TUM School of Life Sciences
Process Systems Engineering

TUM MLZ

Neutron imaging for the investigation of the lyophilisation of amorphous bulk solids

Sebastian Gruber, Mathias Hilmer, Nicole Vorhauer-Huget, Michael Schulz, Juergen Peters, Petra Foerst

Motivation

Lyophilisation as gentle dehydration technique for pharmaceuticals and foods (e.g. vaccines)

Lyophilisation of bulk solids is not yet fully understood (Fig. 2)

Sublimation front structure is an important process indicator (Fig. 2)

Impact of particle and pore size on sublimation front

Aim: Quantitative evaluation of local ice content

Experimental Setup

Instrument Antares, L/D = 800

LiF:ZnS Scintillators 50 / 100 µm

Test material: Maltodextrin DE 12

Particle sizes 70 µm / 3500 µm

Particles frozen in liquid N

Solid concentrations 0.05 and 0.2 w/w

Small particles: radiography

Large particles: continuous tomographies

Sample environment

Newly designed sample stick with better insulation / heat conductivity and heater (Fig. 1)

Chamber pressure: 10 Pa

Shelf temperature: - 18 °C

Sample stick
heater temperature: 0 °C / - 20 °C

Cryostat
(chamber walls) temperature: -42 °C

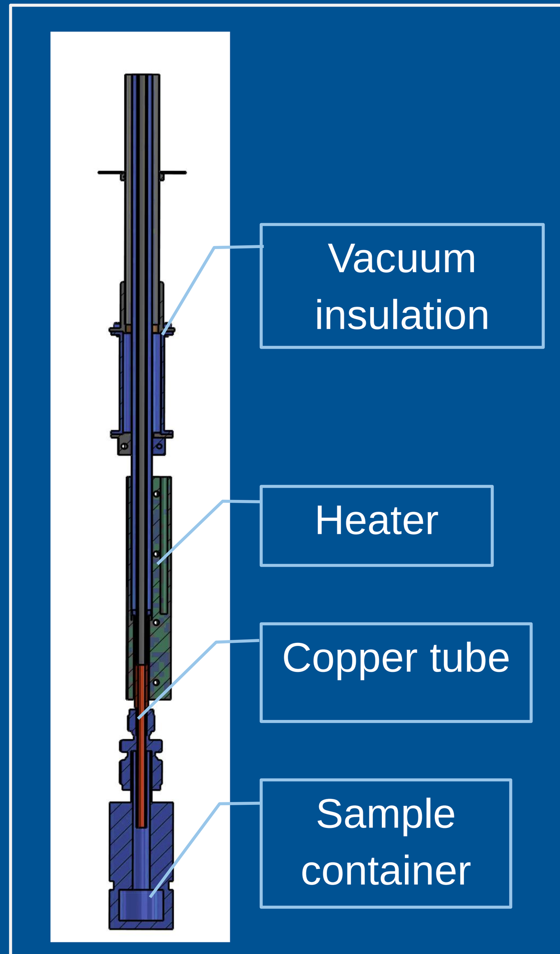

