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Pickup velocity of nanoparticles

Jia Wei Chew
Singapore Membrane Technology Center, Nanyang Environment and Water Research Institute,Singapore, jchew@ntu.edu.sg

J. Ruud van Ommen
Chemical Engineering, Delft University of Technology, The Netherlands

Aditya Anantharaman
School of Chemical and Biomedical Engineering, Nanyang Technological University, Singapore

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Pickup Velocity of Nanoparticles

Aditya Anatharaman[a], J. Ruud van Ommen[b], Jia Wei Chew[a]

Nanyang Technological University (Singapore)

Delft University of Technology (Netherlands)

NANYANG TECHNOLOGICAL UNIVERSITY

TU Delft Delft University of Technology

Fluidization XV, May 2016

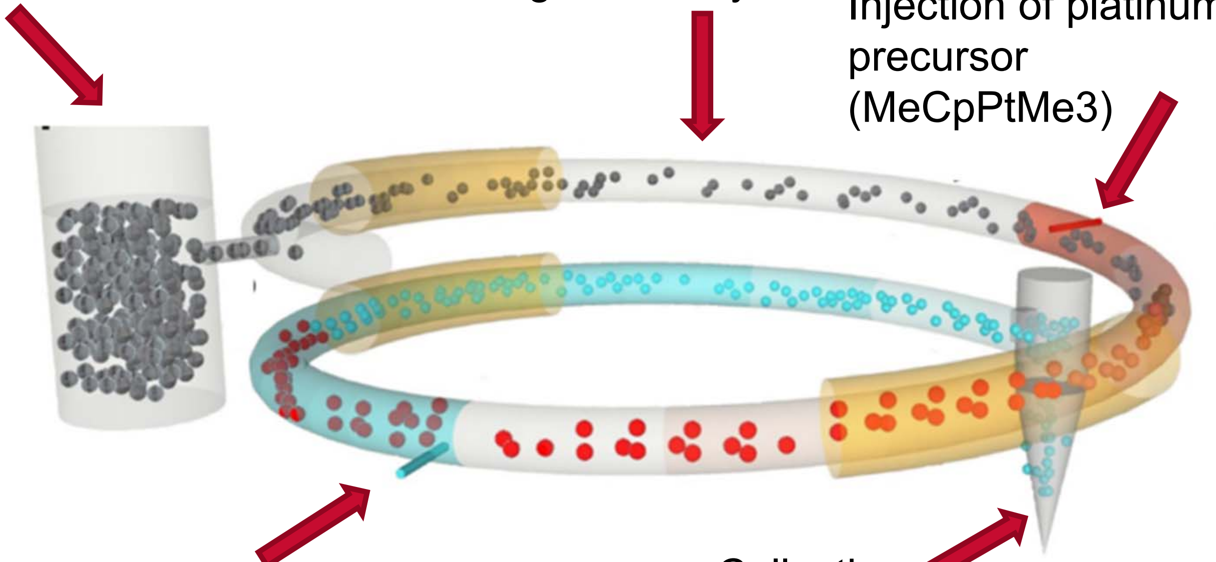
Introduction

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)

