AEROSOL SPECTROSCOPY FOR ASTROPHYSICAL DUST GRAIN INVESTIGATION

Oct. 8-10 2009
Grain Formation Workshop

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Factors to influence on MIR band profiles

Crystallinity

Polymorph （多形）

同一物質が複数の異なった結晶構造を取る

e.g. **SiO_2**

α-quartz (trigonal: 三方晶系)

α-tridymite (orthorhombic: 斜方晶系)

α-cristobalite (tetragonal: 正方晶系)

Chemical compositon

Mg, Fe, Al, Si, Ti, Ca, S, …

e.g. Olivine

San Carlos $Mg_{1.96}Fe_{0.16}Si_{0.89}O_4$

Sri Lanaka $Mg_{1.56}Fe_{0.40}Si_{0.91}O_4$

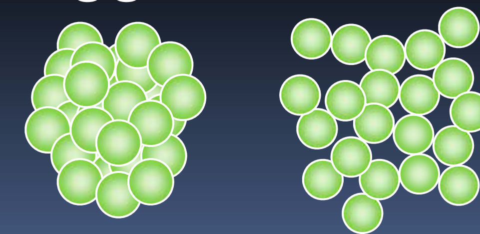
(Koike et al. 2003)

Morphology

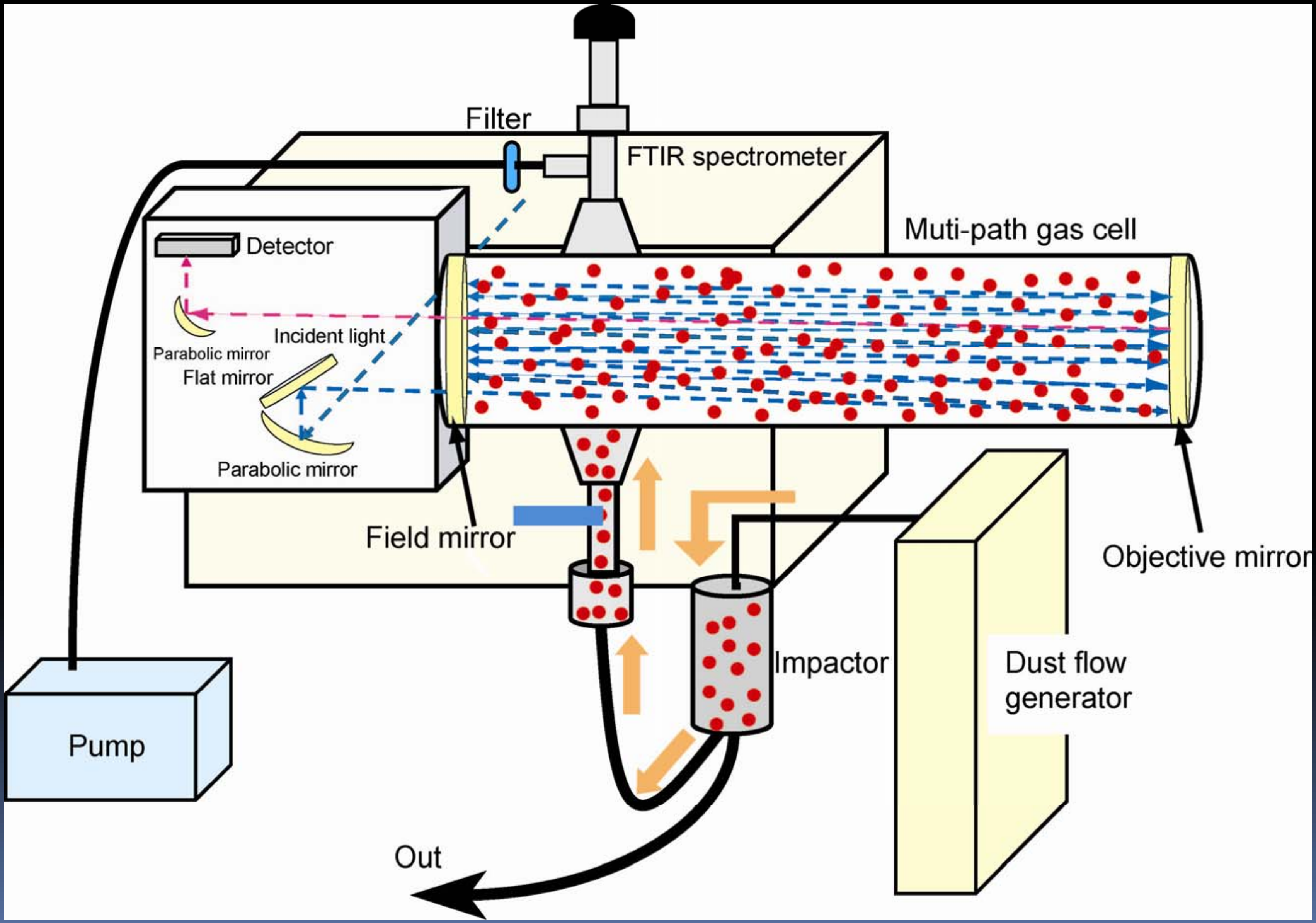
✓ **Size**

✓ **Shape**

✓ **Agglomeration**



Experiment


Filter
FTIR spectrometer
Detector
Muti-path gas cell
Incident light
Parabolic mirror
Flat mirror
Parabolic mirror
Field mirror
Objective mirror
Impactor
Dust flow generator
Pump
Out

Samples

Silicate

- ✓ Forsterite (Mg_2SiO_4)
- ✓ Fayalite ($Fe_{0.64}Si_{0.36}O_4$)
- ✓ Olivine (e.g. $Mg_{1.96}Fe_{0.16}Si_{0.89}O_4$)
- ✓ Enstatite ($MgSiO_3$)
- ✓ Diopside (e.g. $Ca_{0.45}Mg_{0.54}O_{0.99}O_3$)
- ✓ Hypersthene (e.g.$Mg_{0.63}Fe_{0.36}Si_{0.9}O_3$)
- ✓ Wollastonite ($CaSiO_3$)
- ✓ Kaolinite ($Al_2Si_2O_7 \cdot 2H_2O$)
- ✓ Talc ($Mg_{3.33}Fe_{0.1}Si_4O_{10}(OH)_2$)