Fig. 1: Sample stick

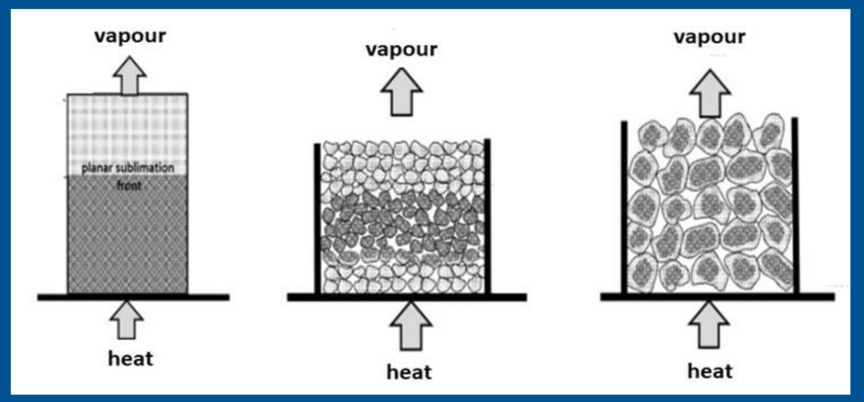

Fig. 2: Schematic illustration of sublimation front in bulky solids

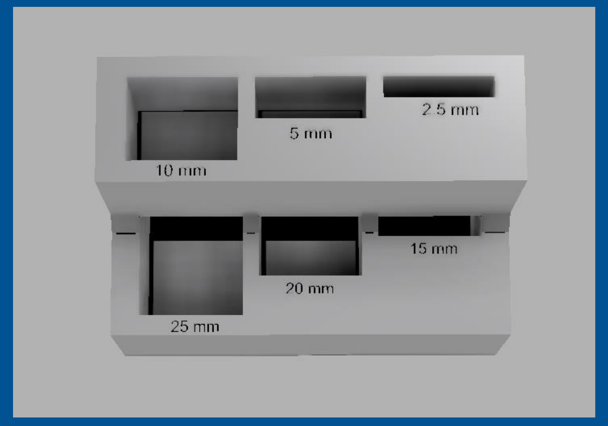

Fig. 3: Step wedge with frozen and dried sample for quantitative evaluation of local water content

Image analysis

Dark field (DF), Open Beam (OB) and gamma spot correction

Grey values:

$$T = \frac{IM(t) - DF}{OB - DF}$$

$$T' = \frac{T(t)}{T(t_0)}$$

Definition of sublimation front:

Evaluation of 1st derivative of averaged grey values T‘

Contact
TU Munich
Process Systems Engineering
Petra Först (petra.foerst@tum.de) and
Sebastian Gruber (sebi.gruber@tum.de)
Gregor-Mendel-Str. 4, 85354 Freising

Results from the radiography

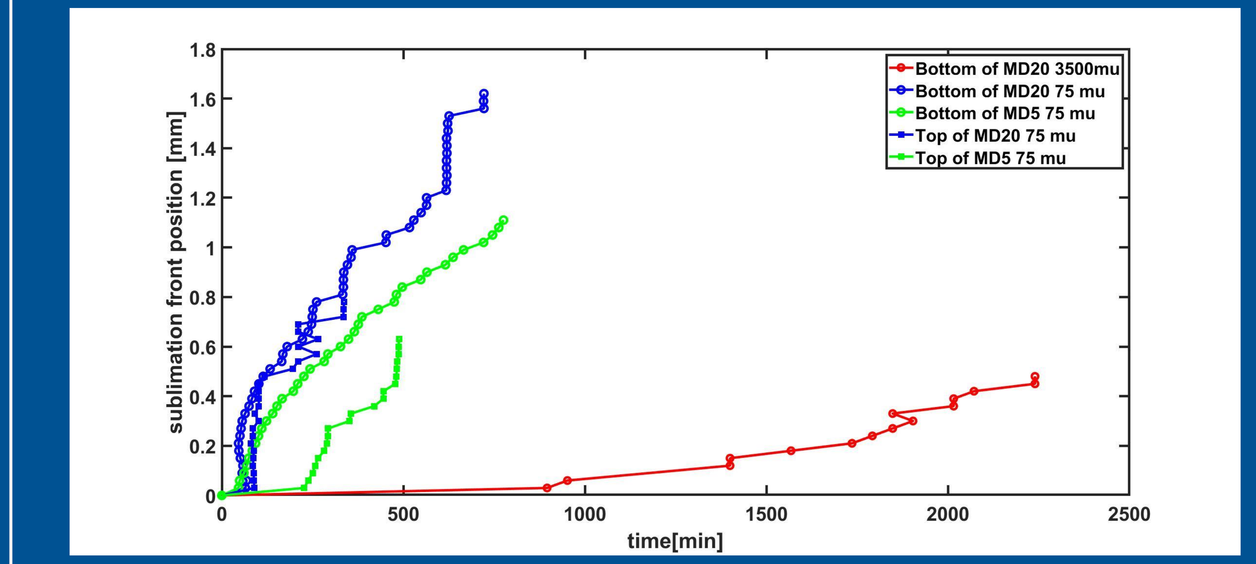

Fig. 4: Position of sublimation fronts for small particles

Sublimation front observed at bottom and top

Particles with higher solid concentration dry faster

Behaviour in contrast to exisiting models in literature and in contrast to frozen solutions

Possible explanation lies in intercorrelation between heat conductivity and sublimation front position (large difference in heat conductivity of dry and frozen particles)

