

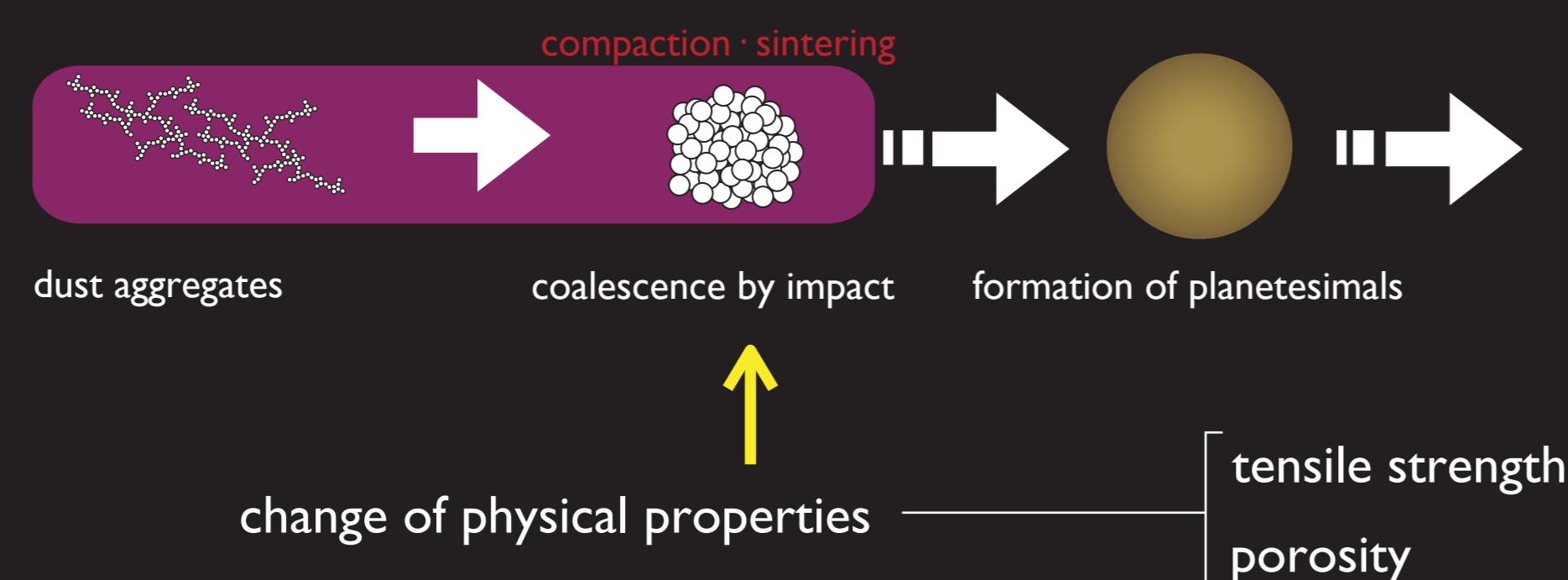
# Experimental study of sintering: Relation between neck radius and strength

Nagisa Machii(machii@stu.kobe-u.ac.jp)and Akiko M. Nakamura  
Graduate School of Science, Kobe University

Abstract: We performed laboratory experiments to study the effect of sintering as one of the processes that could strengthen a planetary body. The sample used in our experiments was soda-lime glass bead of 5 mm in diameter. We measured the neck radius and tensile strength of the neck and found that the tensile strength is not always proportional to the cross section of the neck. According to detailed observation of the neck, there is obvious difference in the structure of the cross section of the neck. It seems that the difference may relate to the different mechanism of sintering.

## Introduction

### Formation of planetesimals



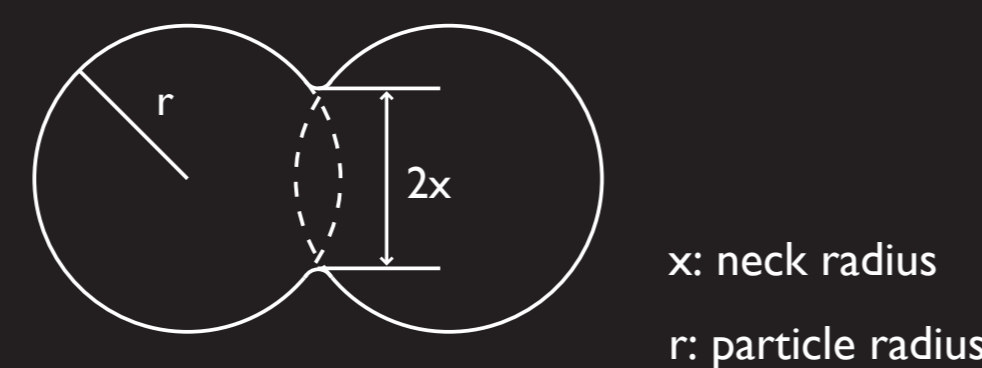
We focus to study about early stage of the formation process of planetesimals. At some points during formation and evolution of a solid planetary body from dust aggregates to asteroids, the body must have gained finite strength comparable to those of meteorites. When the strength of a body changes, the result of impact will also change.

