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Pickup velocity of nanoparticles

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Pickup Velocity of Nanoparticles

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Fluidization XV, May 2016

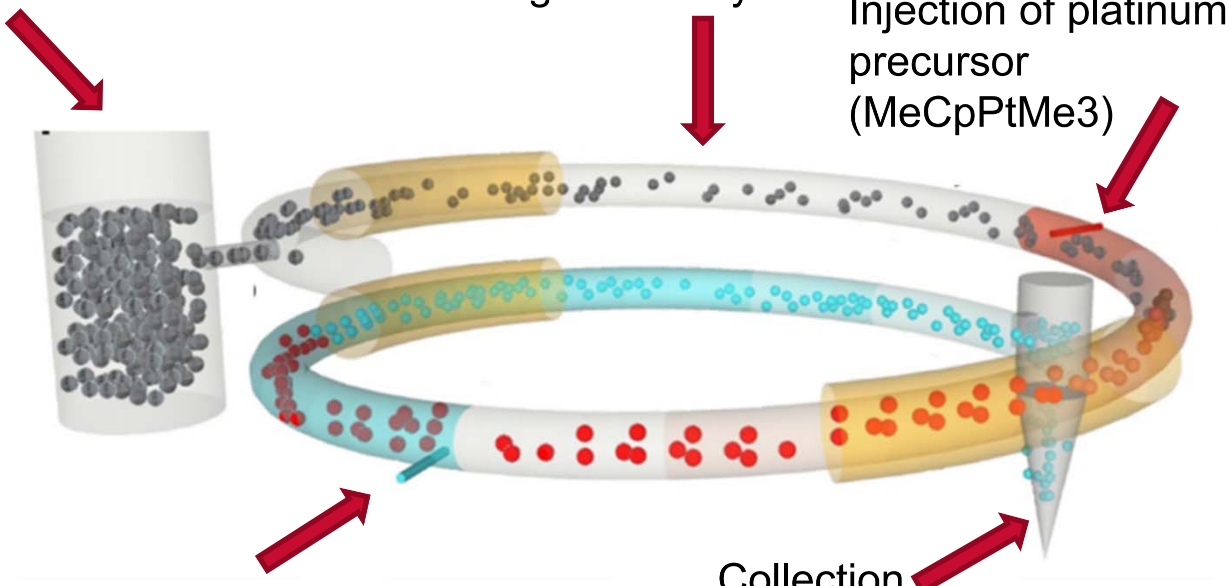
Introduction

Pneumatic transport reactor for coating nanoparticles

Titanium oxide
nanopowder
(P25)

27 m long reactor
4 mm int. diameter
5 m/s gas velocity

Injection of platinum
precursor
(MeCpPtMe3)

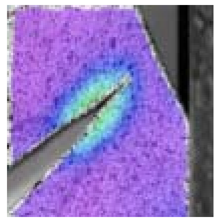


Injection of O3

Collection
1 g / min product

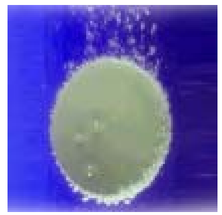
Catalysts

Q-dots for PV



Self-healing mat.

Li-ion batteries



Controlled release

Nuclear medicine

van Ommen *et al.* (2015)
J. Vac. Sci. Technol. A 33, 021513

Coming 6 months:
scale up to 1kg/min via

delftIMP
INTENSIFIED MATERIALS PRODUCTION

Introduction

- Critical velocities for gas-solid pneumatic conveying
  - Minimum pickup velocity (U_{pu}): Minimum fluid velocity necessary to start the motion of a particle initially at rest (Halow 1973)
  - Minimum saltation velocity (U_{salt}): Maximum fluid velocity at which the suspended particles commence to sediment (Cabrejos and Klinzing 1992)
- Why U_{pu} is important
  - Start-up; re-suspesion
  - Provides operational rule-of-thumb

First systematic study of pneumatic conveying of nanoparticles

Halow JS, (1973). Chemical Engineering Science, 28, 1-12
Cabrejos FJ, Klinzing GE (1992). Powder Technology, 72, 51-61