Al_2O_3

- ✓ Corundum (α-Al_2O_3)
- ✓ γ-Al_2O_3
- ✓ χ–δ–κ-Al_2O_3

$MgAl_2O_4$ (Spinel)

TiO_2 (Rutile & Anatase)

$CaTiO_3$ (Pervoskite)

Al_2TiO_5 (Tialite)

SiO_2

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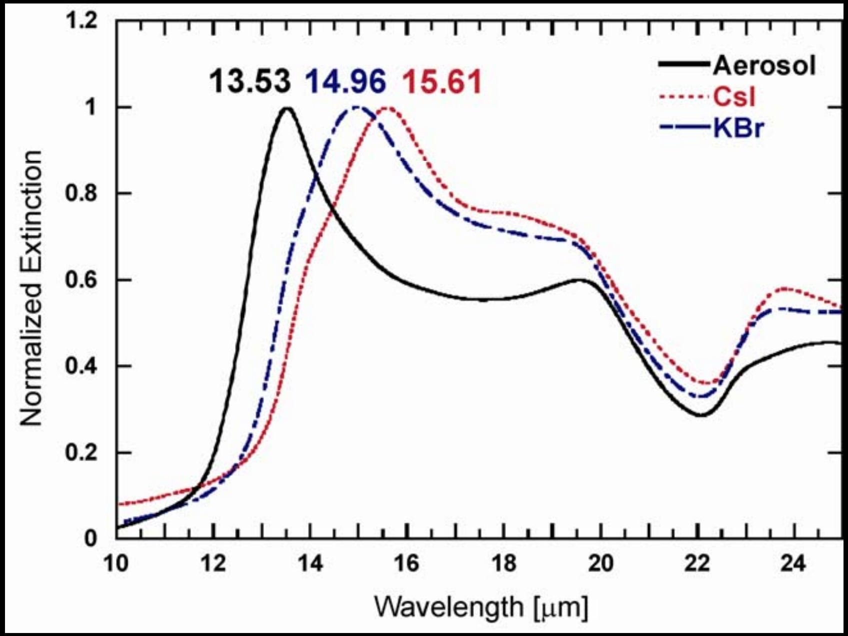
<Medium effect>



TiO_2 (Rutile)

ε_m

N_2 → 1.0

KBr → 2.3

CsI → 3.0

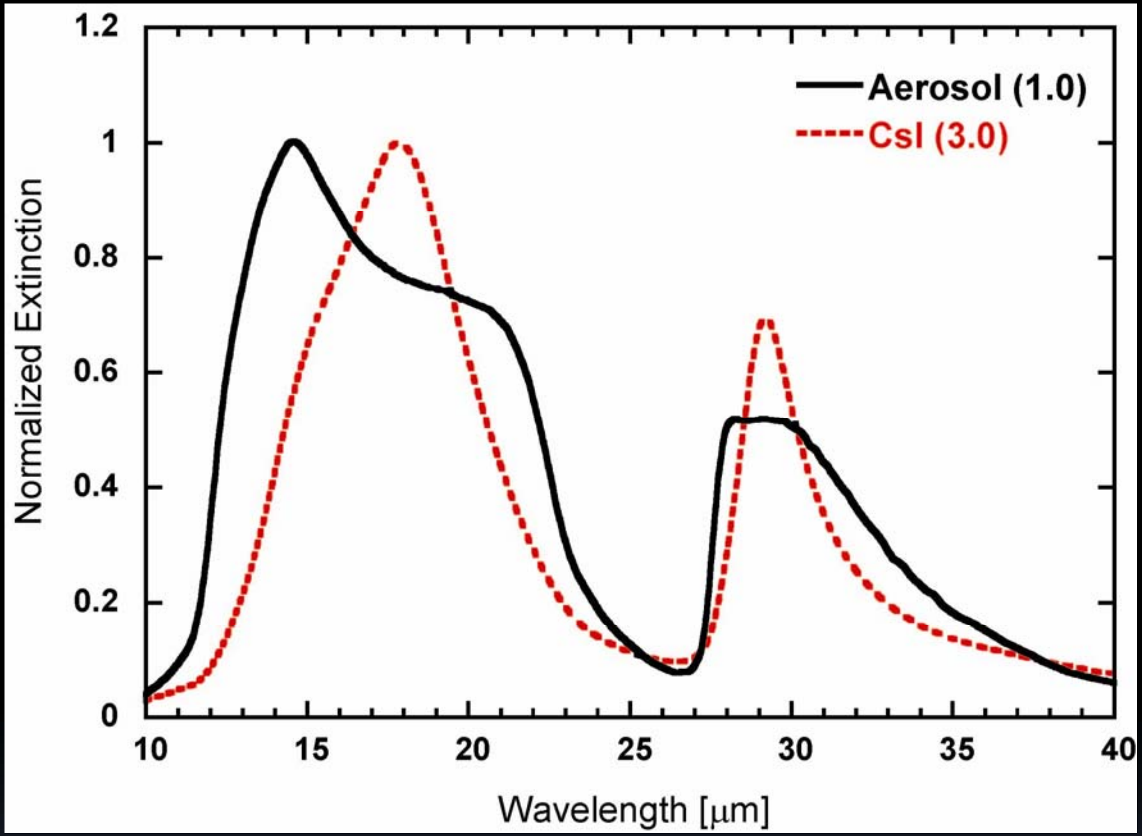
The influence of its electromagnetic polarization.