### What is "sintering" ?

Sintering is a process in which connection between contacted particles grows when heated below the melting point.

### Definition of neck

Neck is a connected part between particles.  
Its radius is called "neck radius".



## Purpose of This Work

We investigate the change of strength of the dust aggregates due to sintering.  
→ relation between neck growth of the sintered sample and its tensile strength

Our previous work: Sintering experiments of the aggregates consisting of silica microparticles

### Sample

polydisperse amorphous silica(SiO<sub>2</sub>) particles  
particle diameter: 0.8±0.3µm(HWHM)

Physical parameters of samples			
radius (mm)	height (mm)	porosity (before sintering)	porosity (after sintering)
2.5	2-4	0.41 ± 0.1	0.36 ± 0.04

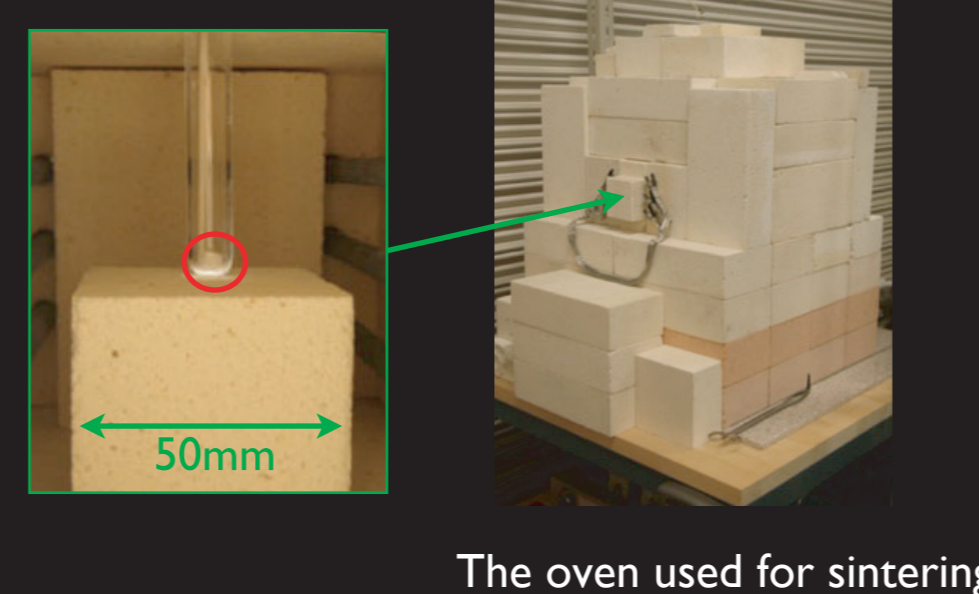


How to make a sample: Particles are

1. poured into a stainless cylindrical container,
2. compressed by applied pressure of 500 MPa using compression testing machine,
3. formed a pellet shape.

