

Generating Spherical Silver Particles Through Heterogeneous Condensation in a Tandem Silver Particle Generator Setup

V. Berger¹, P. S. Bauer¹, K. M. Risby², M. Dollner¹, H. J. Schulz¹, J. Swanson^{1,3}, A. Boies^{1,4}

¹ Catalytic Instruments, ² University of Cambridge, ³ Minnesota State University, ⁴ Stanford University

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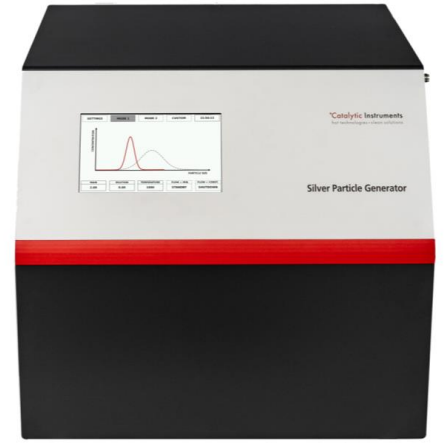
Introduction

Silver particles can be used as calibration aerosol for a variety of applications:

- Brake PN
- PTI
- RDE PEMS-PN
- ISO 27981: Calibration of CPCs
- ISO 15900: Determination of Particle Size Distribution
- CEN/TS 17434: Ambient air - Particle number size distribution of atmospheric aerosol
- CEN/TS 16976: Ambient air - Particle number concentration of atmospheric aerosol

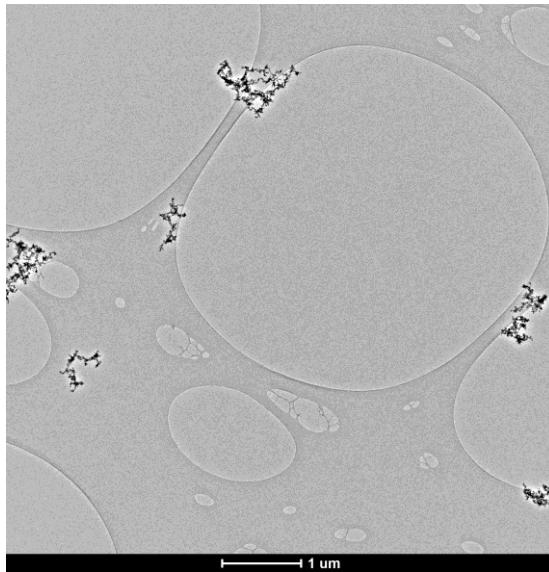
“thermally stable particles”

“using spherical silver particles sized 40 nm produced by the evaporation/condensation method”

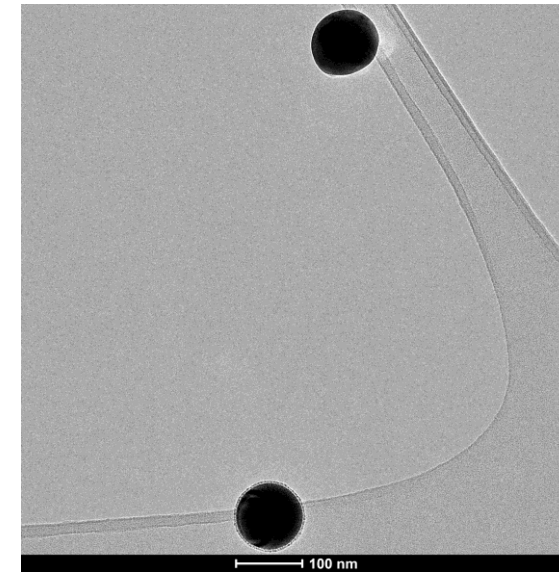


Sintering of Silver Particles

- Heating of particles to change morphology
- Reshaping, compaction into spheres



SINTERING
S8000 @ 400 °C



- 300 nm agglomerates sinter into 100 nm spheres = strong size reduction
- 100 nm thermally stable silver spheres in concentrations up to 50 k/ccm for PCRf calibration possible