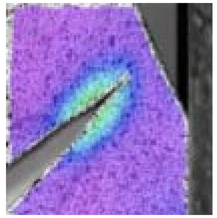


Injection of O3

Collection
1 g / min product

Catalysts

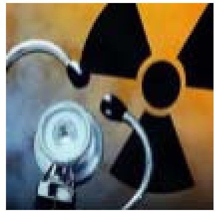
Q-dots for PV



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

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Our six “standard” powders

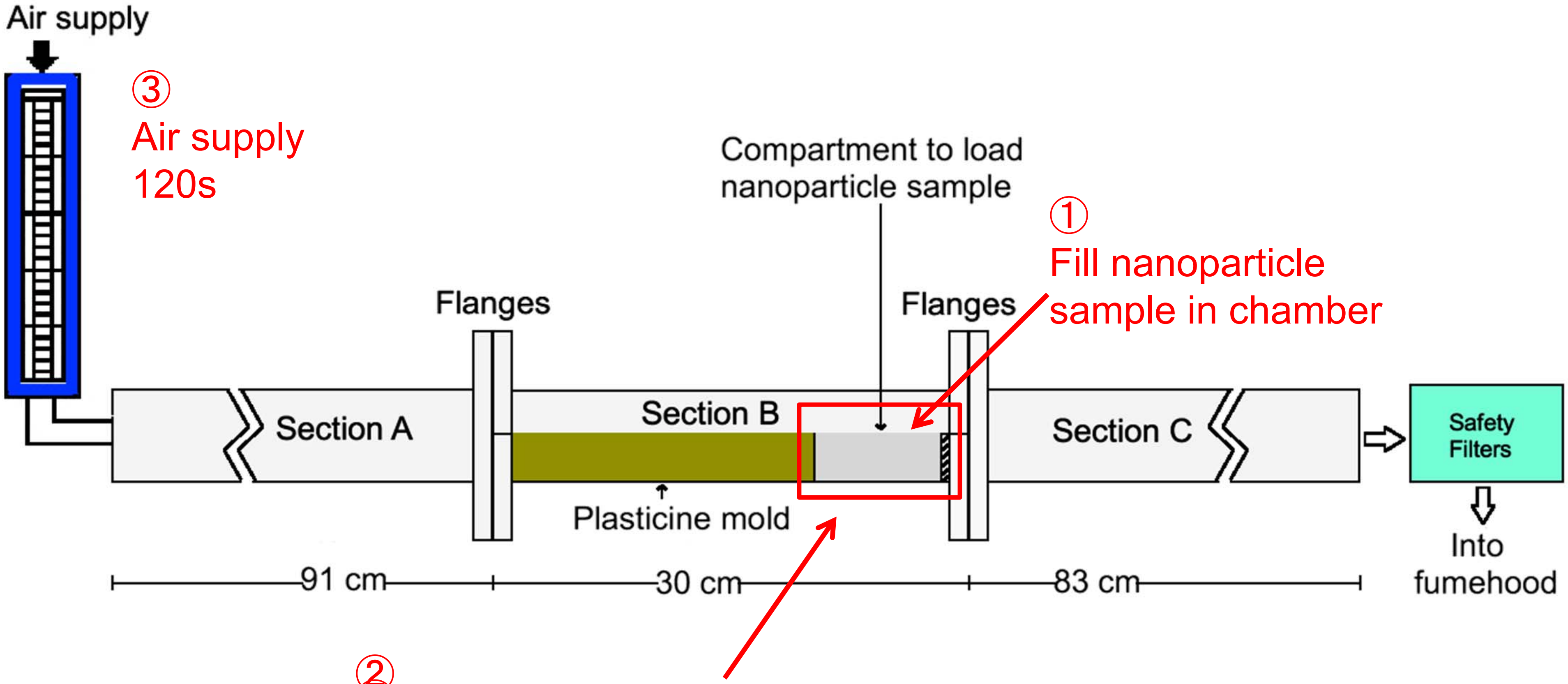
Commercial name (Evonik)	Material	Surf. type	Particle diam. (nm)	Particle density (kg/m^3)	Hamaker coeff. (J)
Aerosil 130	SiO_2	Polar	16	2200	$6.6 \cdot 10^{-20}$
Aerosil R972		Apolar			
Aeroxide Alu C	Al_2O_3	Polar	13	3600	$1.45 \cdot 10^{-19}$
Aeroxide Alu C805		Apolar			
Aeroxide P25	TiO_2	Polar	21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