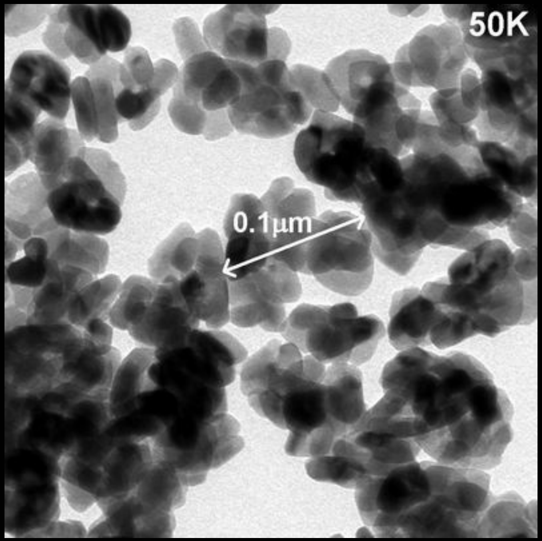
(Tamanai et al. 2009)

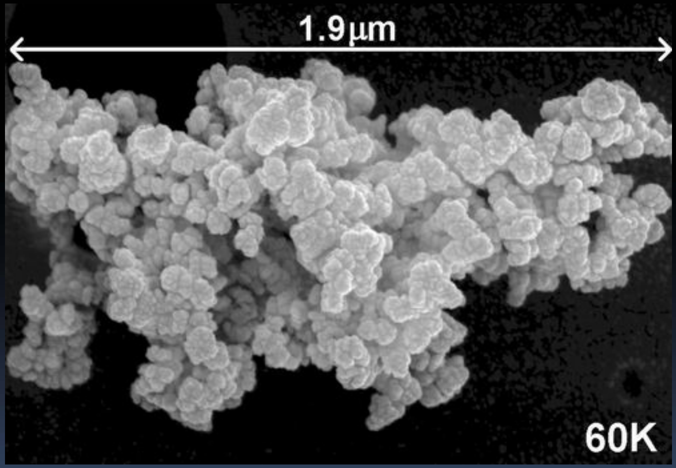
KBr :
(Potassium Bromide)
Mixing ratio 1:500
(sample:KBr)
d=13mm ; mass=0.2g

CsI :
(Cesium Iodine)
Mixing ratio 1:500
(sample:CsI)
d=13mm ; mass=0.22g

Aerosol vs. Pellet Measurements







Tamanai et al. (2009)

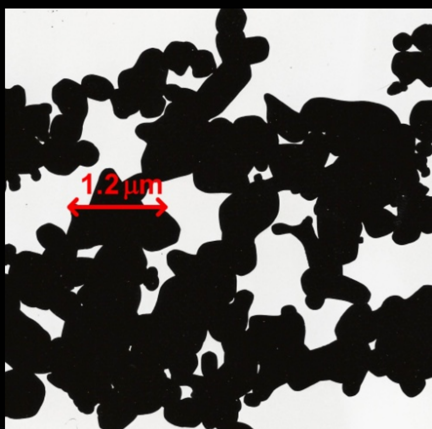
- Using different dispersion methods
- Particles may transform during the grinding procedure
- Sample structure deformation caused by the high pressurization required
- Particle orientation

<Morphological effects>

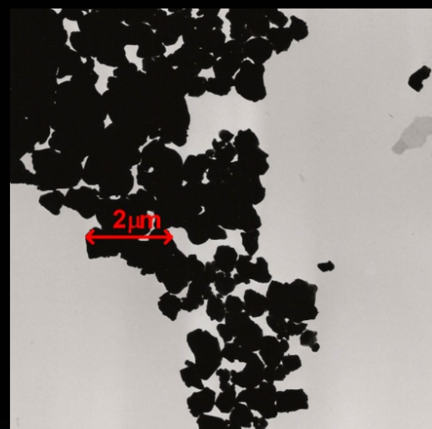
TiO_2 (Rutile)

R1	R2	R3	R4
Irregular shape w/ rounded edges	Irregular shape with not rounded edges	Long and thin	Rounded

