Measuring and Modeling the Interaction of VOCs with Wood in Indoor Environments

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Background

Even though the average person spends nearly 90% of their lifetime indoors, we know very little about the chemical and physical processes of VOCs in indoor environments where there are a variety of surfaces that VOCs can interact with (Diffey 2011). Thus, knowledge about outdoor air cannot fully explain the chemistry and interactions that occur indoors. Without understanding how VOCs interact with individual surfaces, it is difficult to predict and model the behavior of molecules in a room that may have a dozen different surfaces. By isolating the VOC behavior with individual surfaces, indoor models can be improved and give better insight into where VOCs are coming from and where they are going. My goal is to better understand how VOCs interact with indoor wood surfaces such as: flooring and furniture. Because wood is not often used without a protective coating or varnish (an umbrella term for any sort of wood coating or stain), the behavior of VOCs will be studied using three types of wood: pine, oak, and maple, in conjunction with two commonly used varnishes: lacquer and shellac.

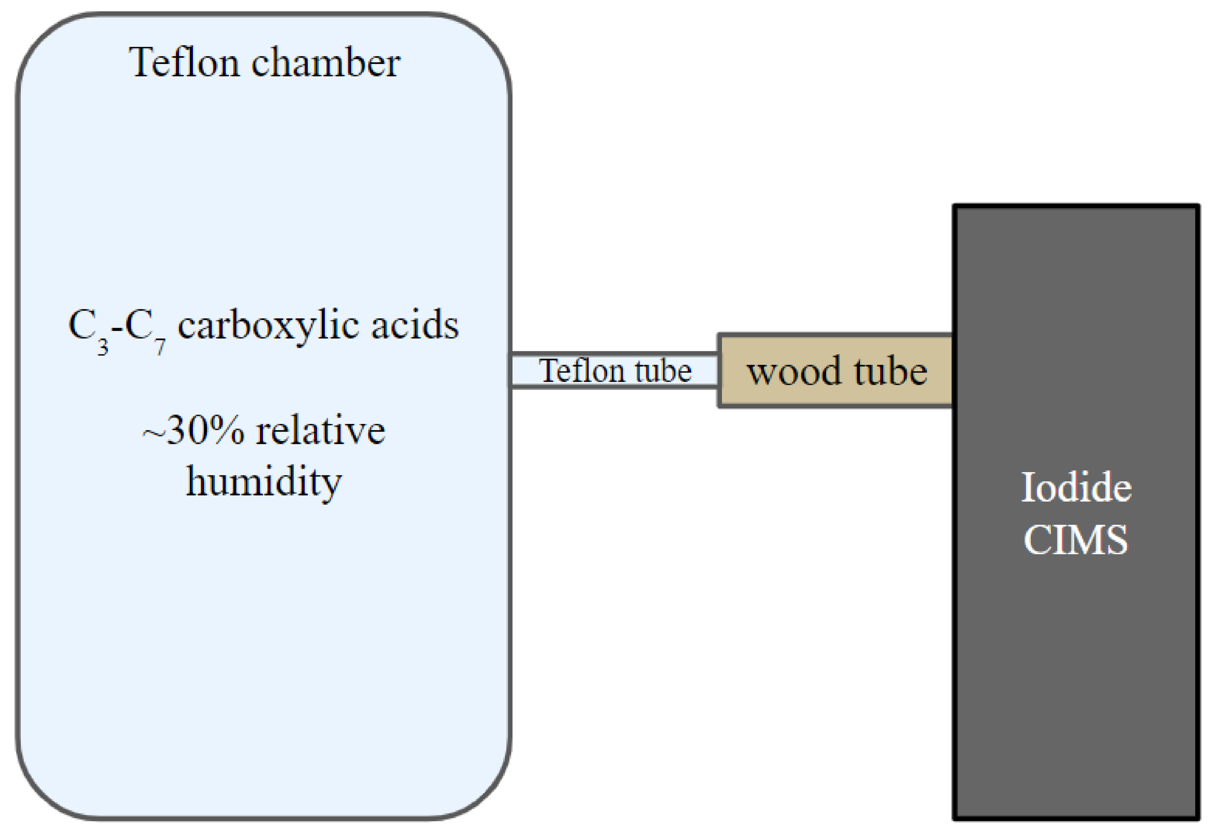

Figure 1. Experimental setup for tubing experiments.