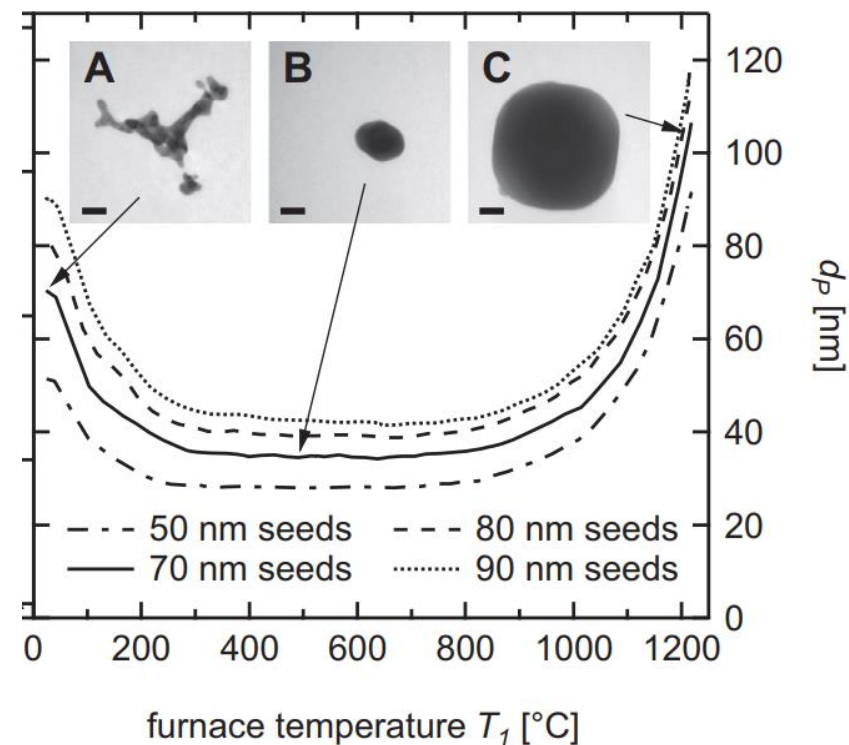
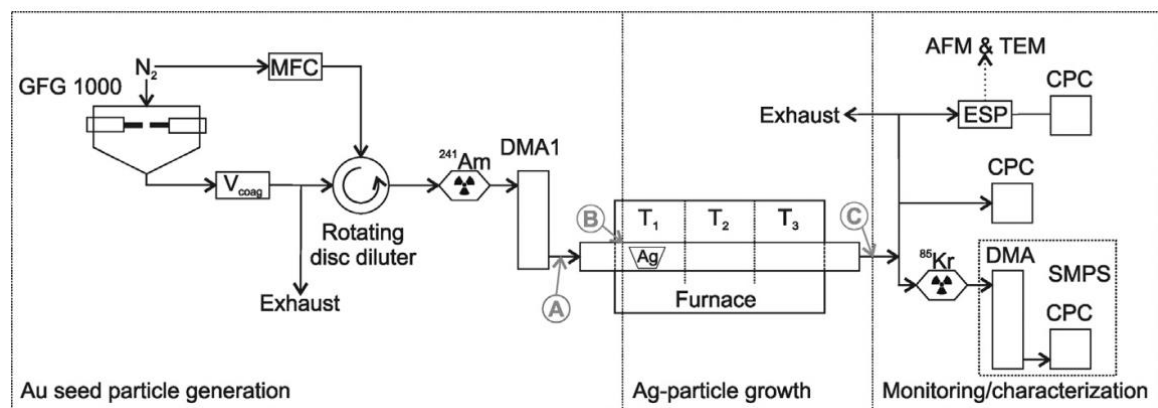
Alternative Process – Heterogeneous Condensation

Zihlmann et al. 2014:

- + Monodisperse gold seed particles
- + Sent into hot tube furnace with silver
- = heterogeneous condensation of Ag onto Au
- = monodisperse, spherical Ag-Au particles