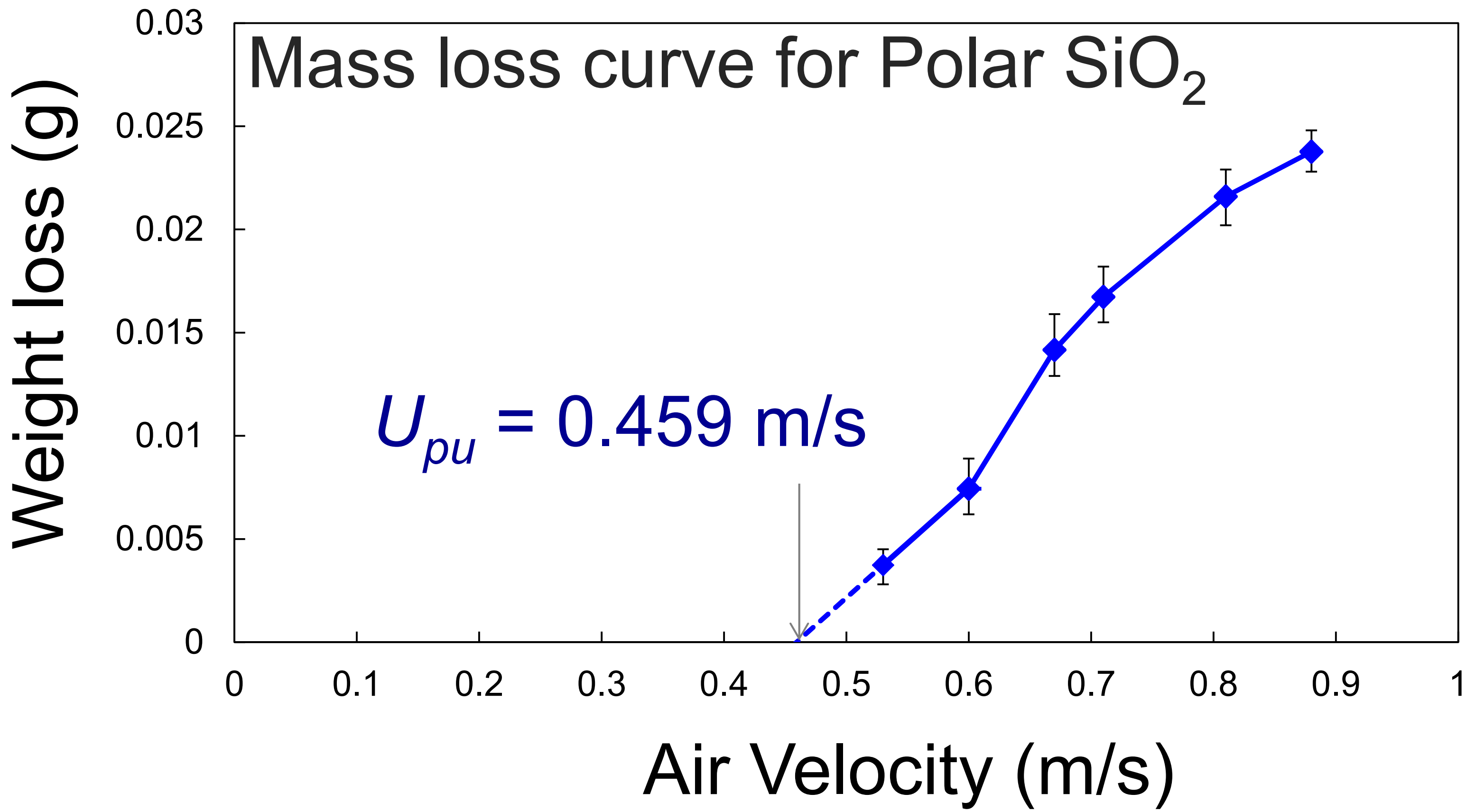
① Fill nanoparticle sample in chamber

② Weigh bottom part of Section B and assemble apparatus

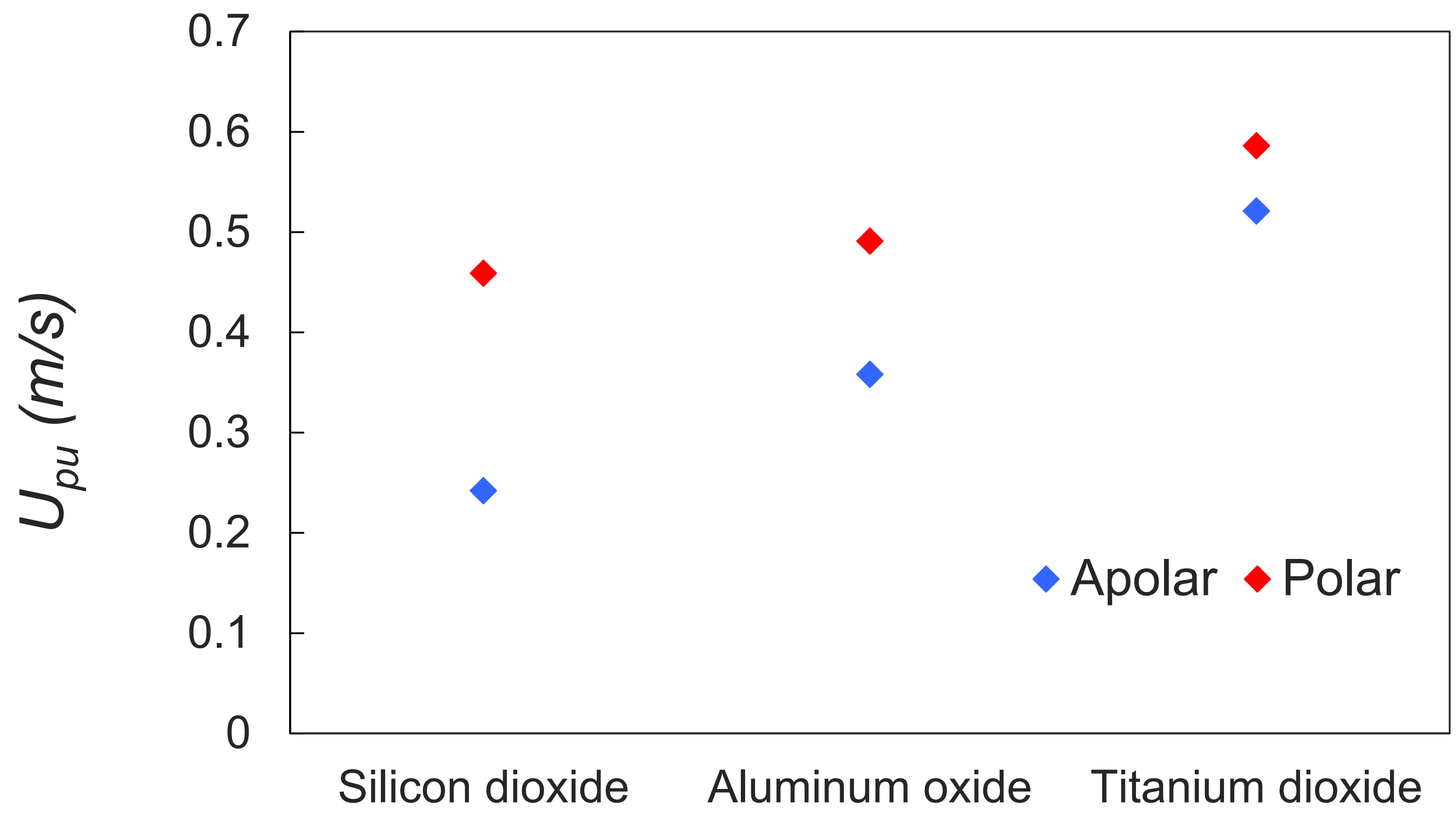