Tubing Experiments

- Teflon chamber filled with C_3 – C_7 carboxylic acids (shown in Figure 1)
- Teflon chamber humidified to match the humidity of the room
- Passivated the wood tube (coated or uncoated) with carboxylic acids by flowing air from the chamber, through the tube, and into an iodide chemical ionization mass spectrometer (I-CIMS)
- Depassivated the wood tube by flowing room air through the tube and into an I-CIMS

Modeling

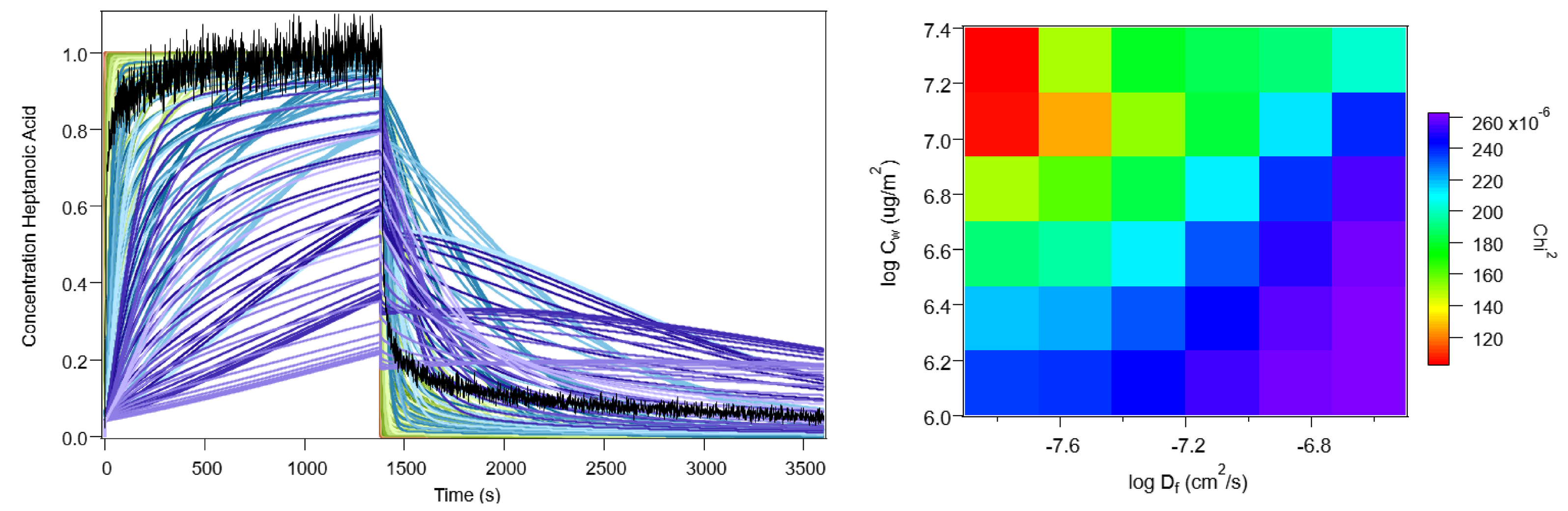

Figure 2. Left: Experimental passivation and depassivation of heptanoic acid. Right: χ2 test to compare model data and experimental data.

- Iterates through a range of C_w and D_f values to simulate passivation and depassivation tubing data (developed by Lucas Algrim)
  - C_w = absorptive capacity (µg/m^3)
  - D_f = diffusion coefficient (cm^2/s)
- Compare the simulated data to experimental data
- Use χ^2 test to determine which combination of C_w and D_f most closely represent experimental data (shown in Figure 2)

Fourier Transform Infrared Spectrometry

- Place thin film over crystal
- Trap VOC above film (shown in Figure 3)
- Monitor growth of VOC signal as is travels through film (shown in Figure 4)
- Integrate the peak area growth over time to determine D_f

$$D_f = \frac{4L^2}{\pi^2 \tau}$$

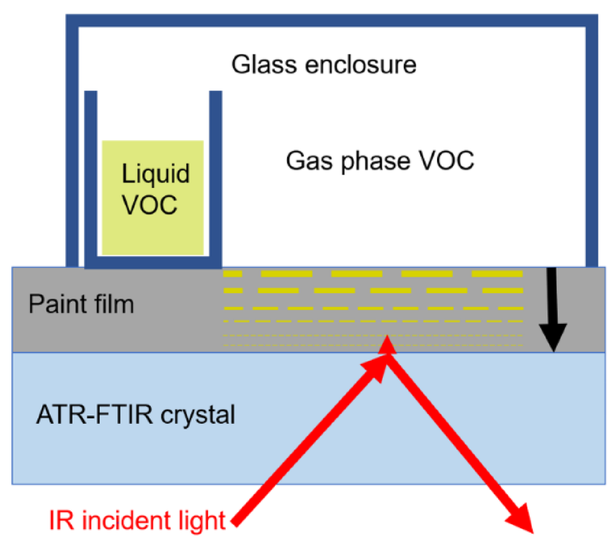

Figure 3. ATR-FTIR experimental setup (image by Algrim).