Our six “standard” powders

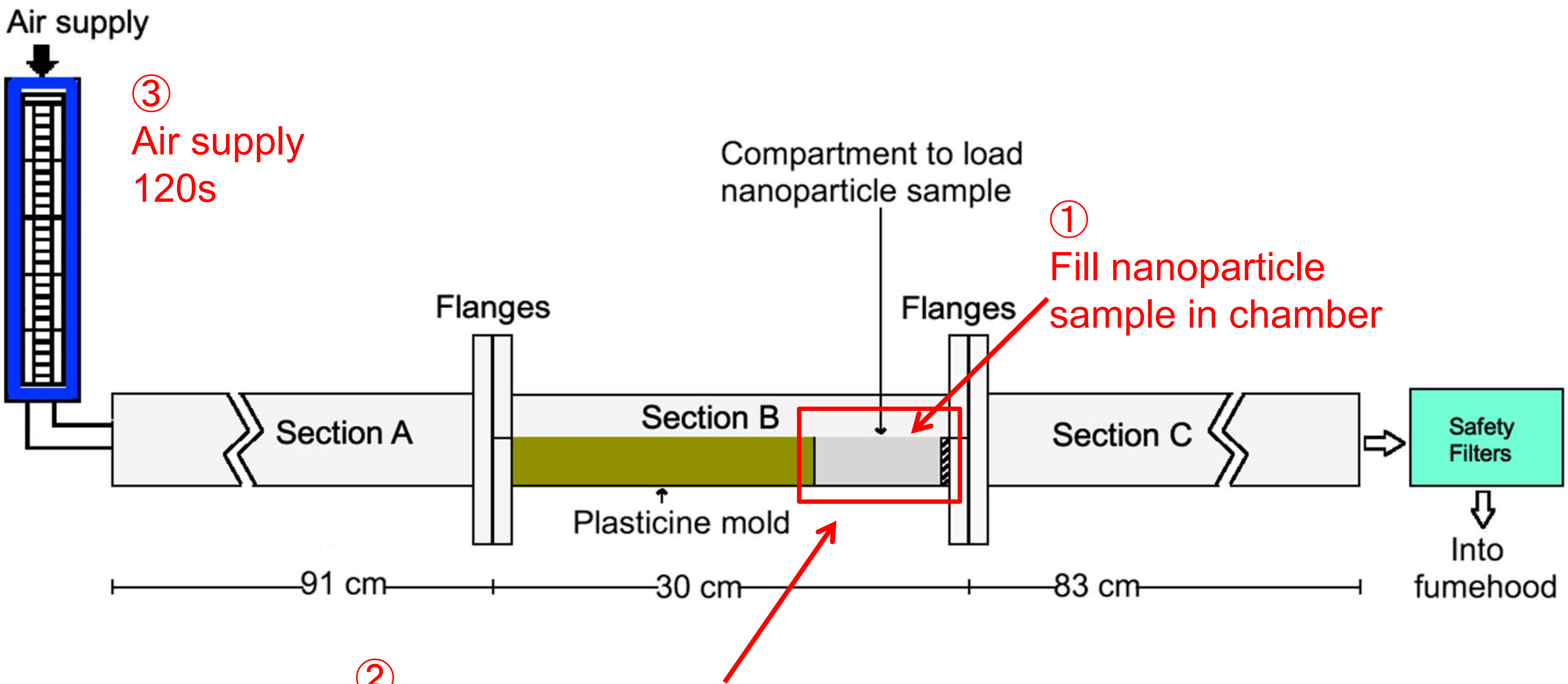
Commercial name (Evonik)	Material	Surf. type	Particle diam. (nm)	Particle density (kg/m^3)	Hamaker coeff. (J)
Aerosil 130	SiO_2	Polar	16	2200	$6.6 \cdot 10^{-20}$
Aerosil R972		Apolar			
Aeroxide Alu C	Al_2O_3	Polar	13	3600	$1.45 \cdot 10^{-19}$
Aeroxide Alu C805		Apolar			
Aeroxide P25	TiO_2	Polar	21	4000	$1.54 \cdot 10^{-19}$
Aeroxide T805		Apolar			