③ Air supply 120s

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

Determining U_{pu}

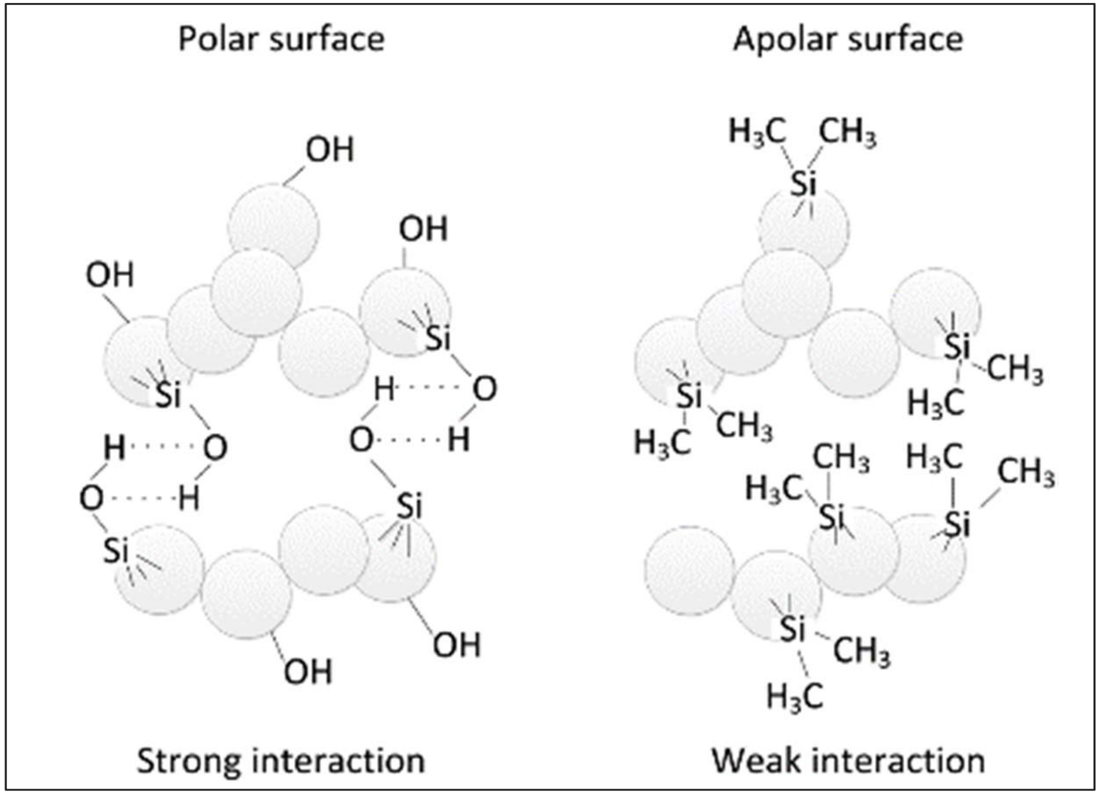


U_{pu} Values



0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
