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Atmospheric Measurement Techniques
Discussions

Interactive comment on "Experimental methodology and procedure for SAPPHIRE:a Semi-automatic APParatus for High-voltage Ice nucleation REsearch" *by* Jens-Michael Löwe et al.

Anonymous Referee #1

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The manuscript by Löwe and co-authors gives an in-detailed description on the SAPPHIRE, an instrument to study the impact of electric fields on ice nucleation in water droplets. Though it is possible that electric fields might impact ice formation in clouds and induce icing of infrastructure, it is not well studied to-date.

For experiments in SAPPHIRE, droplets of equal sizes are generated and placed on a saphhire glass sheet, and covered with silicone oil. Thereafter, the droplets are placed within a housing, where they can be exposed to subzero temperatures and different electric fields. The phase change of the droplets can thereby be monitored with two high- and low-speed cameras.

The manuscript provides a detailed discussion on the boundary conditions of the experimental setup regarding the motion and resonance frequencies of droplets in oil as compared to in air, the electric field strength distribution in the different materials (sapphire, liquid water, and oil), and a potential charge effect on the droplets. The authors demonstrate that the SAPPHIRE instrument is capable of simulating relevant conditions regarding the impact of electric fields on the freezing behaviour of droplets. Thus I recommend its publication in AMT.

The manuscript is well written and clear, and I only have the following minor comments:

Technical:

- Citation style for references in brackets should be changed to ". . . (Smith et al., 2009), see manuscript preparation guidelines for authors.

- The figures' caption text sizes seem to be too small, please double-check.

- Please insert spaces between number and unit, and units must be written exponentially , following the guidelines of AMT.

- I recommend to be consisten with either using °C or K (e.g. you note temperatures in °C, while cooling rates are given in K min-1)

General:

- Page 1, line 18: A reference for the relevance of ice nucleation in atmospheric research should be given here.

- Page, 1, lines 18 – 19: You might want to include the field of food science, where freezing processes are used to preserve food (e.g. You et al., 2020).

- Page 2, lines 33 – 34: The overview study by Kanji et al. (2017) might be suited for citation as well.

- Page 2, lines 53 – 54: Statement "Since ice nucleation in sessile water droplets may be affected by a variety of factors such as the droplet size, their proximity to other droplets, and contamination on the substrate surface or in the droplet…" needs a reference.

- Page 3, line 59 and page 4, lines 92 – 93: It might be useful to additionally state the electrical and thermal conductivities at sub-zero temperatures, e.g. at -20°C.

- Page 4, line 104: What is the meaning of ÏŚ_d, as compared to ÏŚ (page 11, line 192)? - Page 5, line 116: Why did you introduce áźł?

- Page 5, lines 118 – 119: I suggest to be more quantitative here and to highlight that the temperature distribution across the sapphire substrate is 0 °C, at least using your temperature sensor.

- Page 11, line 200: What is the temperature uncertainty arising from your temperature sensor? It would be helpful to have a total temperature uncertainty at the minimum temperature, combining the sensor uncertainty and the deviation from the target temperature from the calibration.

- Page 12, Figure 8: Please introduce or the abbreviations used for the axis labels (ÏŚ_g, ÏŚ_h), and also be consistent with either using °C or K.

- Page 13, lines 234 – 235: Please specify here that, although your measurement setup allows accurate temperature control down to -34°C, that heterogeneous nucleation experiments can only be performed down to approximately -25°C, where all your droplets are frozen; otherwise this sentence might be misleading for the readers.

- Page 14, line 266: "Figure" should be abbreviated.

- Page 16, lines 316 – 318: Which value has the permittivity of oil? How much higher is it as compared to air, and how much lower as compared to water?

- Page 18, lines 350 – 351: Could you quantify to which value the electric field strength is limited to prevent the formation of a Taylor cone? And would this effect be important

for droplets in real-world, e.g. would the droplet size be reduced significantly?

- Page 19, lines 374 and following: You might also refer to the discussion of Niedermeier et al., (2011) regarding stochastic and singular ice nucleation.

- Page 20, lines 390 – 391: Please also add to the discussion that the remaining scatter of the freezing behaviours using the same sample ensemble might also be related to the method′s uncertainty, e.g. temperature uncertainty, or determination of freezing events via a camera.

- Page 21, line 409: "Visualized"

- Page 21, line 412: Although your freezing apparatus might be capable of reaching temperatures down to -40°C, your droplets are freezing at temperatures warmer than – 25°C; thus you cannot investigate any effect of an electric field on liquid droplets colder than this temperature. Thus the statement "… a temperature of −40 °C, may be imposed onto the droplet ensemble." Is not correct, since there would not be any liquid droplets colder than -25°C, only frozen droplets.

- Page 21 lines 429 – 430: You could also state here that this effect would rather cause an underestimation on the effect on ice nucleation.

- Page 22, line 441 – 442: This might also be related to your preparation of the samples, e.g. not preparing the droplets clean enough, such that it is not necessarily a stochastic effect.

References

Kanji, Z. A., Luis A. Ladino, Heike Wex, Yvonne Boose, Monika Burkert-Kohn, Daniel J. Cziczo, and Martina Krämer. 2017. "Overview of Ice Nucleating Particles." Meteorological Monograophs. doi: 10.1175/amsmonographs-d-16-0006.1.

Niedermeier, D., R. A. Shaw, S. Hartmann, H. Wex, T. Clauss, J. Voigtländer, and F. Stratmann. 2011. "Heterogeneous ice nucleation: exploring the transition from stochastic to singular freezing behavior." Atmospheric Chemistry and Physics. doi: 10.5194/acp-11-8767-2011.

You, Youngsang, Taiyoung Kang, and Soojin Jun. 2020. "Control of Ice Nucleation for Subzero Food Preservation." Food Engineering Reviews. doi: 10.1007/s12393-020-09211-6.

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