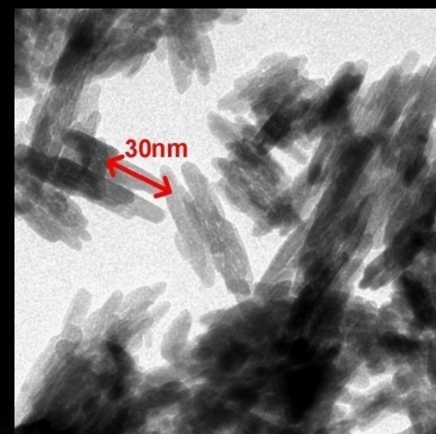
R1



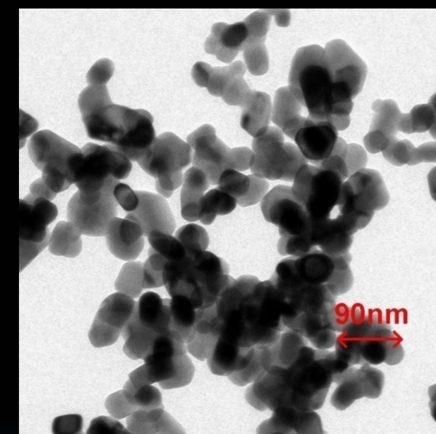
R2

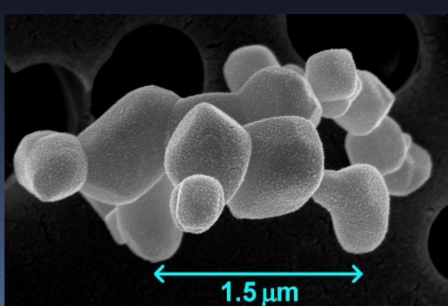


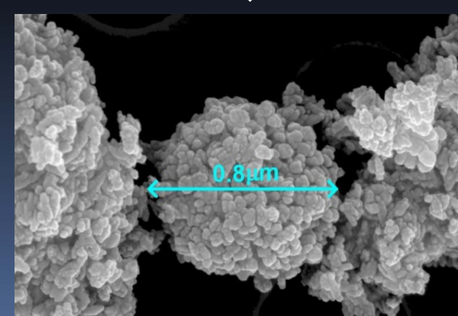
R3

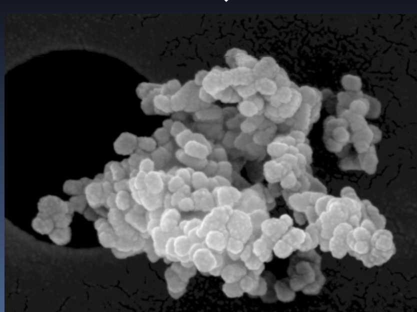


R4

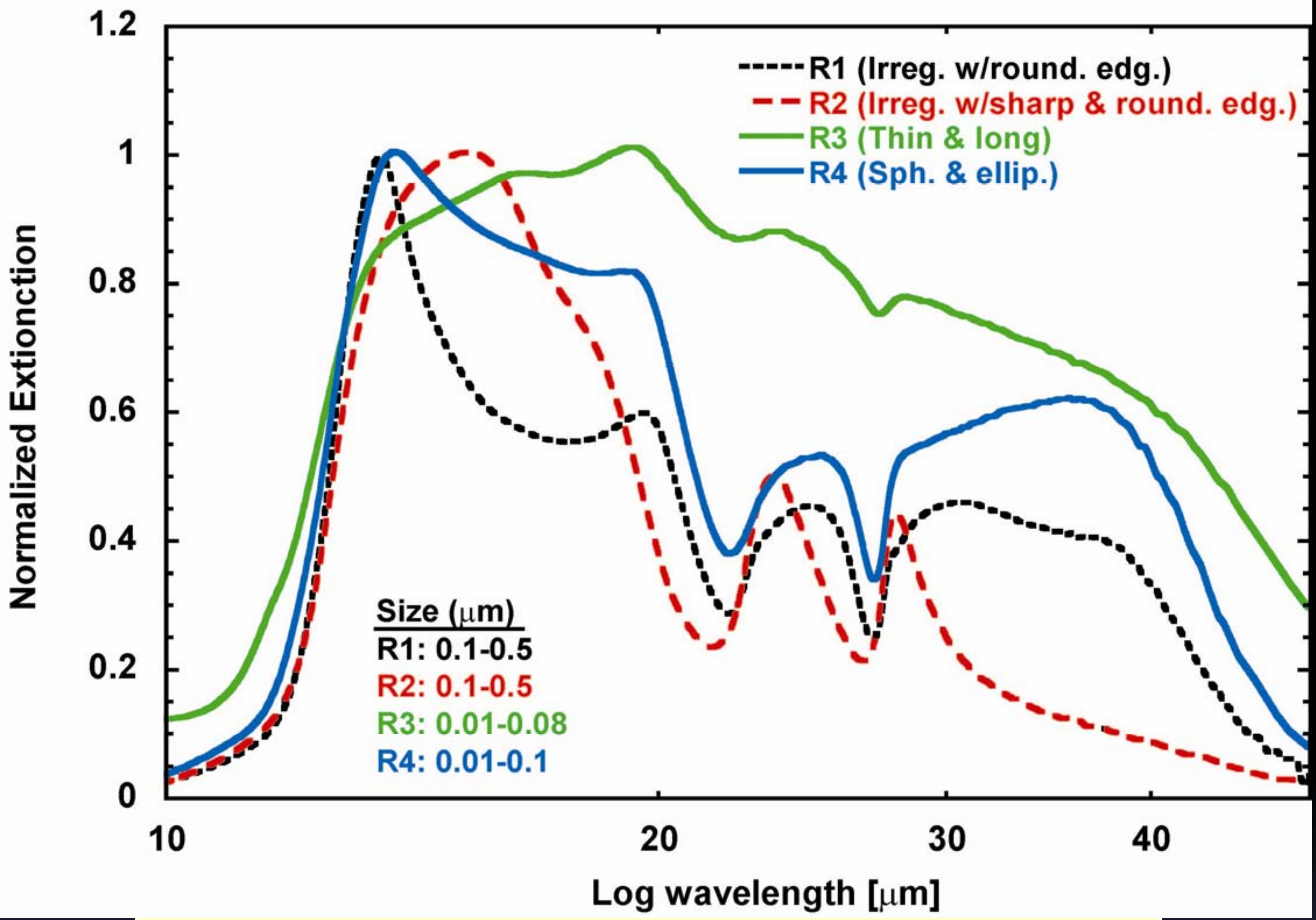








(TEM & SEM images: at Pathology w/ Dr. Nietzsche)



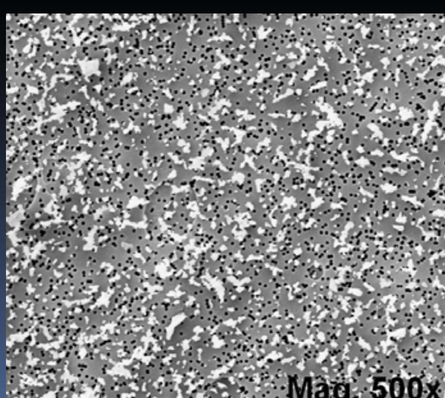
Peaks (microns)

R1	13.53	19.56	24.70	30.30	35.80
R2	15.33		23.51	27.95	
R3	16.47	19.25	23.39	28.27	
R4	13.85	19.27	25.15	35.87	

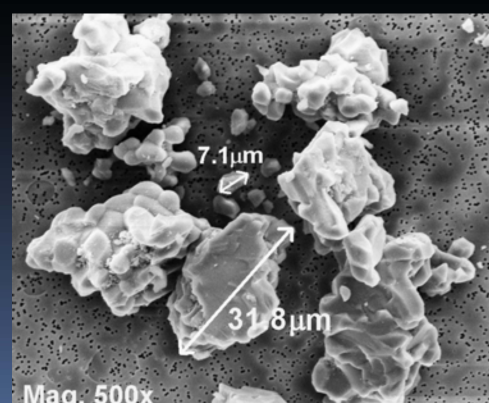
Morphological effect --- Size

- Extinction measurements of ***large-sized particles*** (2 – 50 μm)

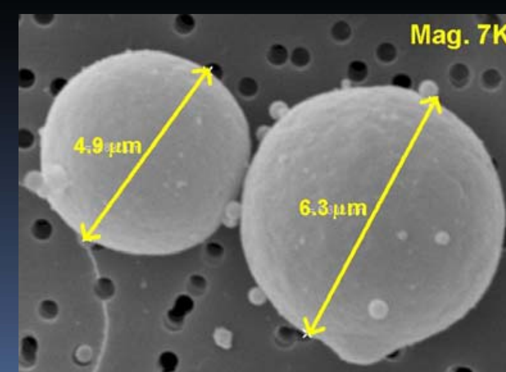
- ***Mixture measurements*** --- How small-sized particles exert an influence on the extinction spectra when they are present in a same environment with larger ones   (0.5 μm & 5 μm particles)