### Experimental conditions

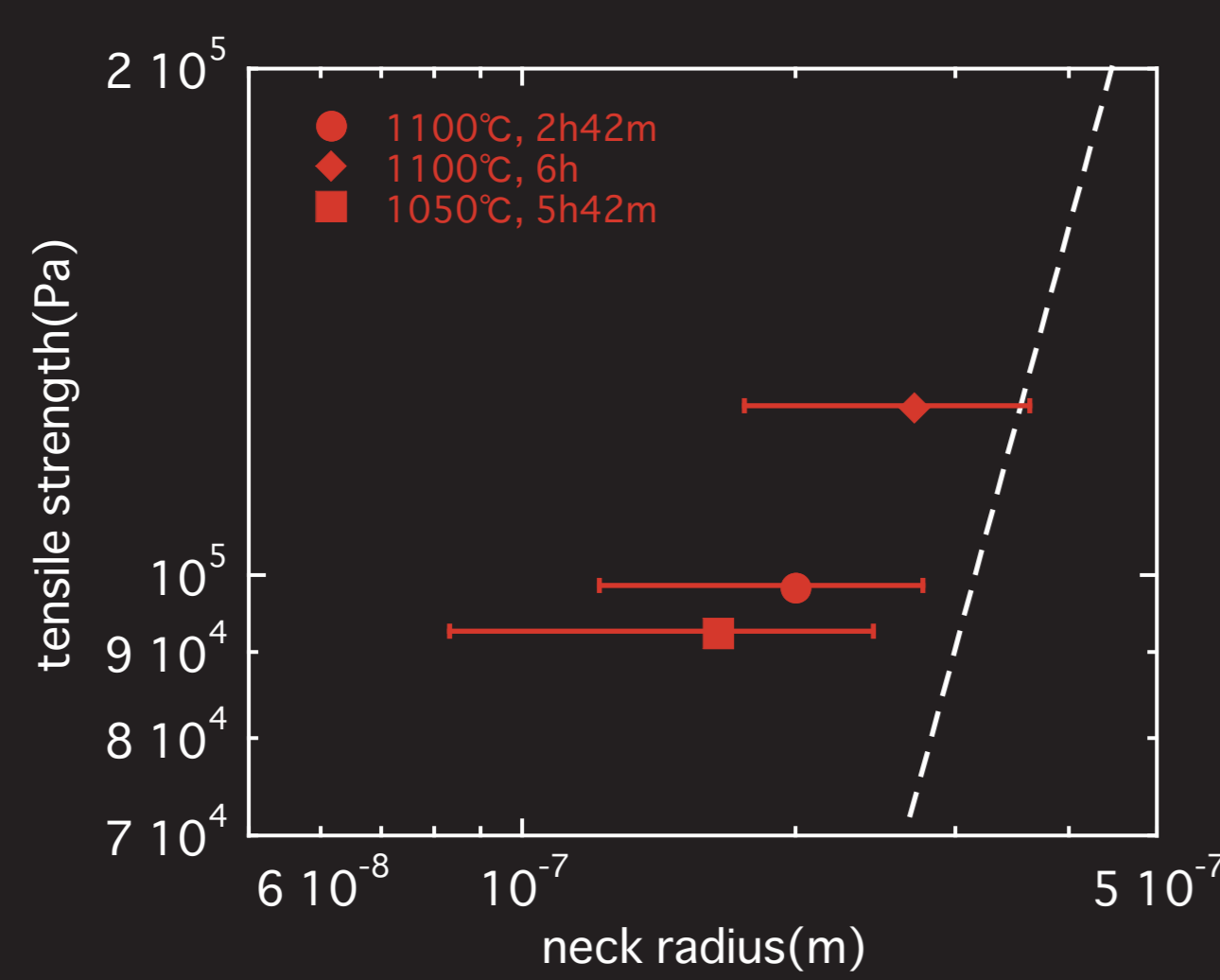
heating temperature (°C)	duration time (h)	ambient pressure (Pa)
1050 - 1100	2 - 6	20



### Measurements of neck: Scanning Electronic Microscope

### Measurements of tensile strength of samples: Brazil disc test

Results: Relation between neck radius and tensile strength of sintered silica samples



Tensile strength  $\propto$  neck radius  
Why?