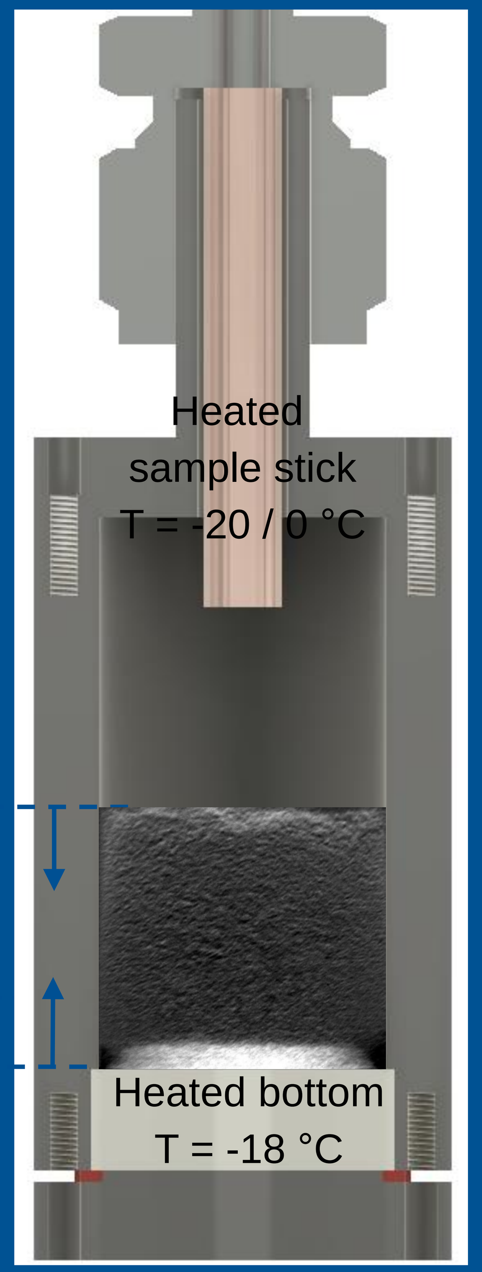

Fig. 5: Sample cell

Results from the tomography

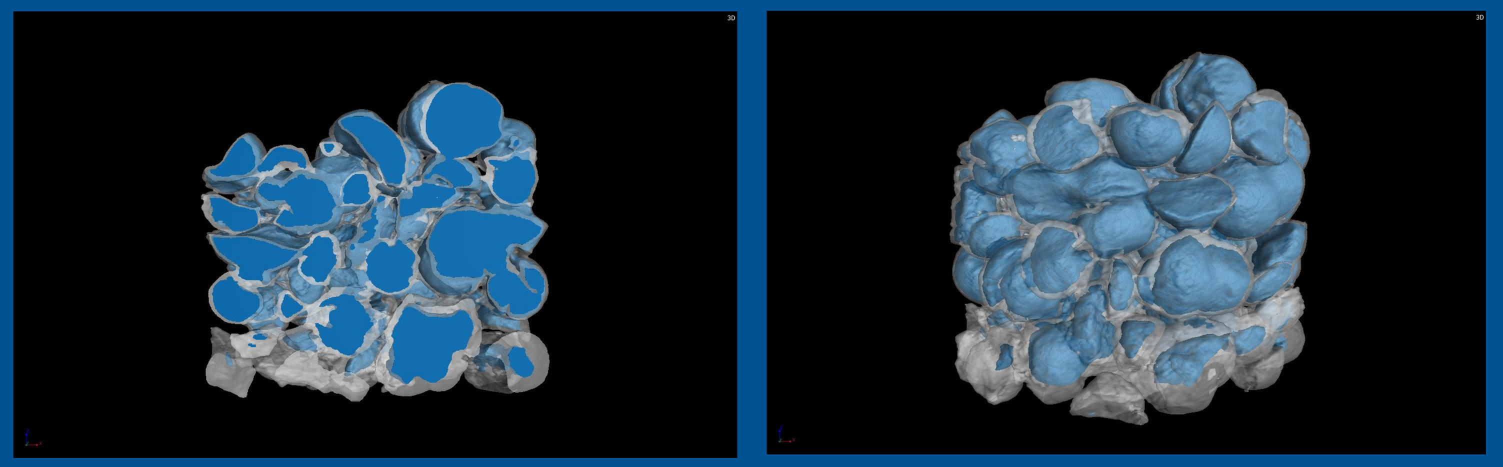

Fig. 6: Tomographic images of large particles showing ice in dark and dried material in light blue

Continuous tomography during drying cycle (43 tomographies)

Multiple sublimation fronts occur in large particles

Sublimation front structure depends on distance from heating shelf

Publications
Gruber et al. (2020), CES https://doi.org/10.1016/j.ces.2019.115268
Foerst et al. (2020), CET 10.1002/ceat.201900500
Hilmer et al. (2020), Rev. Sci.Inst. ; https://doi.org/10.1063/1.5126927