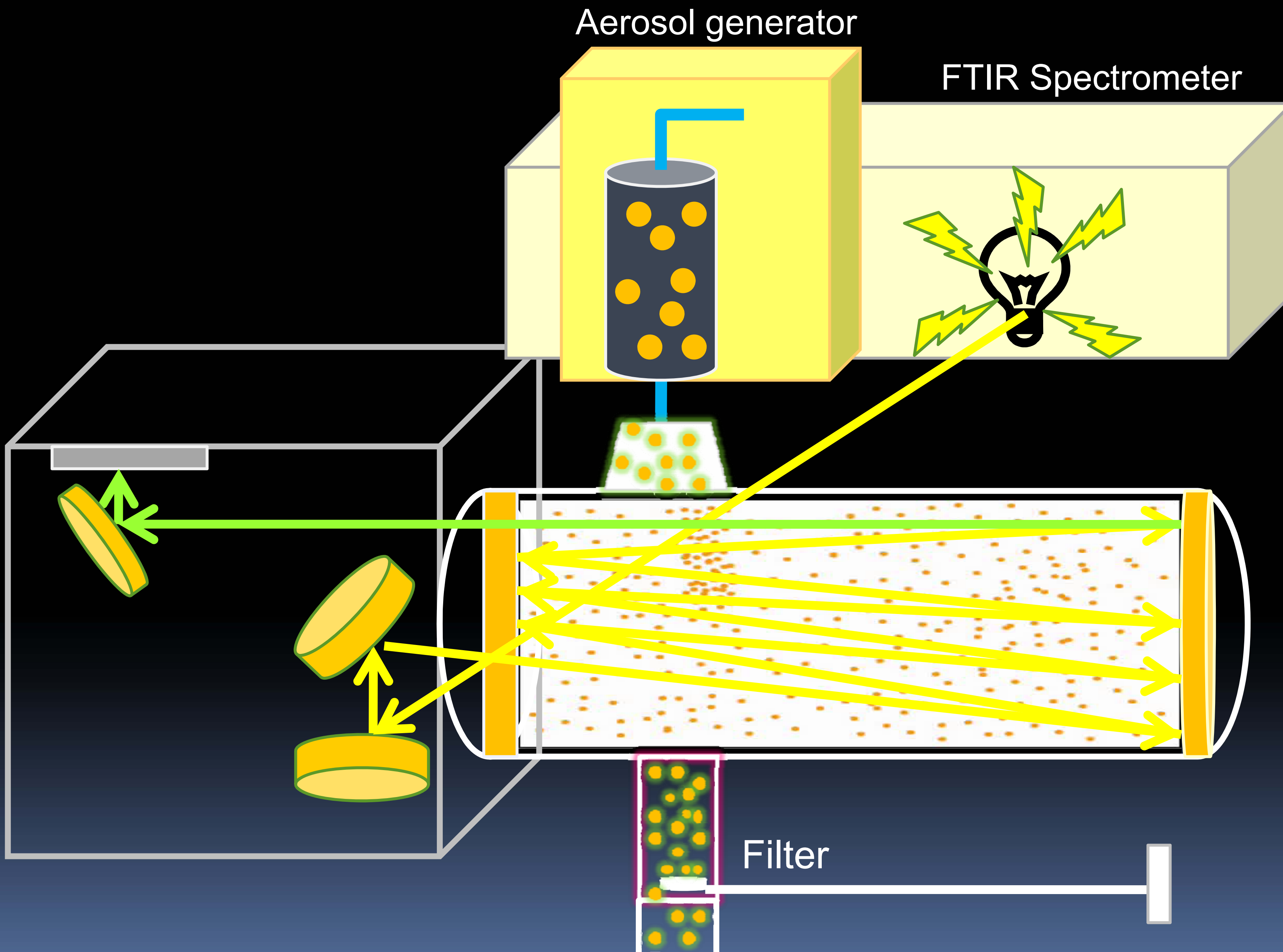
Cry-Mg_2SiO_4 (< 1μm)



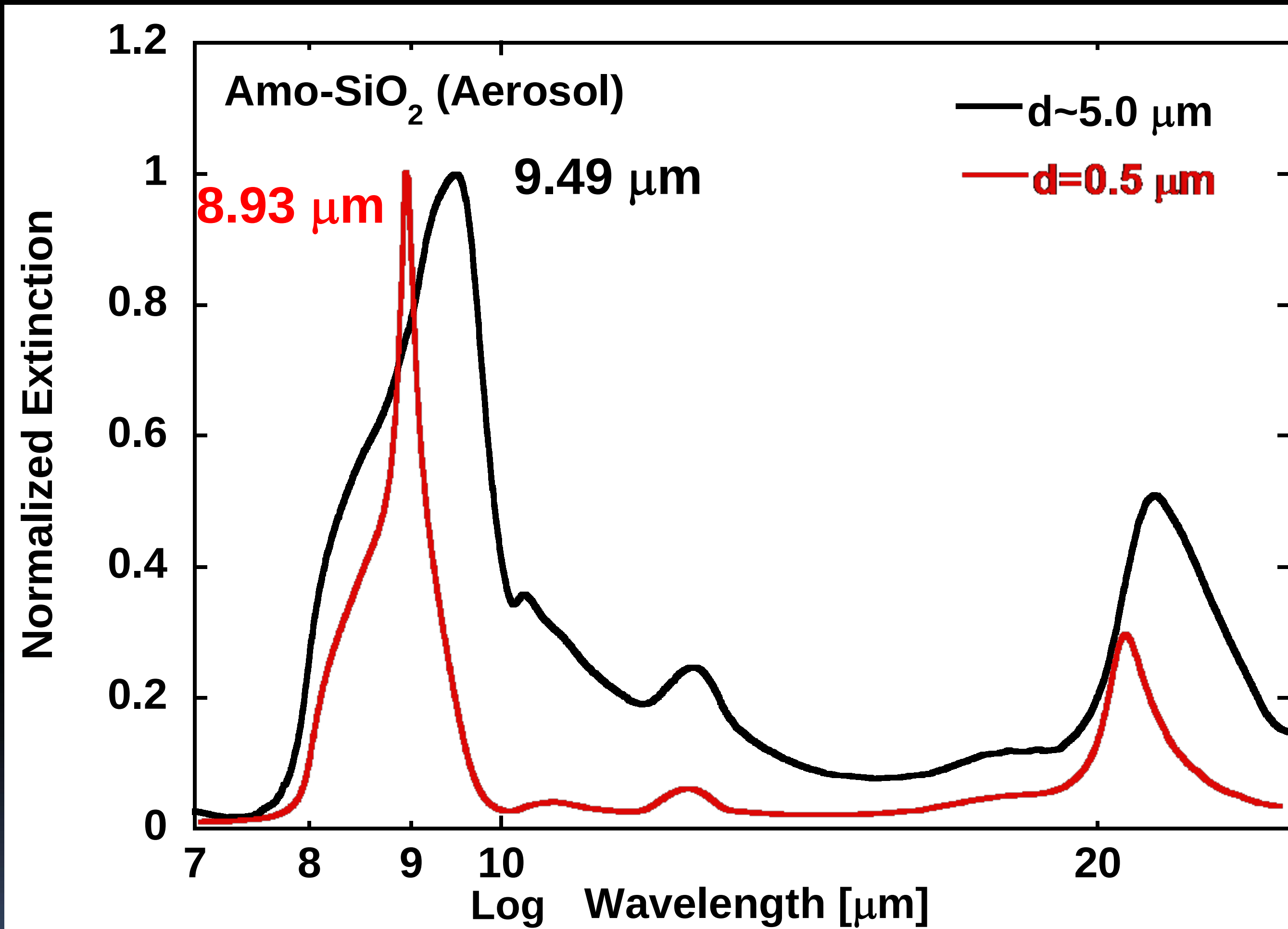
Cry-Mg_2SiO_4 (~ 16 μm)