## Results

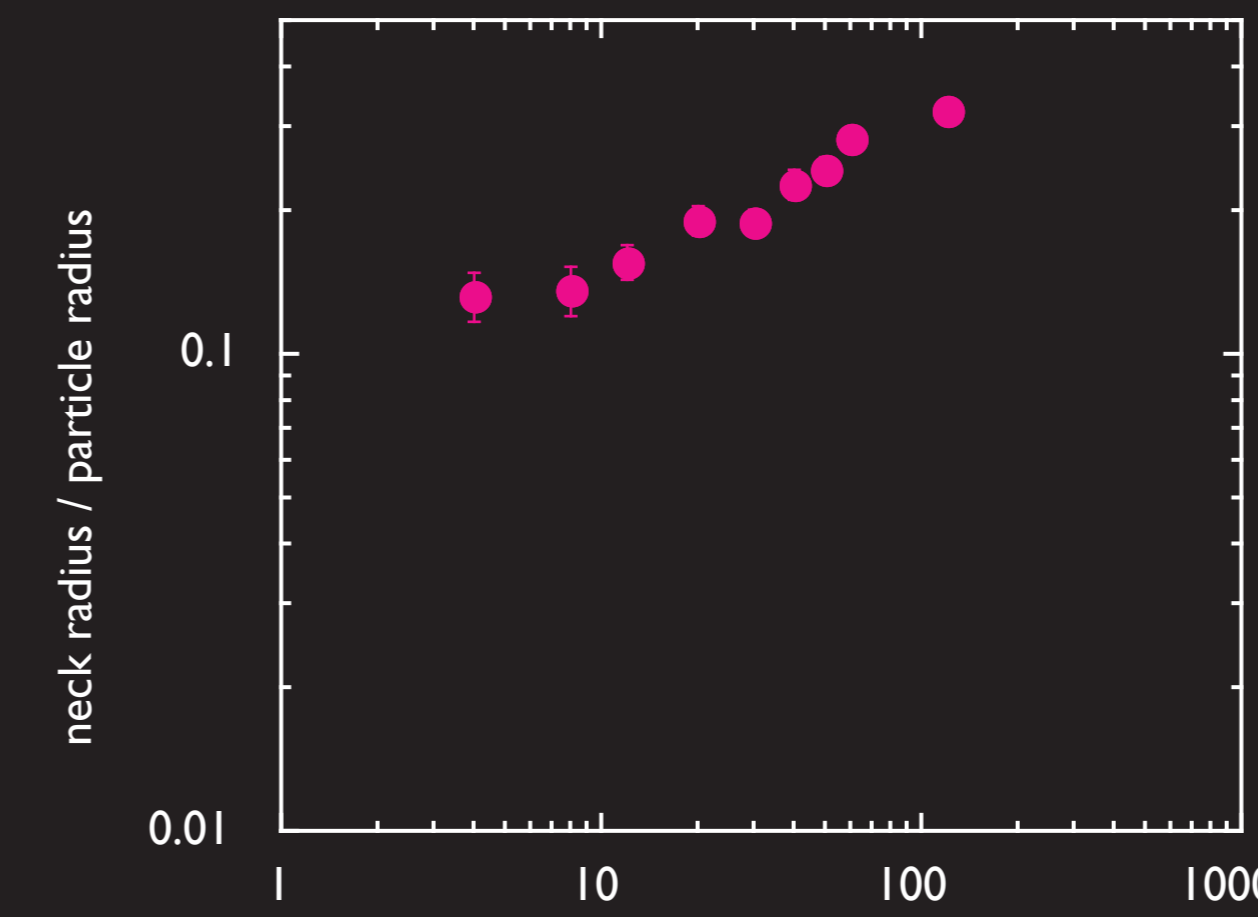


Fig.1. The relation between neck radius and heating time

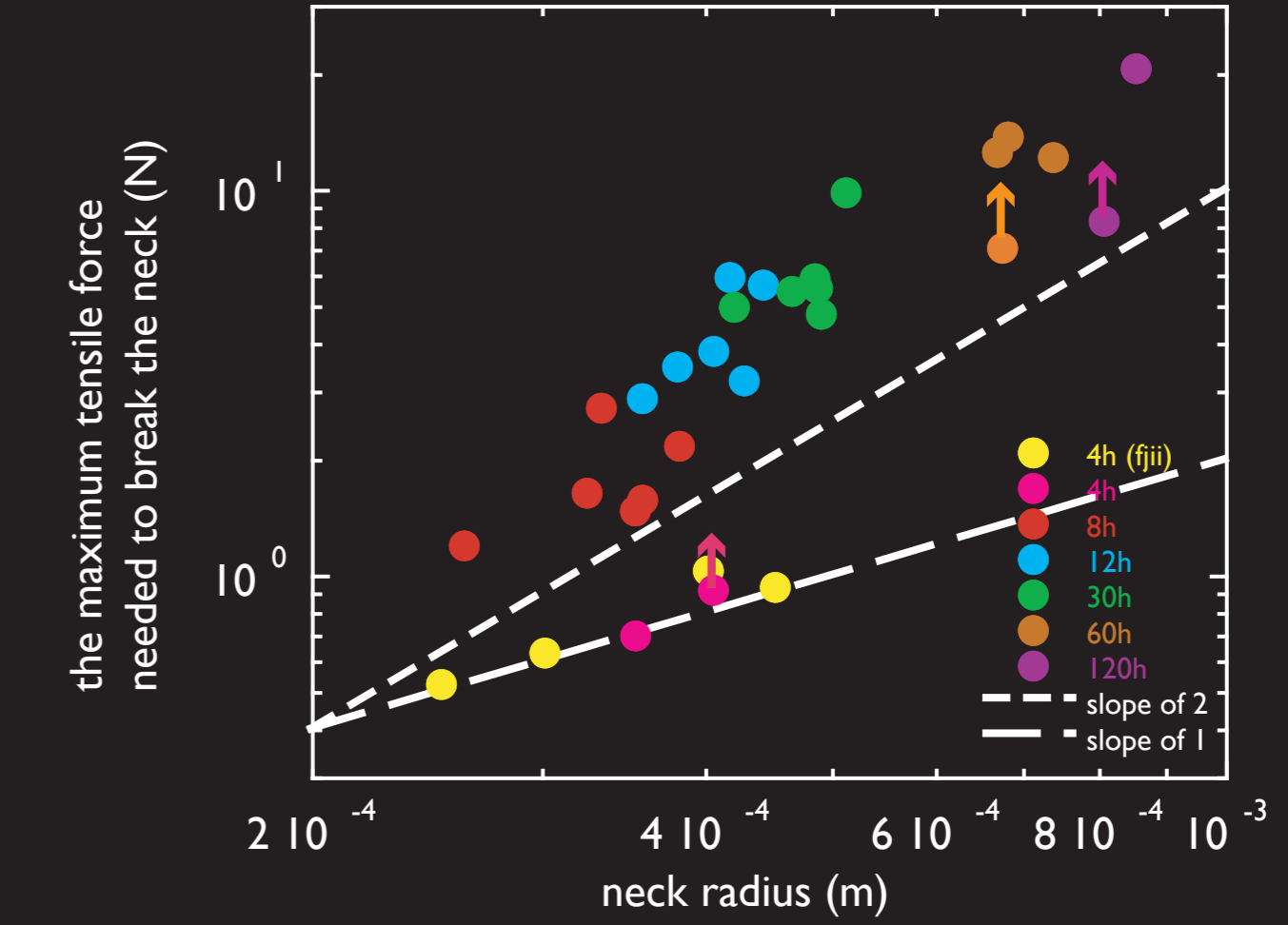


Fig.2. The relation between neck radius and the maximum tensile force needed to break the neck

### Neck radius vs tensile strength

Samples of 4 hours sintering: Tensile strength  $\propto$  neck cross section

Samples of 4-12 hours sintering: Big scatter in tensile strength

Samples of 12 hours (or more) sintering: Tensile strength  $\propto$  neck cross section

