EPSC Abstracts
Vol. 12, EPSC2018-214, 2018
European Planetary Science Congress 2018


# Sintering of micrometer-sized water-ice particles

**Bastian Gundlach** (1) and Judy Ratte (1) and Jürgen Blum (1) and Joachim Oesert (2) and Stanislav N. Gorb (2)
(1) Institut für Geophysik und extraterrestrische Physik, Technische Universität Braunschweig
(2) Zoologisches Institut, Christian-Albrechts-Universität zu Kiel

## Abstract

Inside granular materials, the sinter process leads to the growth of a neck between connected particles and, therewith, to an increase of macroscopic physical properties, such as the mechanical strength, or the thermal conductivity of the granular packing. Here, we report on novel experiments conducted to investigate the sinter process of micrometer-sized water-ice particles. Based on the experimental results, we developed a model that is capable to describe the sinter process of granular materials. This model can be used to study icy surfaces of Solar System bodies, such as comets, or icy satellites.

## 1 Introduction

Sintering is a process that transports material from particles in contact into their neck region. This mass transport is mainly driven by the temperature of the material and by the need of the system to minimize its surface energy. The transport of mass into the neck region leads to an increase of the neck area and, therewith, to an increase of the bonding strength (tensile strength, compressive strength) and of the thermal conductivity of granular materials.

In the context of particle sintering, six material transport mechanisms are known [1]. For water ice under astrophysical conditions (low pressures and temperatures), the vapor transport process, driven by the sublimation of water-ice molecules from the surface of the particles and recondensation of these molecules inside the neck region, is the dominant mechanism [1, 3, 5].

The understanding of the sinter process of small (micrometer-sized) water-ice particles is important to predict the thermal evolution of icy regolith on the surfaces of Solar System objects. Modelling of the sinter process in the context of cometary activity has been carried out [3, 4], but no experiments have ever been performed to study sintering of water-ice under realistic astrophysical conditions.

Fortunately, technical improvements of the cryogenic scanning-electron microscope technique (cryo-SEM) in the past years provides the possibility to study the sinter process in-situ between micrometer-sized water-ice particles.

## 2 The experiments

The experiments were conducted by observing the neck areas between micrometer-sized water-ice particles with a cryo-SEM (see Fig. 1). The particles were produced by spraying water particles with a pressurized-air driven droplet dispenser directly into liquid nitrogen [2]. After that, the ice particles were transferred into the pre-cooled microscope. Images were taken during the experiment runs to observe the degree of thermal alteration of the ice sample at different temperatures.

The images were analyzed with respect to particle size and sinter-neck size. At the beginning, the sinter

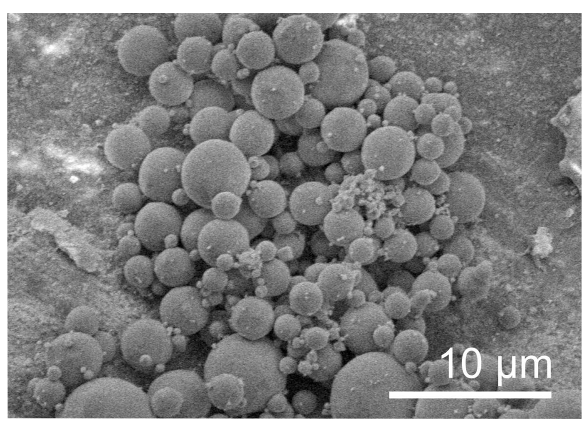


Figure 1: Example of a granular ice sample observed with the cryo-SEM. The acquired images were used to derive the temporal evolution of the sinter neck radii at different (constant) temperatures.

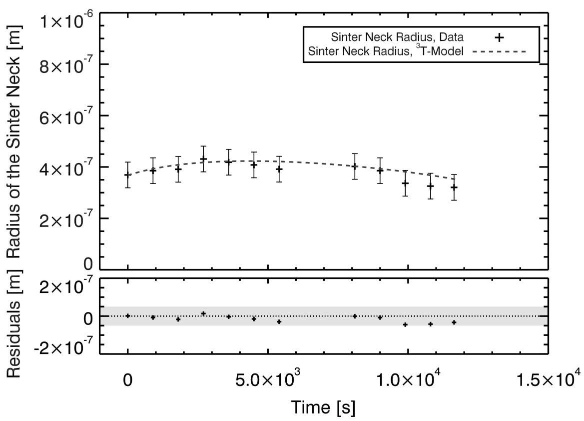


Figure 2: Temporal sinter neck evolution. The pluses are showing the experimental results and the dashed curve visualizes the result of the sinter model. The temperature of the ice samples was 163 K. The bottom panel shows the residuals between measured and modelled data. The gray region around zero denotes one standard deviation error of the measurements.

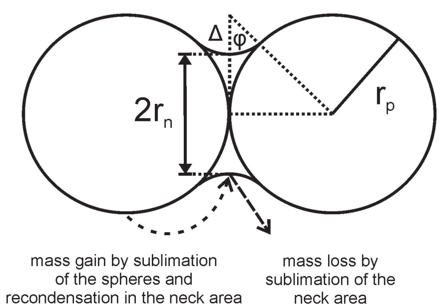


Figure 3: Schematic visualization of the different processes important for the sinter neck evolution of two particles in contact.

process leads to the formation of a neck between the particles (see Fig. 2). However, the formation of the sinter neck is accompanied by mass loss of the particles in contact due to sublimation, with the consequence that the mass transport efficiency decreases. At later stages, the sinter neck shrinks, because sublimation removes more molecules than replenished by the mass transfer.

## 3 The sinter model

The sinter model developed in the framework of this project is based on three main concepts (see Fig. 3): 1) the mass transport from the particles to the neck region leads to the formation and growth of the sinter neck (classically known as sinter process), 2) sublimation leads to shrinkage of the particles in contact, which decrease the effectiveness of the mass transport into the neck region, and 3) the neck area also loses mass due to sublimation. These three concepts define the basis of the developed sinter model (details can be found in our upcoming paper; Gundlach et al., submitted to MNRAS).

## 4 Results and Conclusions

Advances in the cryo-SEM technology enabled the possibility to study the sinter process between micrometer-sized water-ice particles. Based on the obtained experimental results, we developed a sinter model that takes, not only the importance of the mass transfer, but also of the sublimation process, into account. This model can be used to study the thermal evolution of icy Solar System objects, such as comets, or icy satellites. Details of the model results will be presented during the EPSC 2018 in Berlin.

## Acknowledgements

We acknowledge the DFG for supporting this work (project: GU 1620/1-1).

## References

[1] J. R. Blackford: Sintering and microstructure of ice: a review. Journal of Physics D: Applied Physics, 2007, 40, R355-R385.

[2] B. Gundlach and S. Kilias and E. Beitz and J. Blum: Micrometer-sized ice particles for planetary-science experiments - I. Preparation, critical rolling friction force, and specific surface energy. Icarus, 2011, 214, 717-723.

[3] K. J. Kossacki and N. I. Kömle and G. Kargl and G. Steiner: The influence of grain sintering on the thermoconductivity of porous. Planetary and Space Science, 1994, 42, 393-398.

[4] L. Ratke and H. Kochan and H. Thomas: Laboratory studies on cometary crust formation: The importance of sintering. Asteroids, Comets, Meteors, 1991, 497-500.

[5] F. B. Swinkels and M. F. Ashby: A second report on sintering diagrams. Acta Metallurgica, 1981, 29, 259-281.