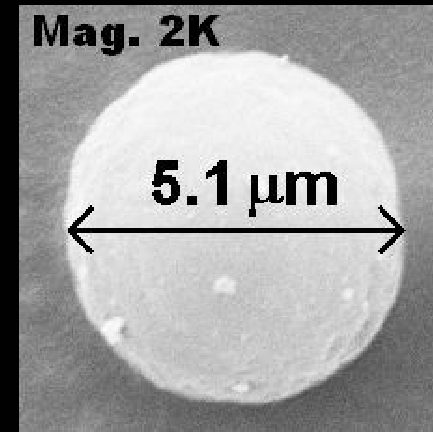


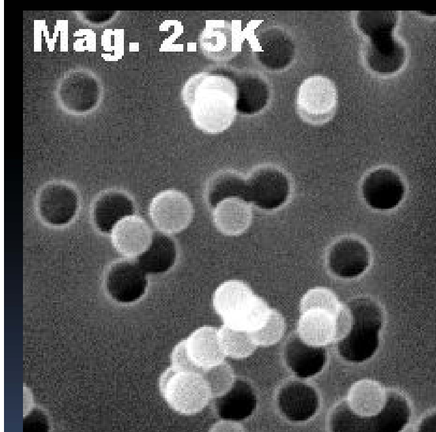
Amorphous SiO_2 (d=0.5 & ~5 μm)


Aerosol generator
FTIR Spectrometer
Filter

Exp. 1 Large Particles (SiO_2 monosphere)