## Discussion

### Mechanism of sintering

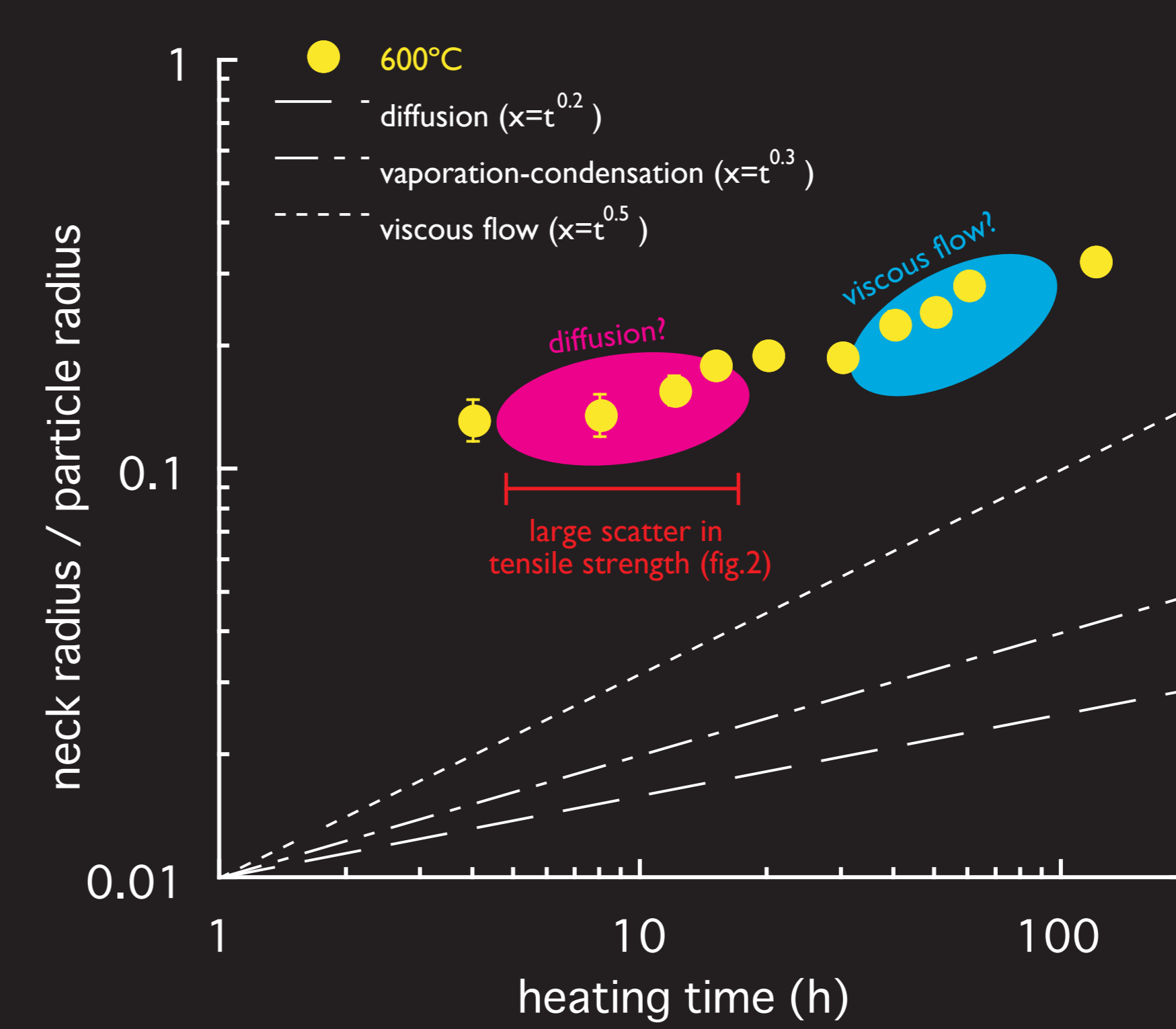


Fig.3. Normalized neck radius versus sintering duration. Relations for different sintering mechanisms (diffusion, viscous flow, and evaporation-condensation) are shown for comparison.

