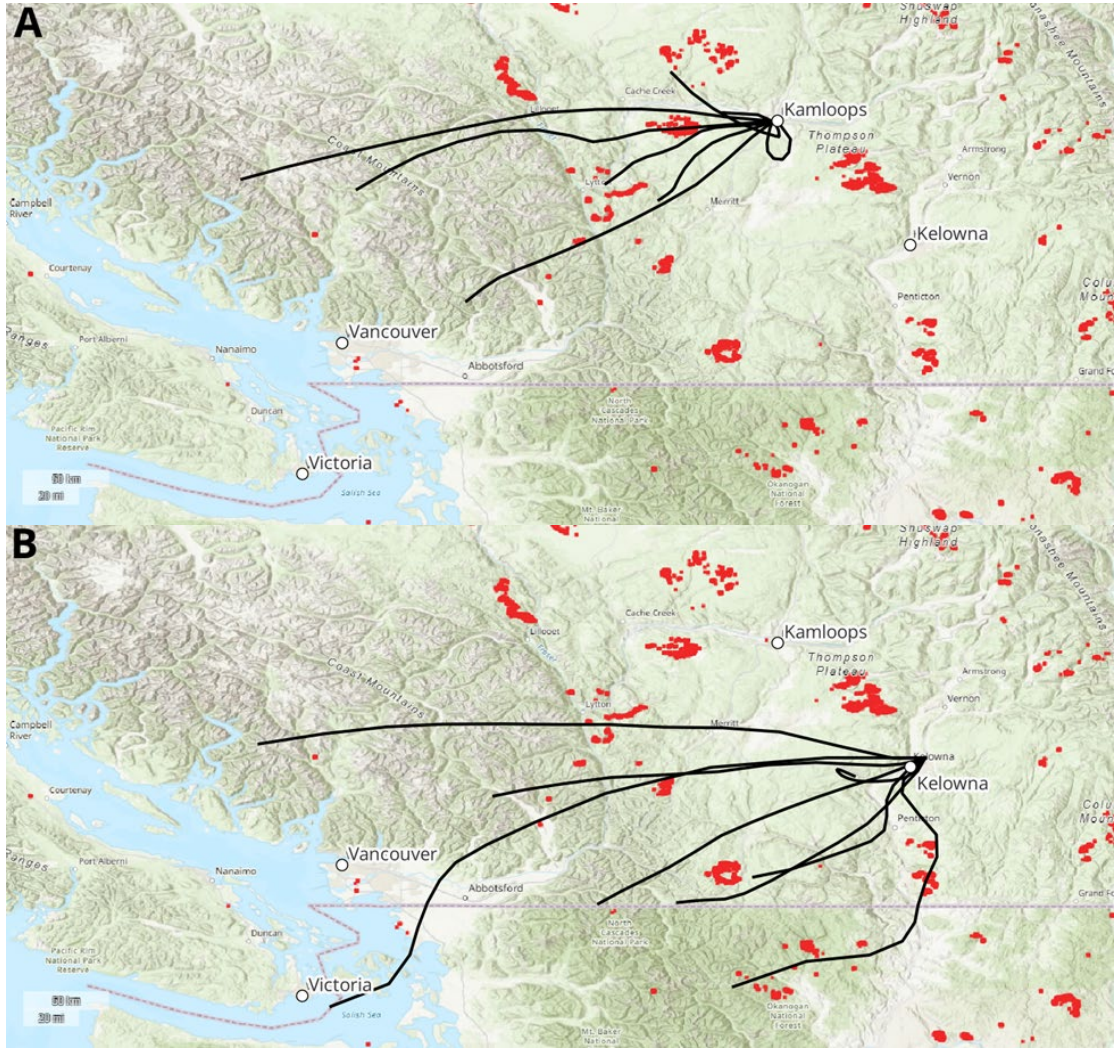


All samples were ~95% organic.

Phase separation driven by differences in polarity between organic species, not the presence of inorganics.

Aerosol Mass Spectrometry, continued

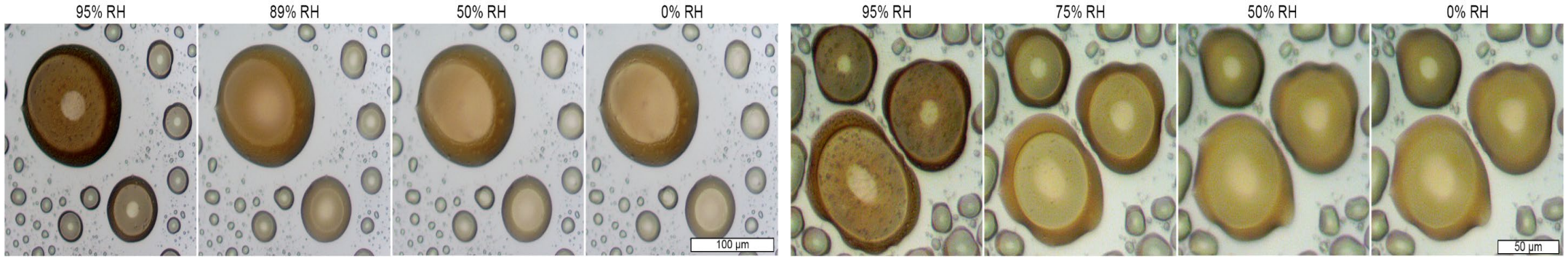




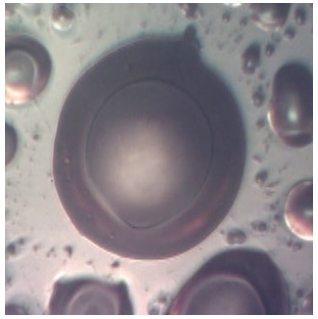
- The field samples are more oxidized than the lab generated samples.
- HYSPLIT trajectories show that our smoke is 3 to 12 hours old.

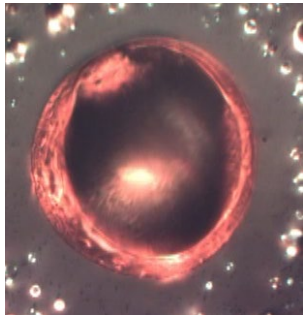
Conclusions

BBOA, both from the lab and the field, contains two phases.



The viscosity of field samples is much higher than our lab generated samples.





These are also supposed to be videos

Future work:

- Determine the impact of aging on BBOA's viscosity and phase behaviour.
- Investigate how different fuel sources impact the phase behaviour.
- Try experiments at different burning temperatures.

Acknowledgements

Bertram group

Field sampling teams:

Prof. Wesley Zandberg, Ieva Zigg, Harrison Meeres (UBC Okanagan)

Max Walton-Raaby (Thompson Rivers University)

Funding:

NSERC

UBC Vancouver-Okanagan Collaborative Research Mobility Awards

This research was conducted on the unceded traditional and ancestral territories of the Musqueam Nation (UBC-V), Syilx Okanagan Nation (UBC-O) and the Tk'emlúps te Secwépemc (TRU).

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