U_pu (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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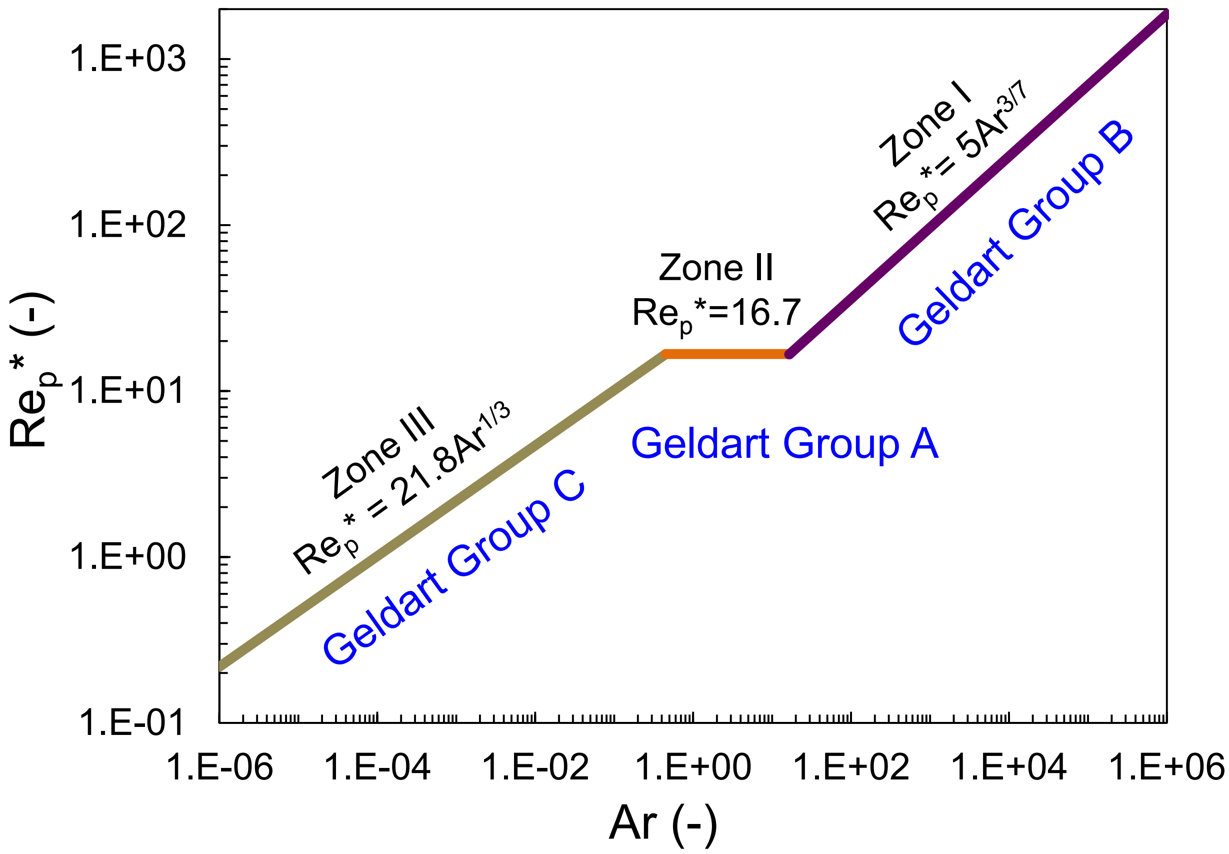
‘Geldart Groups’