### Internal structure of necks

The cross section of the neck is ...

heterogeneous → homogeneous

diffusion → viscous flow

evaporation-condensation, → strengthen connection

expand the contacted area

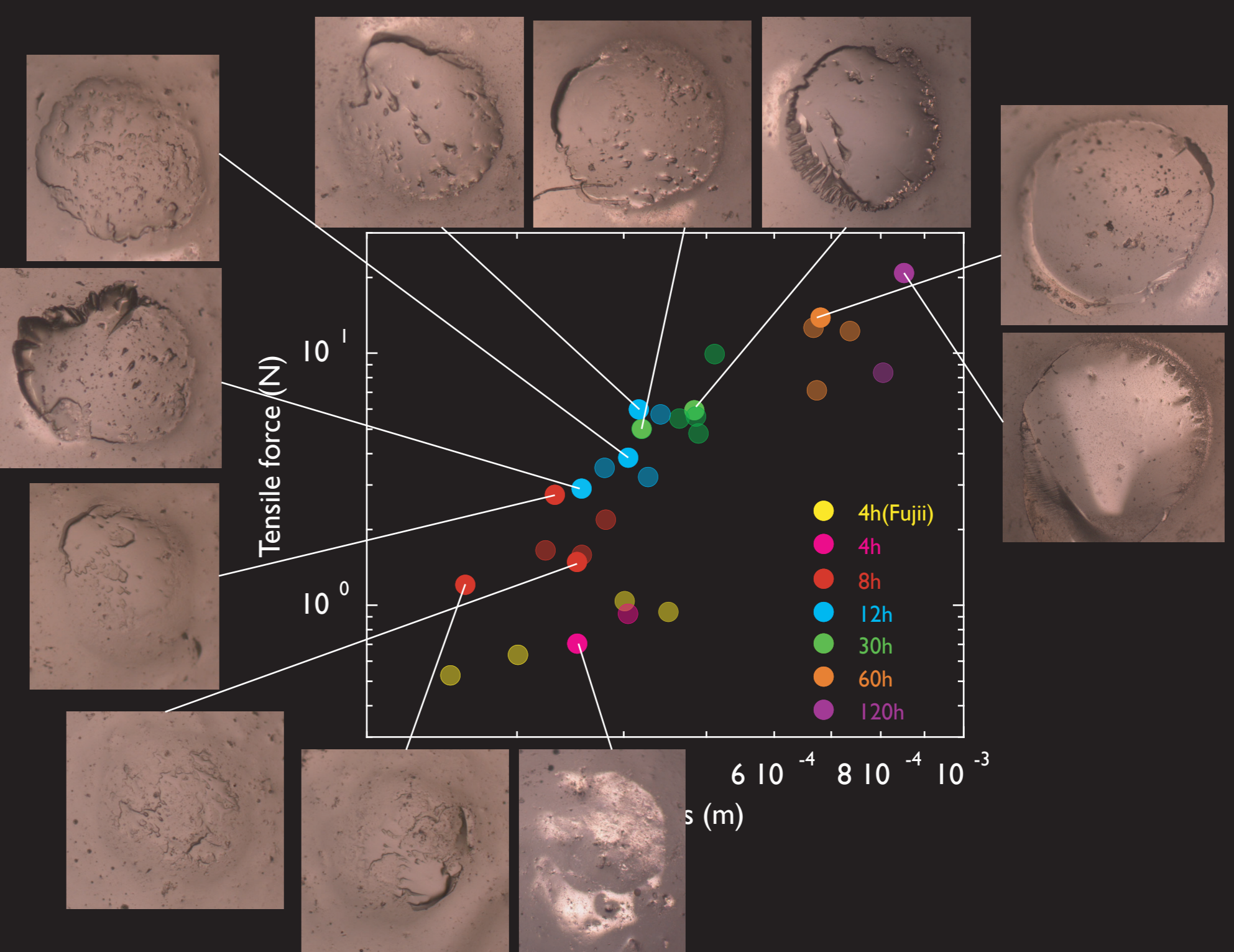
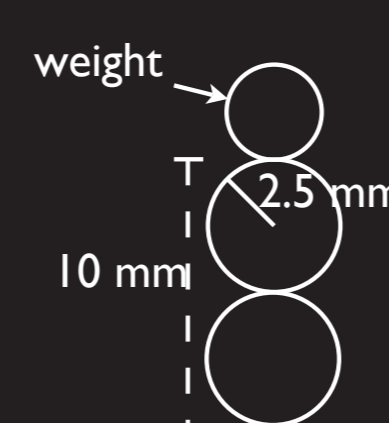