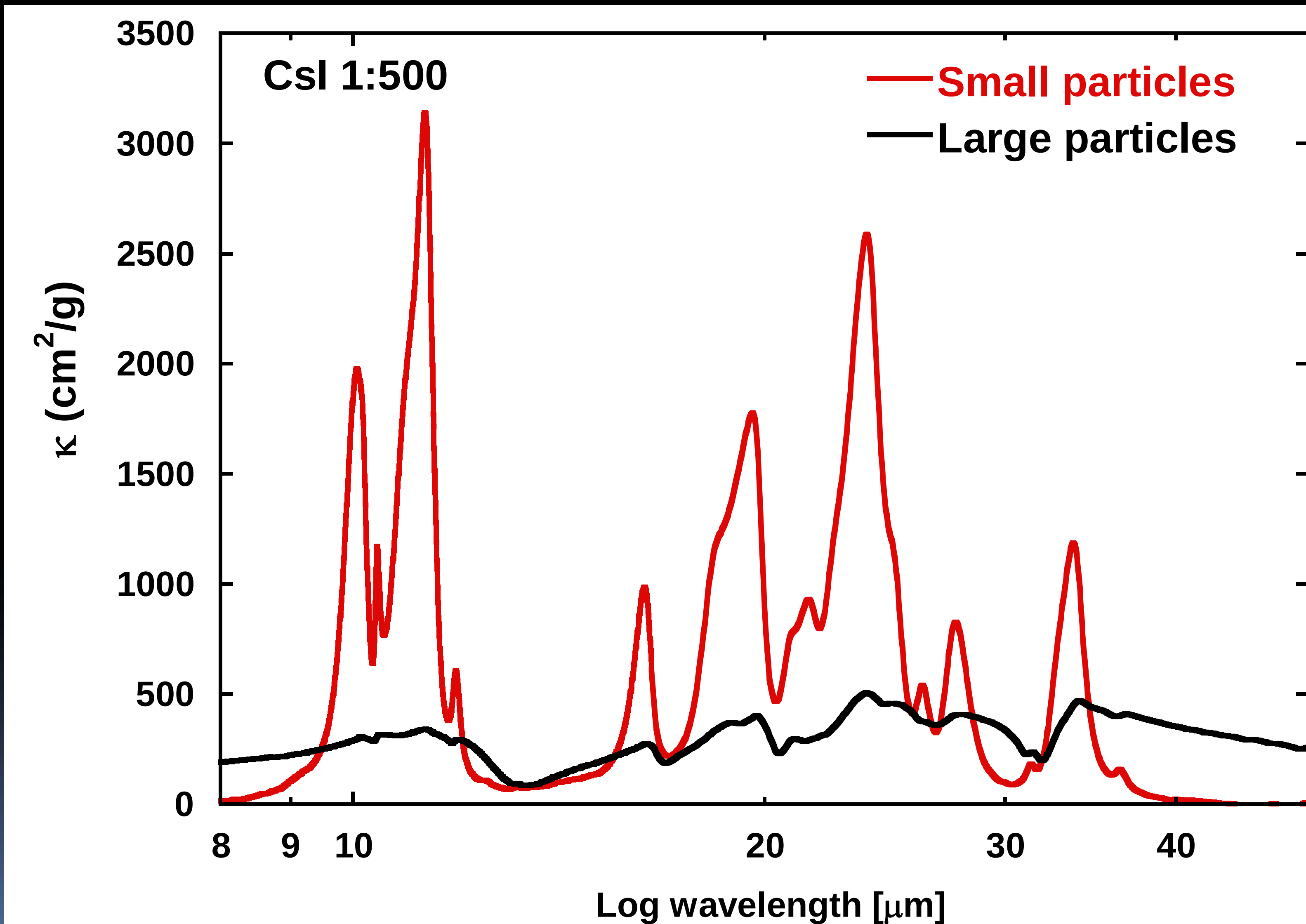


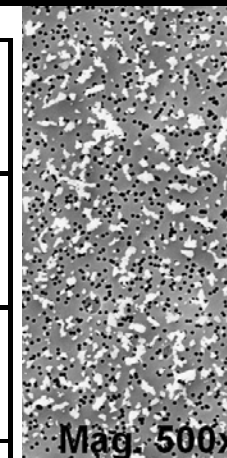


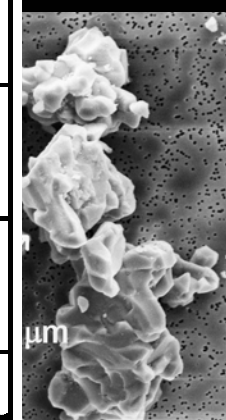


Peaks			
	8.93 μm	9.49 μm	Δλ=0.56 μm
	20.82 μm	21.21 μm	Δλ=0.39 μm

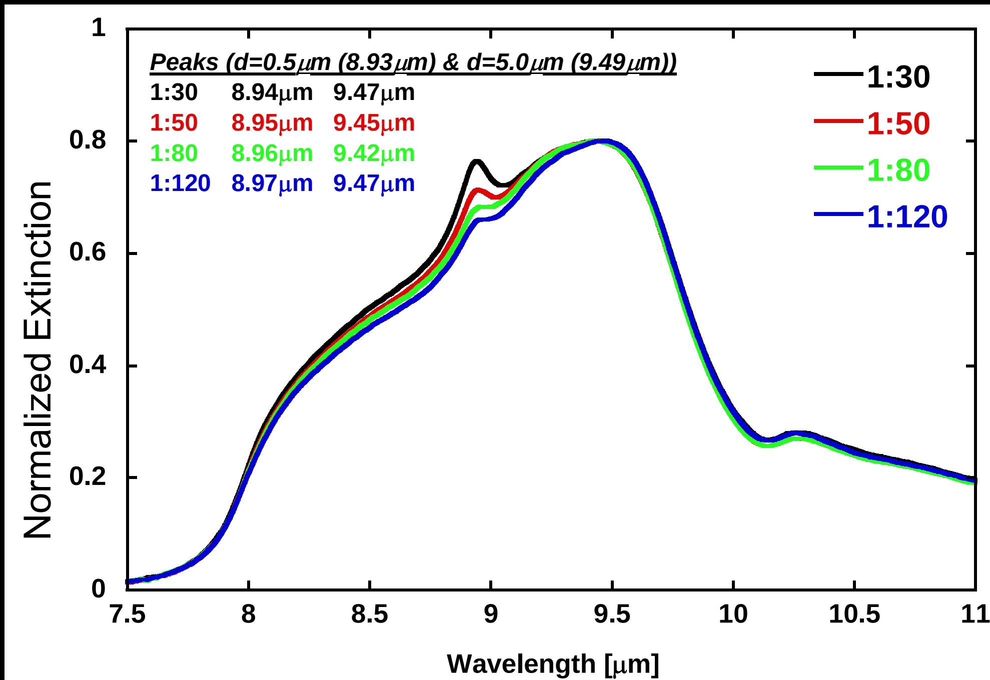
Crystalline forsterite (Mg_2SiO_4)