Earlier studies with these powders

Fluidized bed: Tahmasebpoor et al. Phys. Chem. Chem. Phys. 15(2013) 5788

Powder flow shear tester: Xanthakis et al., *Powder Technol.* 286 (2015) 156

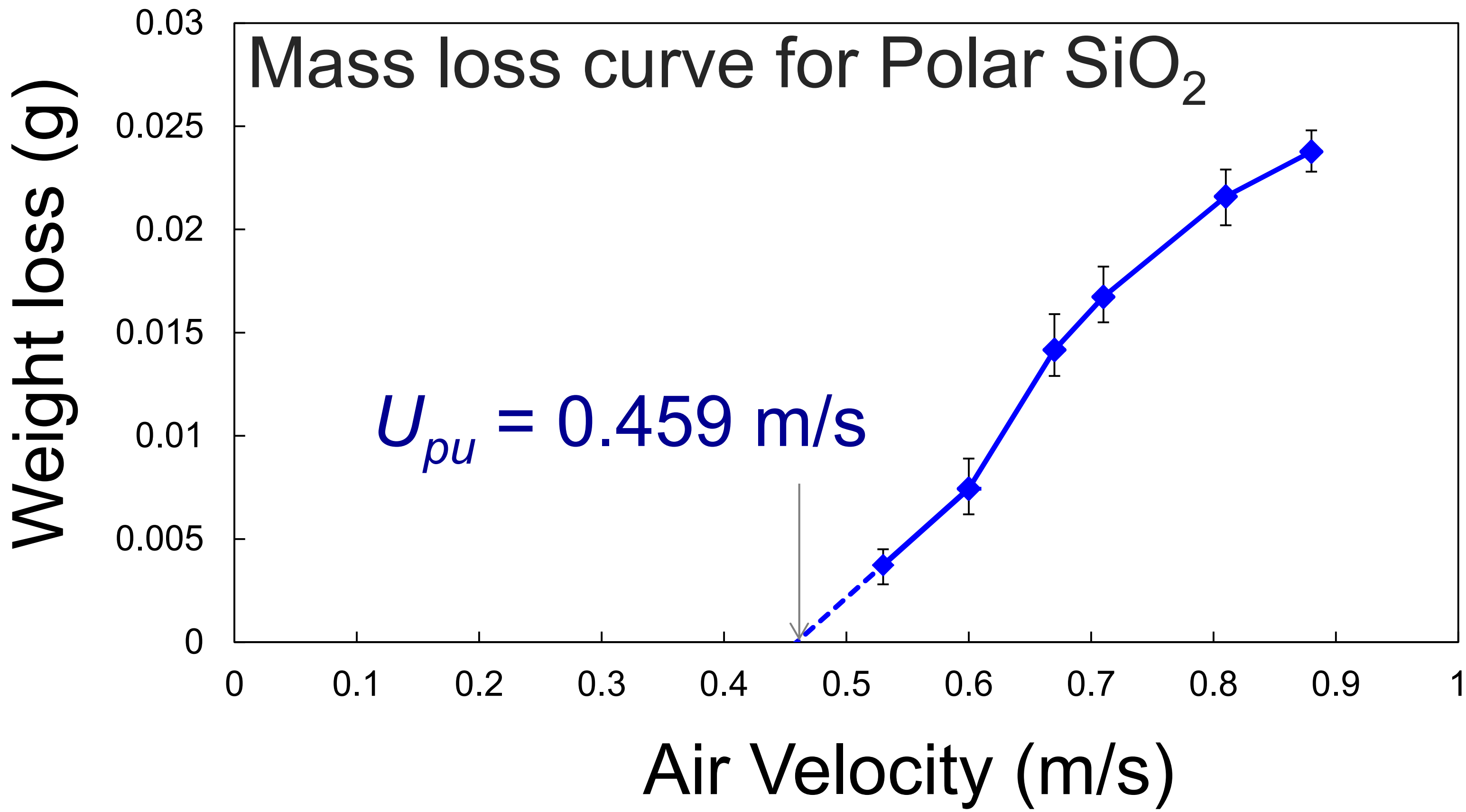
Procedure to Measure U_{pu}



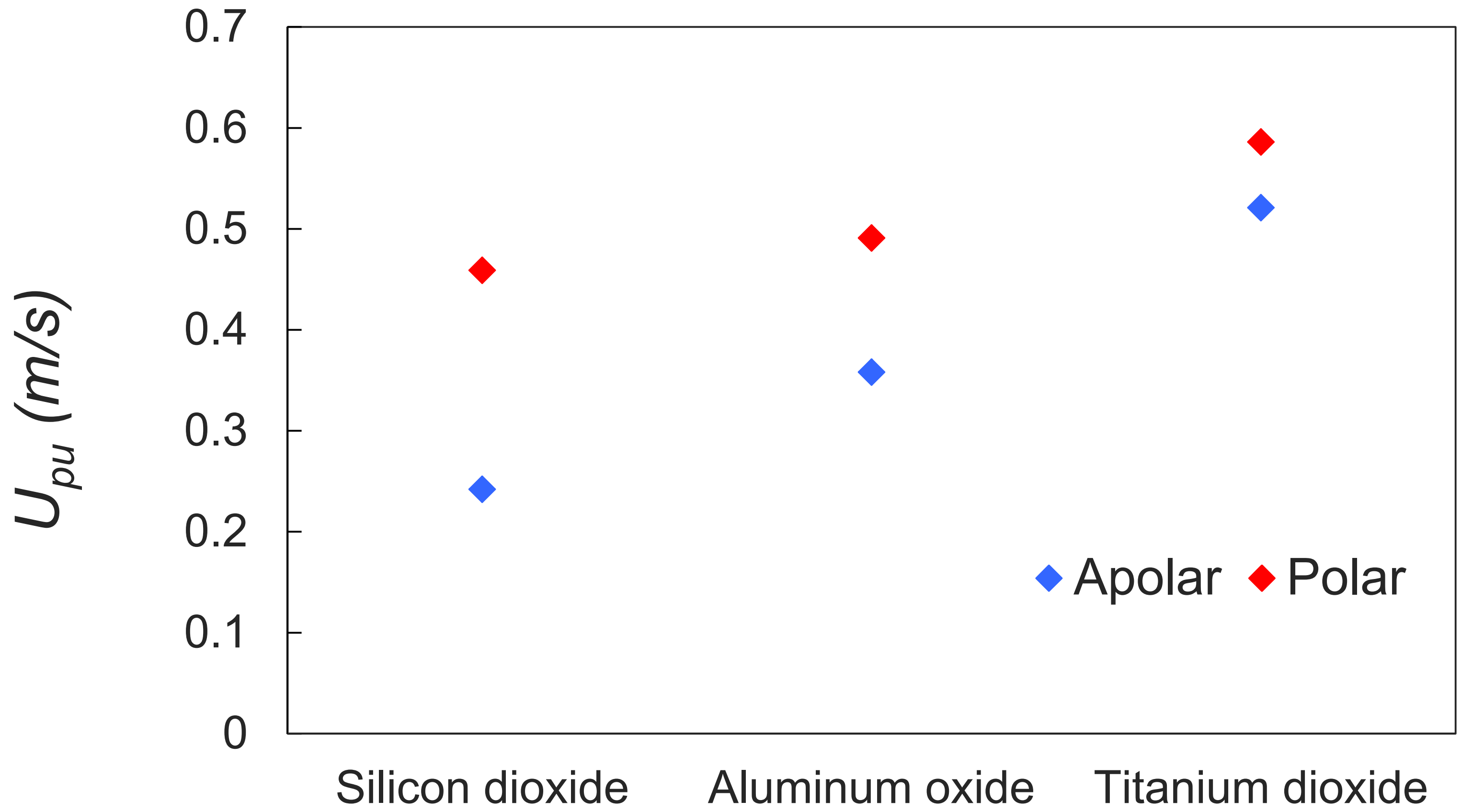
②
Weigh bottom part of Section B and
assemble apparatus