Seeded growth of monodisperse and spherical silver nanoparticles

Simon Zihlmann*, Felix Lüond, Johanna K. Spiegel



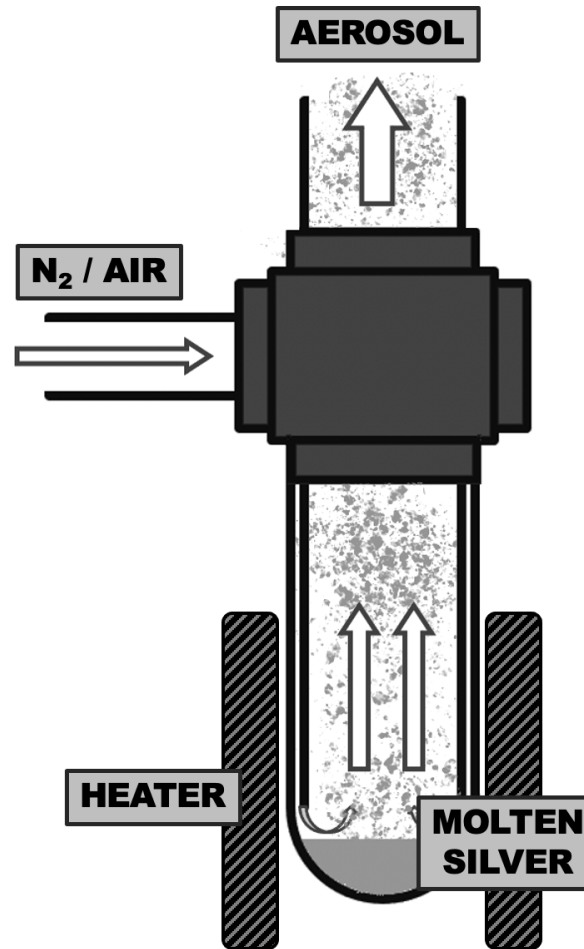
Alternative Process – Heterogeneous Condensation

Objectives:

- Can we reproduce this with two SPGs?
- Can we optimize the process for even larger spherical particles?
- Can we achieve heterogeneous condensation of Ag onto Ag?