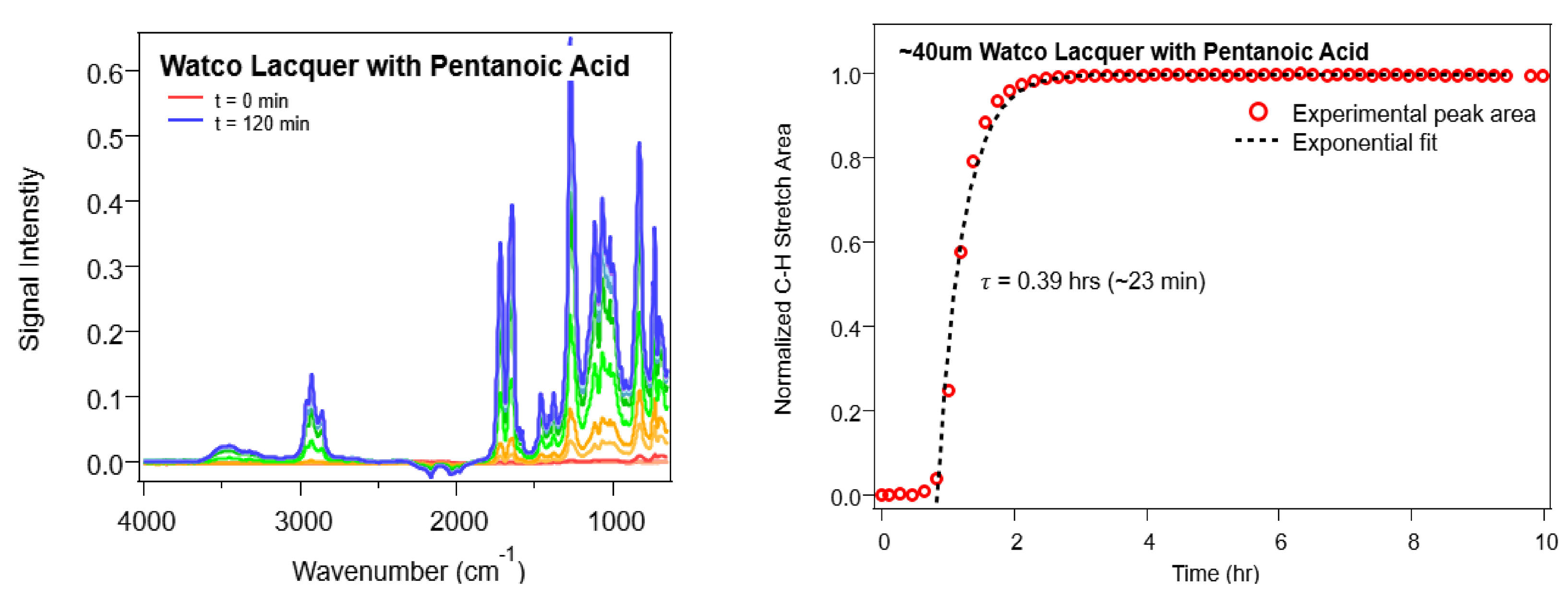

Figure 4. Left: ATR-FTIR signal of a thin film with pentanoic acid. Right: The area under the curve between 2800 and 3000 cm^{-1} over time.

Discussion

- Calculated delay time, or time it takes for VOC signal to decrease by 90%
- Delay time for uncoated tubes depends on porosity of wood
  - More porous = deeper VOC travels into the wood
- Delay time for coated tubes depends on the varnish used, *not* the wood species (shown in Figures 5-6)