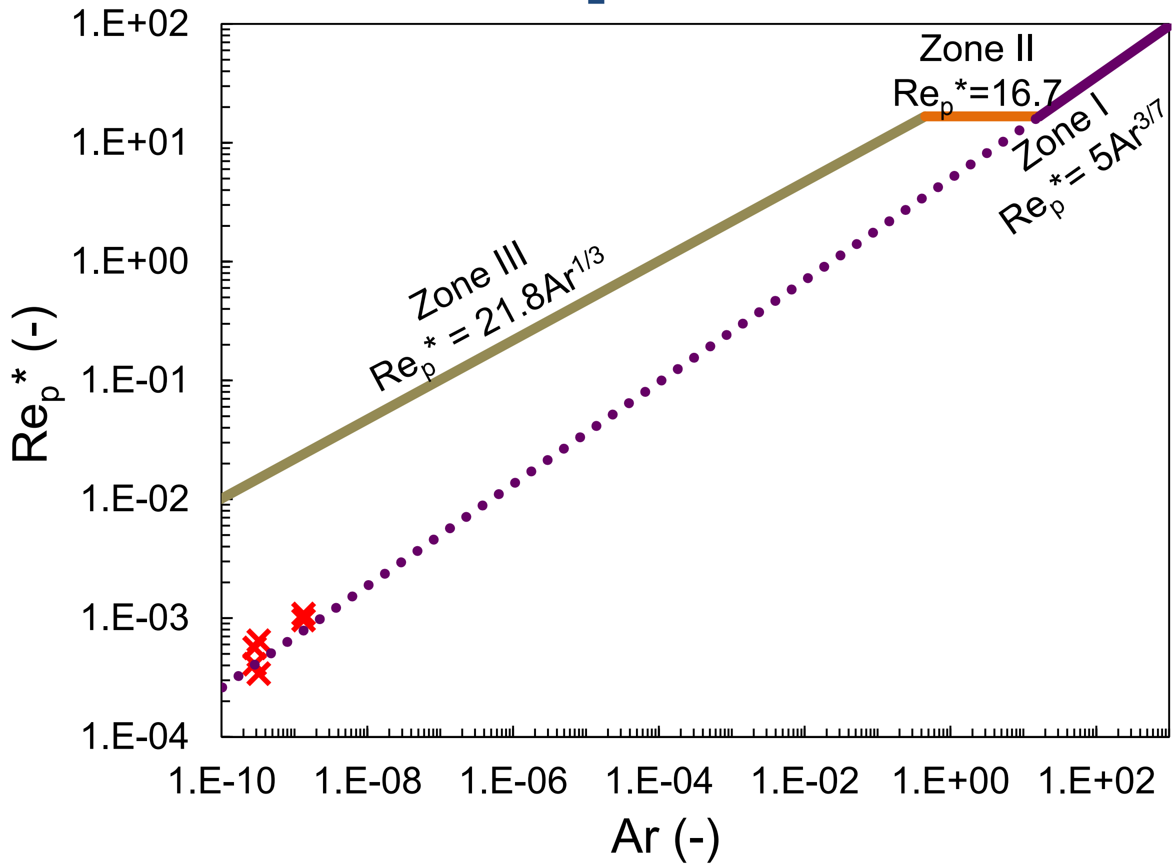
Three-zone model of Kalman et al. (2005)