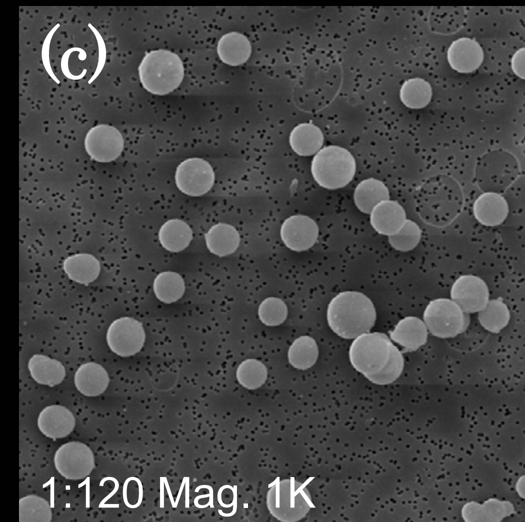


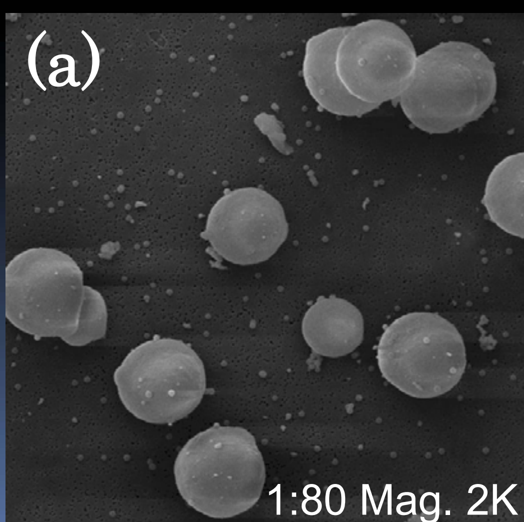


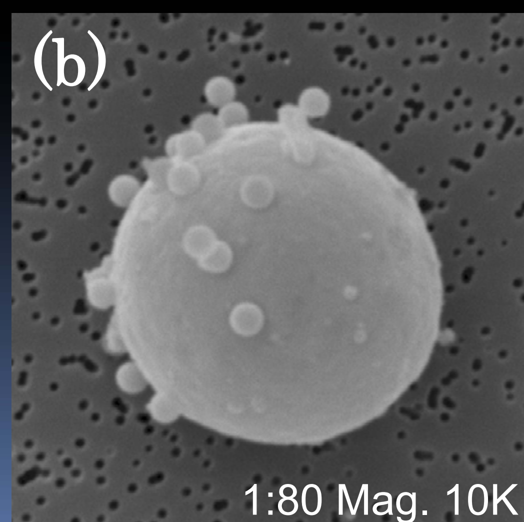


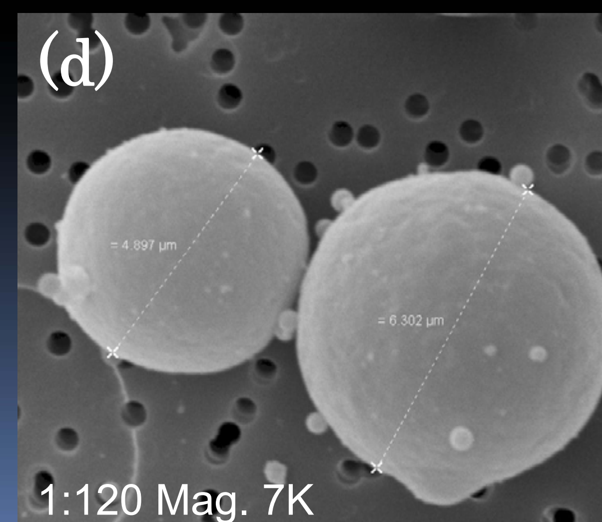
Exp. 2 Mixture (monosphere vs. monosphere)



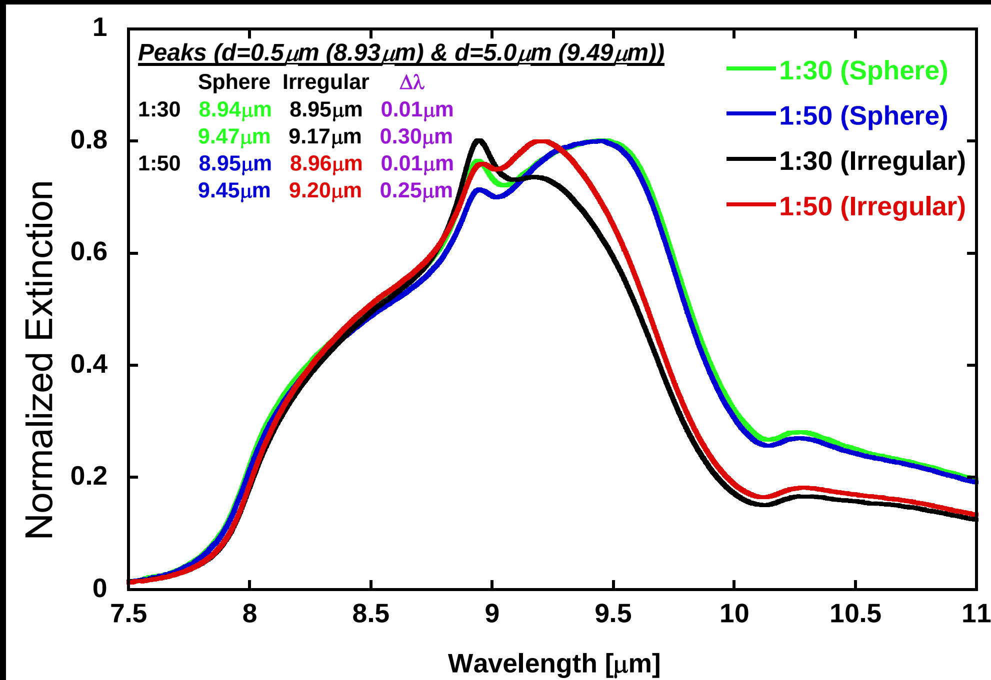






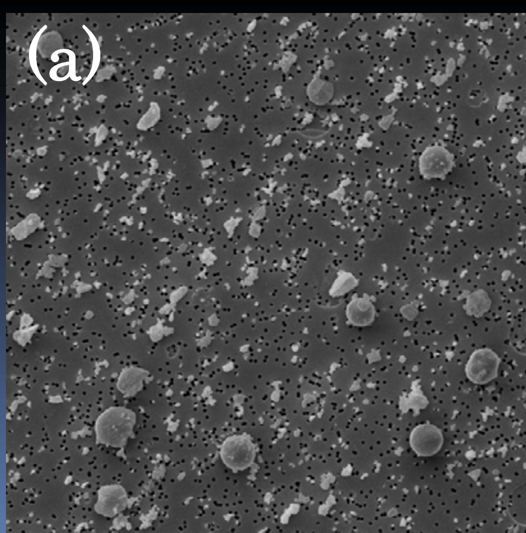


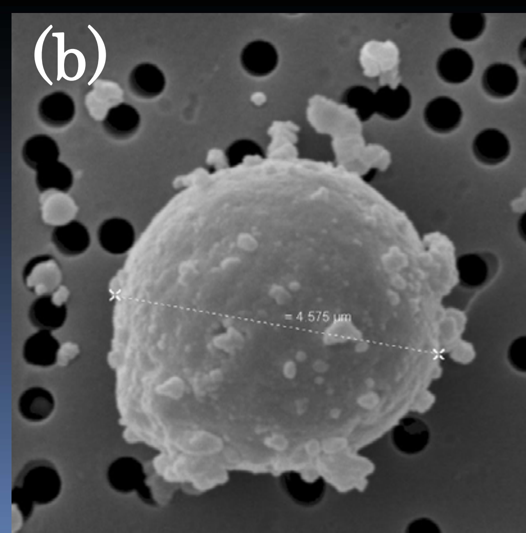
Exp. 2 Mixture (monosphere vs. irregular shape)



0.5 μm monosphere :
crashed 5 μm particles

- Survived 0.5 μm particles show a clear peak at 8.94 μm.
- The peak at 9.5 μm of the 5 μm particles is strongly influenced by the morphological changes (size & shape).





Summary

<Aerosol vs. CsI pellet measurements>

- *Spherical or rounded particles produce larger difference between the spectra compared to the irregular shaped particles.*

<Morphological Effects>

- Rounded grains tend to produce double peaked (rectangular) profiles in comparison with irregular shaped grains.

<Large-sized particles vs. Small-sized particles (Forsterite)>

- Peak positions are not strongly influenced by the particle size, but the bandwidth beyond the 11 μm peak is significantly broadened.

<Mixture of Small- and Large-sized particles (SiO_2)>

- Even mass of the 0.5 μm monosphere particles is 120x less than that of the 5 μm ones, the peak of the 0.5 μm particles clearly appears on the extinction spectrum.