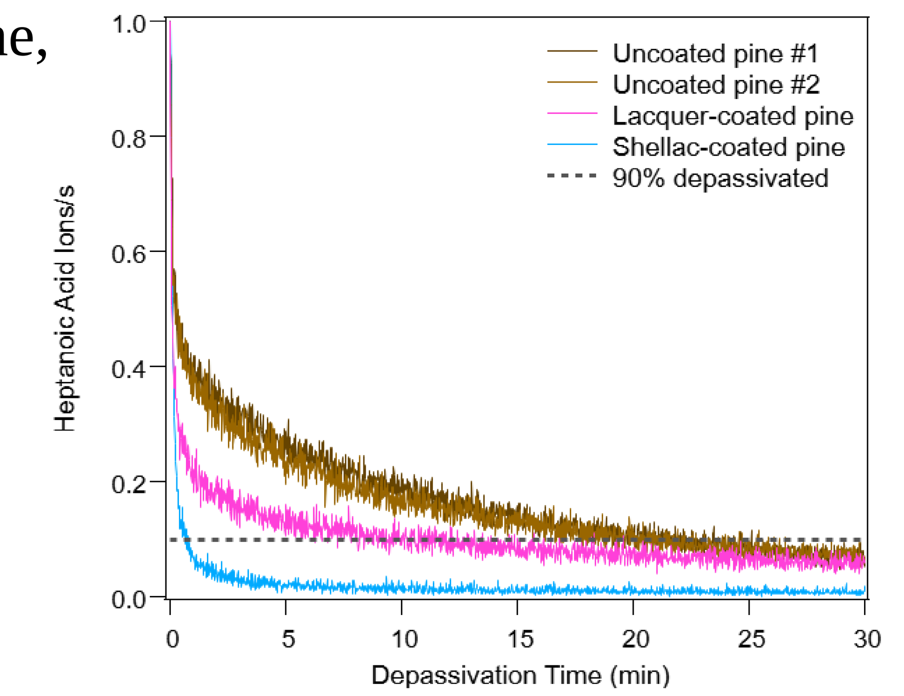

Figure 5. Depassivation from uncoated, lacquer-coated, and shellac-coated pine tubes.

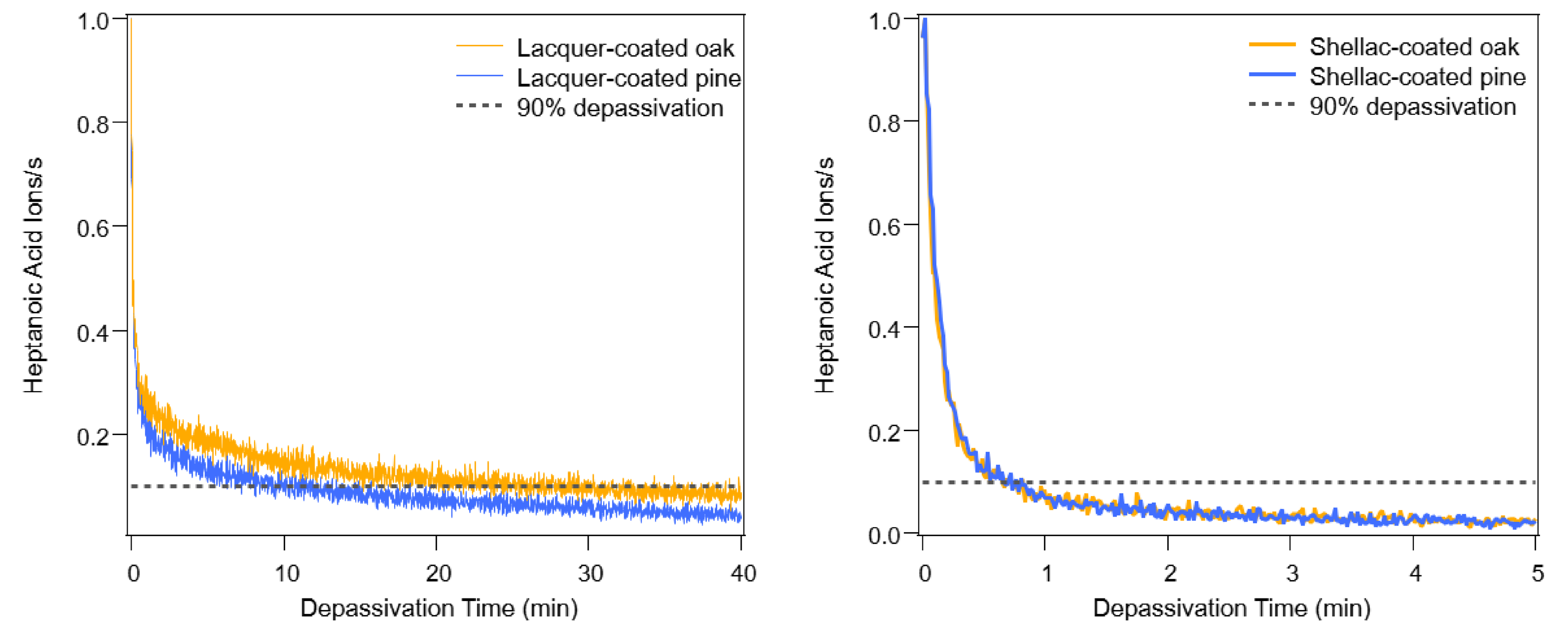

Figure 6. Left: Depassivation from lacquer-coated oak and pine tubes. Right: Depassivation from shellac-coated oak and pine tubes.

Future Plans

- Use ATR-FTIR to verify D_f values from model
- Use GC-FID to quantify C_w of varnish films
- Experiment with additional varnishes

Acknowledgements

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References

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