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

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

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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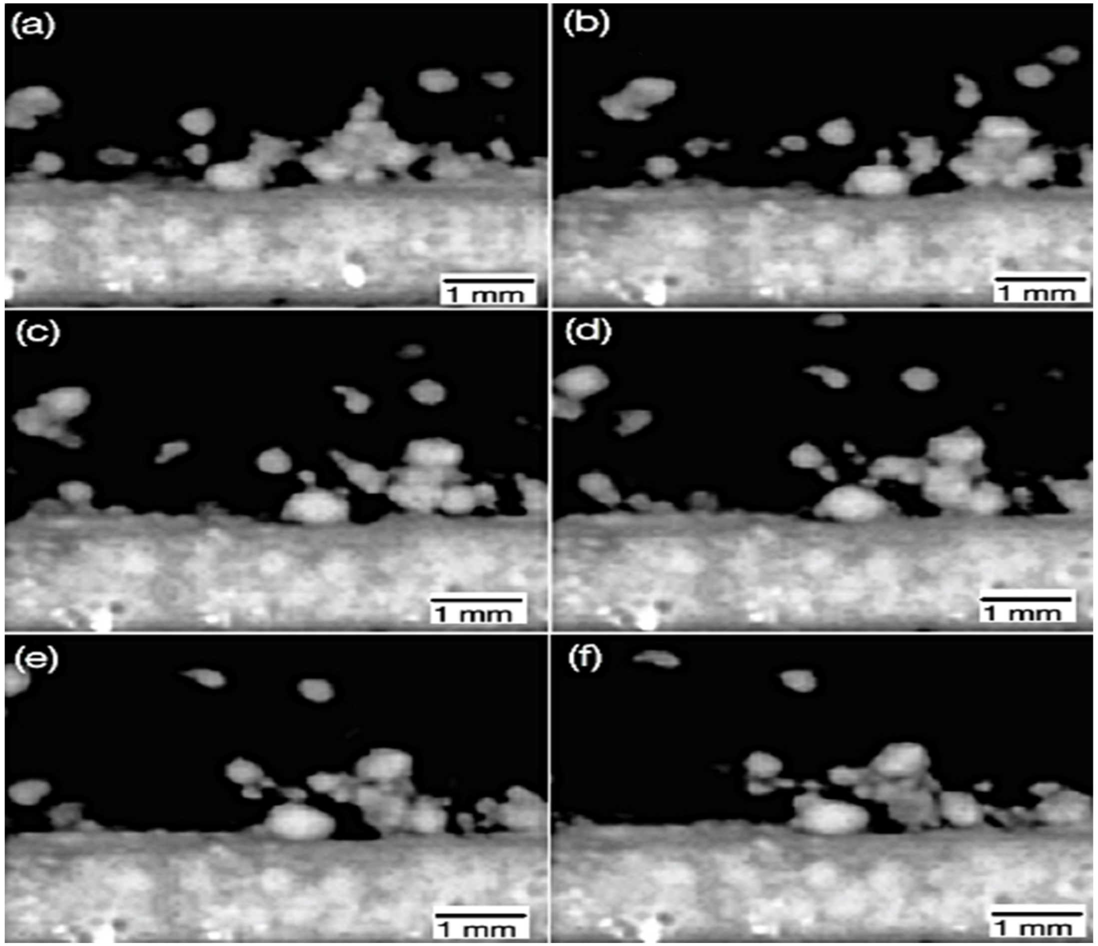
Nanoparticle Agglomerates