④
Disassemble and weigh bottom part
of section B again to note mass loss

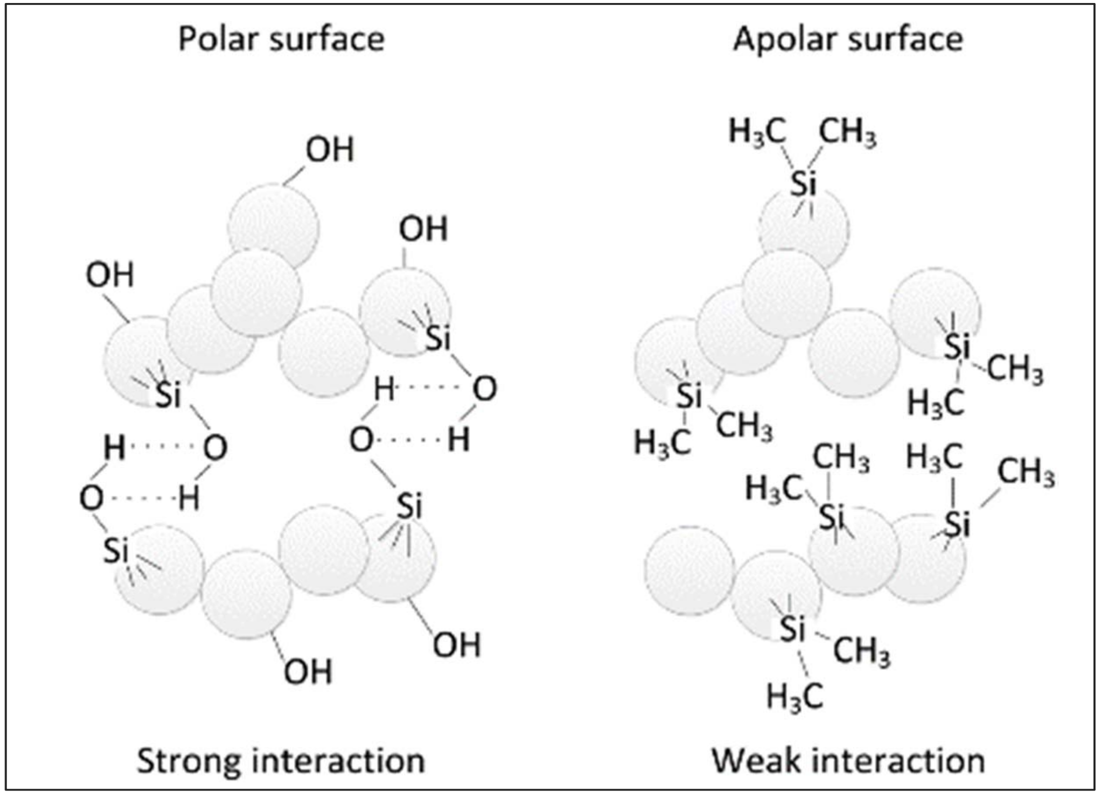
Determining U_{pu}



U_{pu} Values


0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Upu (m/s)
Apolar
Polar
Silicon dioxide
Aluminum oxide
Titanium dioxide

Apolar vs Polar



Polar nanoparticles: Hydroxyl groups on surface,

Apolar nanoparticles: Hydroxyl groups absent, replaced by organic groups during hydrophobization

Tahmasebpoor et al. **(2013)** Physical Chemistry Chemical Physics, 15, 5788

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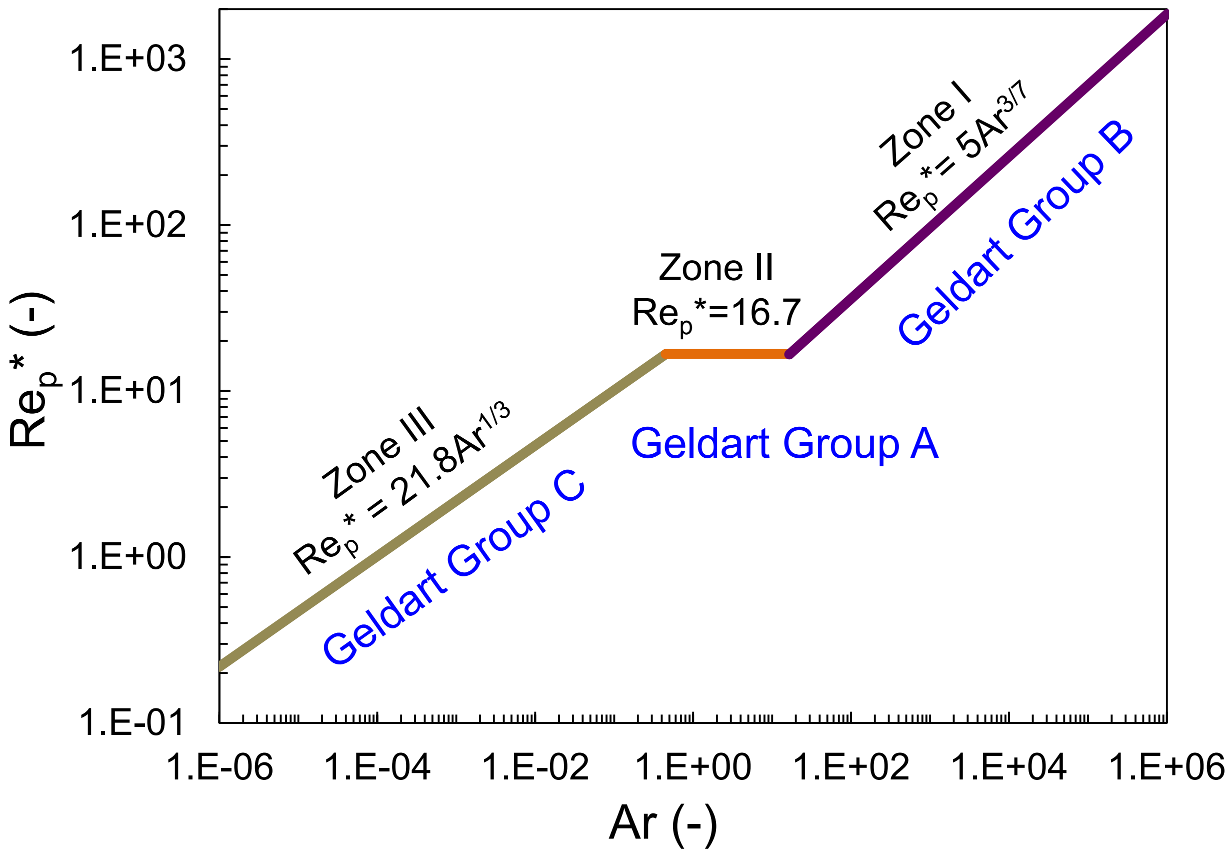
'Geldart Groups'



