

Referee report on the manuscript “Low-Temperature Triple-Capillary Cryostat for Ice Crystal Growth Studies” by Swanson and Nelson.

The manuscript by Swanson and Nelson describes a steady state diffusion chamber designed for high-precision studies of ice crystal growth and sublimation. It appears to be a companion paper to the study of the formation of air pockets in growing ice crystals (Nelson and Swanson 2019) which has been conducted with the apparatus described here. The manuscript presents a very thorough description of the apparatus and discuss deeply the principles of operation and potential error sources. The images of the ice crystals grown with the help of the apparatus are amazing and obviously demonstrate the ability of the system to maintain stable temperature conditions for a very long time.

The manuscript, however, provides no convincing evidence that the apparatus can be used for studying diffusion growth of ice crystals under *predictably controlled* supersaturation conditions. By that I mean that in order to understand and to describe the crystal growth, the water vapor pressure in the vicinity of the crystal has to be set to and precisely maintained at the *predefined* value, which can be either derived from the instrumental parameters or obtained via calibration. This ability has not been demonstrated in the manuscript. Instead, there is a lot of discussion of the potential errors and why they should have negligible effect on the growth rate of the crystal. What I am desperately missing is the characterization of the instrument in terms of supersaturation as a function of a) temperature of the growth chamber, b) temperature of the both vapor sources, c) spatial coordinate in the growth chamber, d) time. As authors themselves put it: *“We conclude that accurately predicting and maintaining a constant S_a at a chamber center without a direct measurement of the supersaturation requires careful calibration”* (page 5 line 34-35), but the calibration is missing. In fact, in the whole manuscript, not a single value of the supersaturation (or vapor pressure) in the growth chamber is given. The closest occasion where the word “supersaturation” is used in conjunction with any numerical values is *“During part A S_a was not highly controlled but conditions were maintained such that $-0.5\% < S_a < 0.5\%$. During part B S_a was controlled such that $T_{VS} = -29.3 \pm 0.4$ °C.”* (page 8 lines 30-31). How this value of S_a has been deduced? Why were the crystals growing if the supersaturation was zero on average?

The explanation why the actual supersaturation cannot be derived from the temperature of VS is offered on page 6, starting from line 1: *“In a highly controlled vapor-source supersaturation, S_{VS} , does not necessarily set the ambient supersaturation, S_a , at the center of the chamber where the crystals are growing if there is unobserved condensate growing on the wall.”* The issue is being addressed by observing the chamber surfaces visually, with the remark *“But it is possible that this ice is so thin as to make it nearly invisible to the eye ”* (page 6 lines 6-7) . I don’t see how one can control AND measure the actual supersaturation under these conditions.

Now, the authors claim that *“..., typically no frost was observed on VSC walls for at least 6 hours”* (page 6 line 20). In this case the question arises, how it was possible to conduct an experiment for 92 hours as described in the section 3? Obviously, this would require multiple de-icing steps as described on page 6, lines 18-19, during which the GC has to be disconnected from the VSC and reconnected to the second VSC with the VS set exactly to the same temperature. Or was the GC just left connected to the VSCs resulting in no supersaturation, as implied by the sentence *“During part A S_a was not highly controlled but conditions were maintained such that $-0.5\% < S_a < 0.5\%$.”*? If the setup was build to study the ice crystal growth at atmospherically relevant conditions, it should be possible to set and maintain supersaturations up to 30%. Nothing in this manuscript tells me that this is feasible.

If calculation of the supersaturation based on the instrumental parameters is not possible, a calibration can be achieved by measuring diffusion growth or evaporation of a reference particle – droplet of a

known solution. Apparently, the authors have done that: “...we have in addition used droplet evaporation measurements done simultaneously with crystal growth measurements to give a direct, and independent, estimate of S_a ” (page 5 line 30). It’s disappointing that this direct and independent estimate of the supersaturation is neither given nor discussed further. The only measurements of the crystal growth rate presented in the manuscript (Figure 6) are not compared with any other measurements or with theory; we learn that the growth rate can be fitted by a two-parameter power-law parameterization, but no further attempt of interpretation is given. Actually, even the fit parameters are not given or discussed, and the reader is informed “A more detail discussion of these results is reported elsewhere” leading to a reference (Swanson 2019a) that has a different title and dedicated to a different topic (I assume this is the reference to the paper in ACPD by the same authors. Actually, the reference to Swanson 2019b leads to nowhere). I have not been able to find any discussion of these results in the companion paper.

I am afraid I cannot recommend publishing the paper in its present form. It should be thoroughly revised aiming at providing a verifiable characterization of the apparatus under wide range of experimental conditions. If the supersaturation cannot be calculated from the instrumental parameters, it should be calibrated in a dedicated experiment with evaporation or condensation of inorganic solution droplet, and the results reported together with the theoretical model used for the simulations. I am not in a position to give advice on the chamber design, but perhaps it would be better to create well-defined wall boundary conditions in the VSC and CG chambers by covering walls with ice than relying on the absence of water adsorbed on the bare metal walls of the chamber.

1. Nelson, J. and B. Swanson (2019). "Air pockets and secondary habits in ice from lateral-type growth." Atmos. Chem. Phys. Discuss. **2019**: 1-51 doi: 10.5194/acp-2019-280.