Fig.4. Detailed observation of the neck

## Experiments

### Sample

soda-lime glass bead  
particle diameter: 5 mm



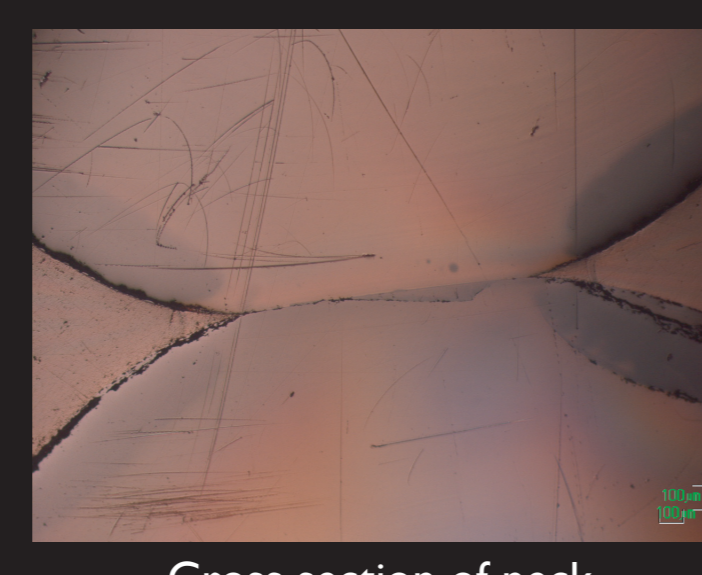
Two particles were set into an alumina tube with a weight on top of one of the particles and were sintered into array shape.

### Experimental conditions

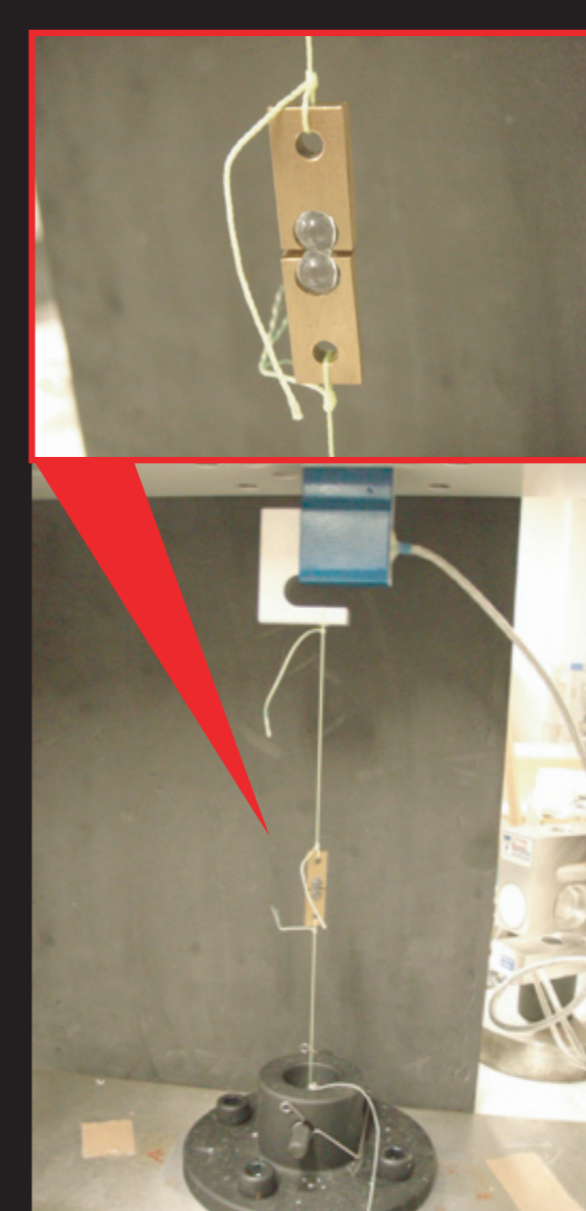
heating temperature (°C)	duration time (h)	ambient pressure (Pa)
600	4 - 120	air pressure

### Measurements of neck: stereomicroscope and polarization microscope

### Measurements of tensile strength: tensile test



Cross section of neck



A picture of tensile test

## Summary and On Going Work

We investigated the relation between neck radius and tensile strength using sintered soda-lime glass beads.  
- Tensile strength was different between the samples of different sintering durations, although the neck radii were similar for these samples.