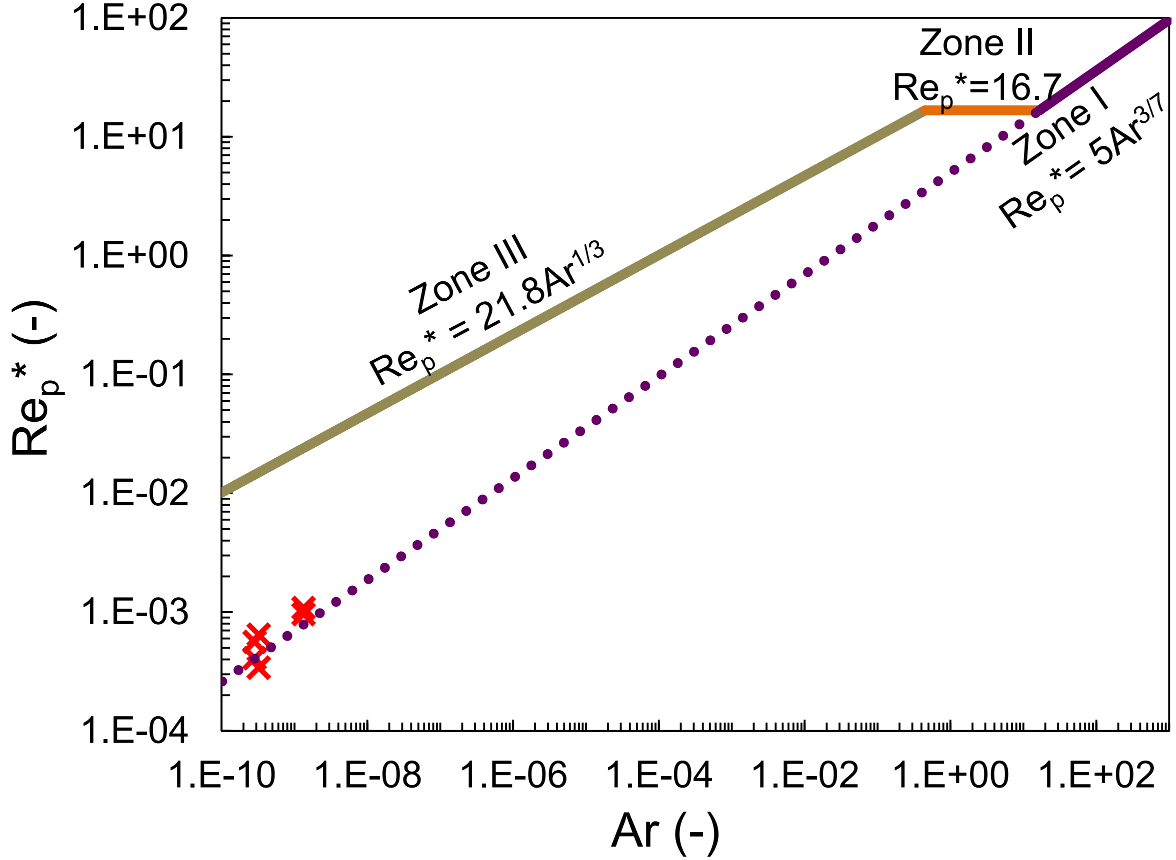
Three-zone model of Kalman et al. (2005)