Unsurprisingly, nanoparticles are entrained in agglomerates

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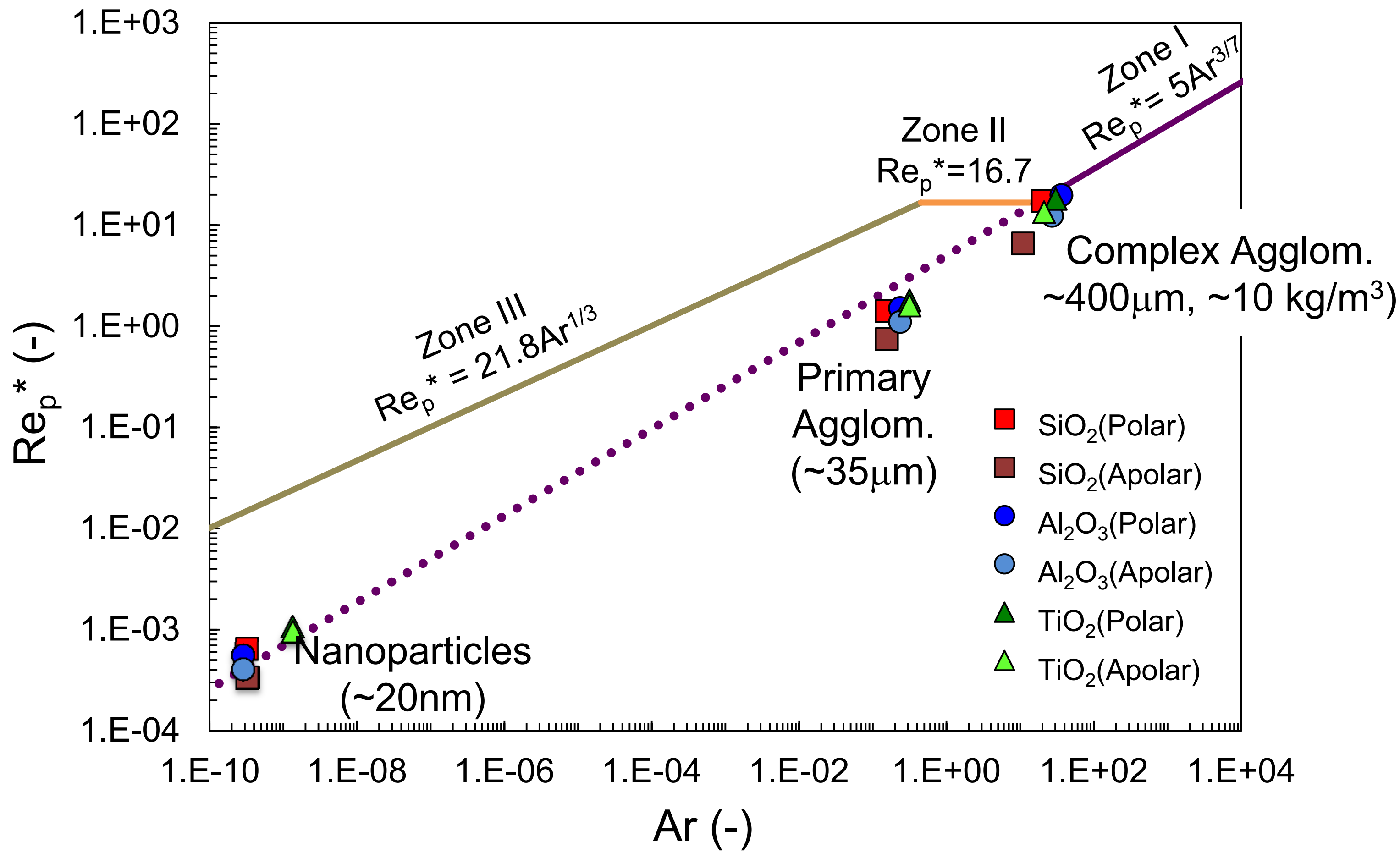
Zones in Pneumatic Conveying



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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