From the detailed observation of the cross section of the neck, was found to be obviously different when heating duration was different.

The cross section is heterogeneous for the samples prepared by shorter heating time, while it becomes more homogeneous with a longer heating time.

Diffusion sintering plays a role in expansion of contact area, while viscous flow sintering strengthens the connection between the particles.

We now examine the process at different sintering temperatures.

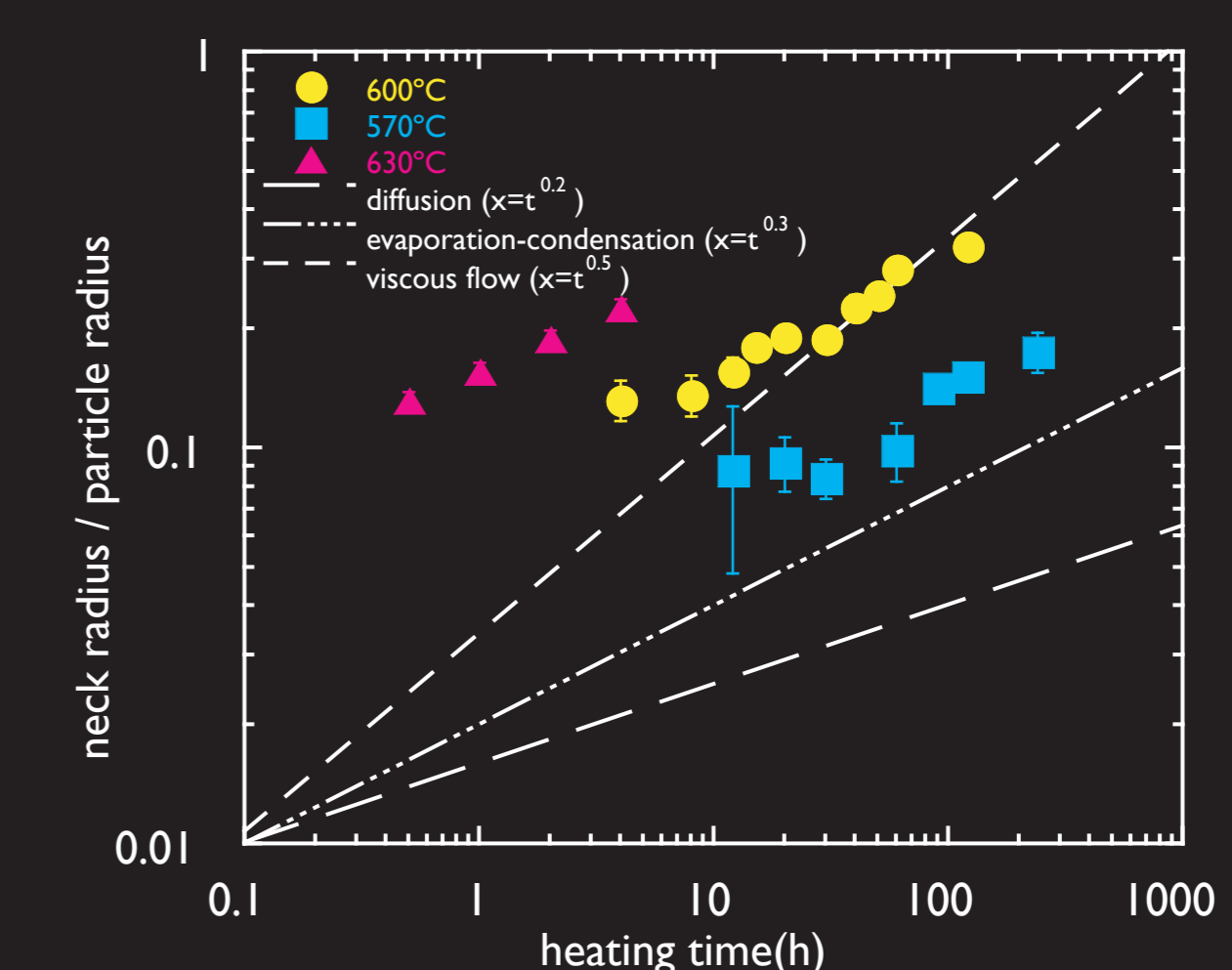


Fig.5. Neck growth at different sintering temperatures