- Zone I: $Re_p^*=5Ar^{3/7}$ for Ar≥*16.5*
- Zone II: $Re_p^*=16.7$ for 0.45<Ar<16.5
- Zone III: $Re_p^*=21.8Ar^{1/3}$ for Ar≤0.45

$$Re_p^* = \frac{\rho_p d_p U_{pu}}{\mu_f\left[1.4-0.8exp\left(-\frac{D/D_{ref}}{1.5}\right)\right]} \quad Ar = \frac{g\rho_f(\rho_p-\rho_f)d_p^3}{\mu_f^2}$$

Kalman et al., **(2005)**. Powder Technology 160, 103-113;

‘Geldart Groups’



- U_{pu} an order-of-magnitude lower than predicted.
  - Re_p* order-of-magnitude smaller than Zone III prediction.
- U_{pu} values agree well with extrapolated Zone I (Geldart Group B) correlation

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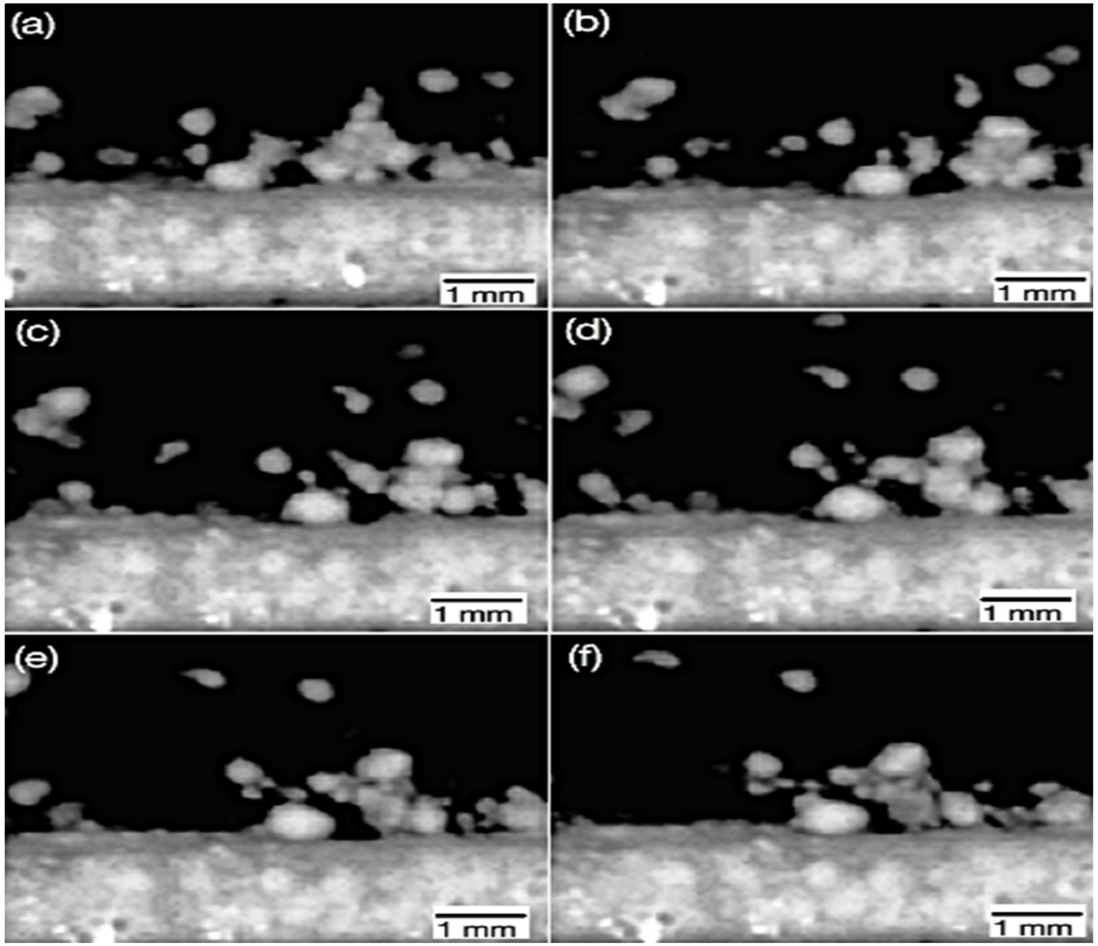
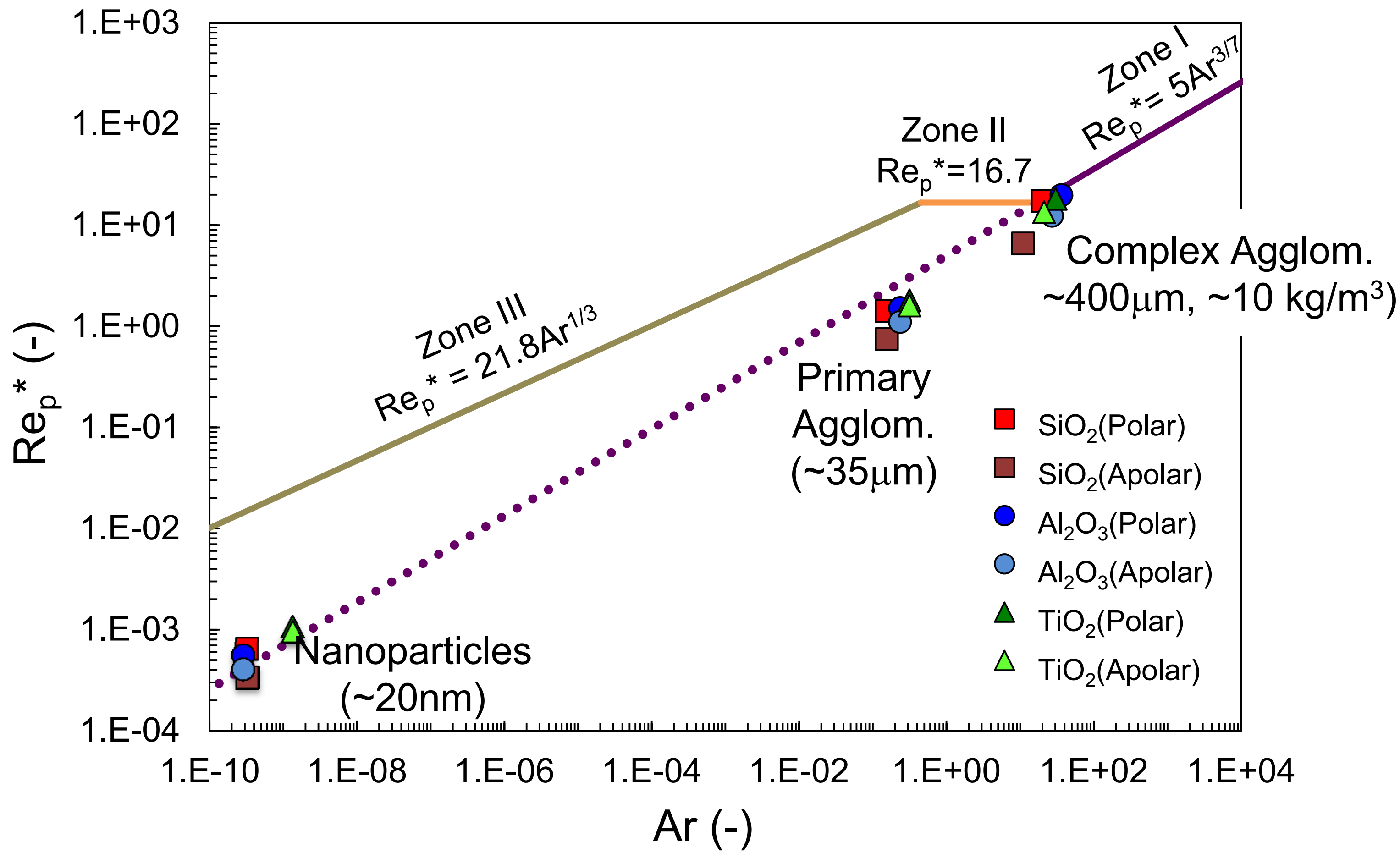
Nanoparticle Agglomerates



Unsurprisingly, nanoparticles are entrained in agglomerates

Zones in Pneumatic Conveying



Primary and complex agglomerates agree well with Zone I (Geldart Group B)

Conclusions

- Nanoparticles can be pneumatically transported!
- Polar nanoparticles have greater U_{pu} than apolar nanoparticles.
- Difference between U_{pu} polar and apolar species decrease in the order:

  $SiO_2 > Al_2O_3 > TiO_2$
- U_{pu} of nanoparticles lower than predicted

  → Nanoparticles are entrained as porous micron sized agglomerates.
- Behavior of nanoparticles corresponds more with pickup Zone I (Geldart Group B) than Zone III (Geldart Group C).

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