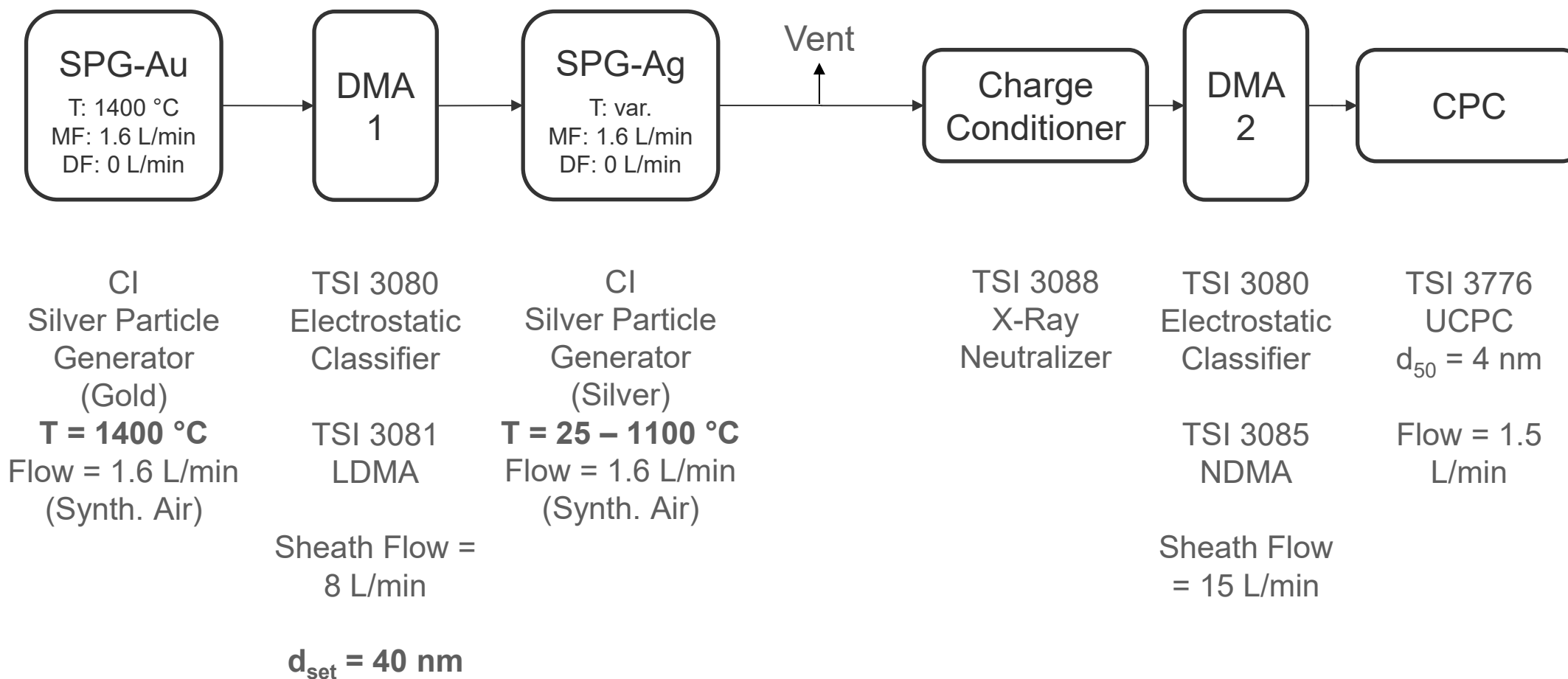


SPG Tube Set

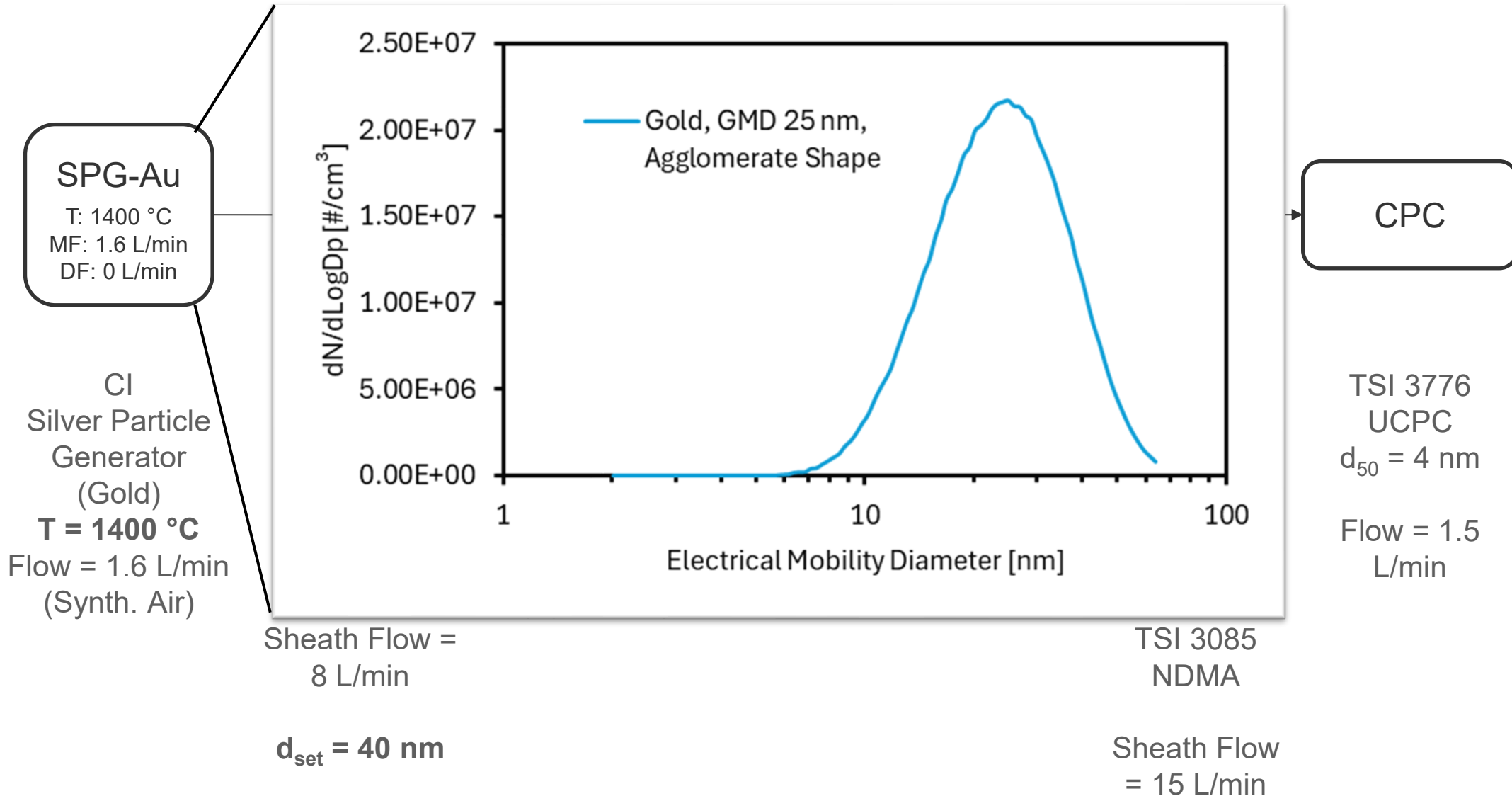


- Alumina (ceramic) tubes
- Cleaned by baking
- One tube set for each material

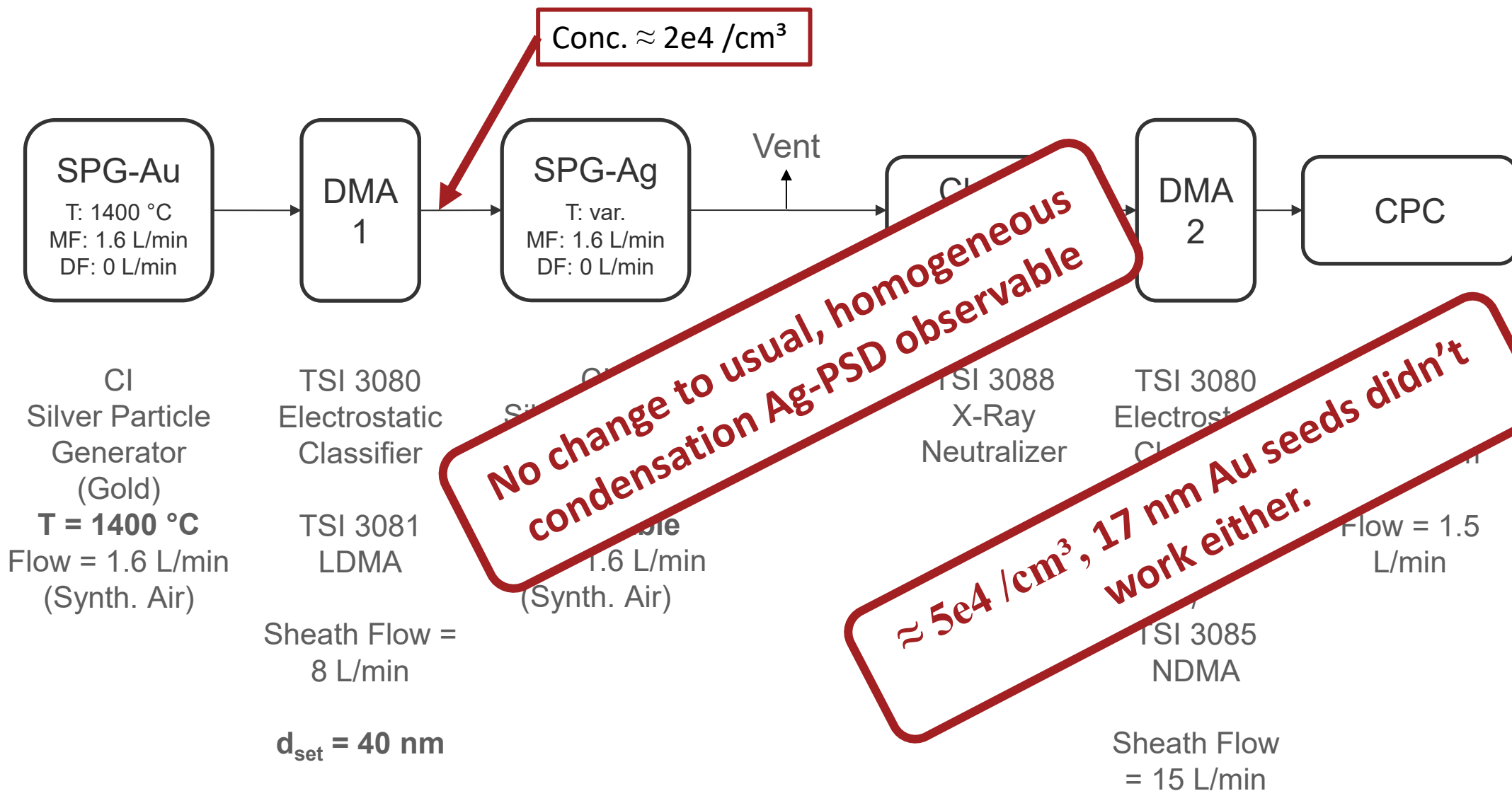
Experiment I – Monodisperse 40 nm Au Seeds



Experiment I – Monodisperse 40 nm Au Seeds



Experiment I – Monodisperse 40 nm Au Seeds



Experiment II – Monodisperse 100 nm Sintered Ag Seeds

Similar Tandem SPG Setup

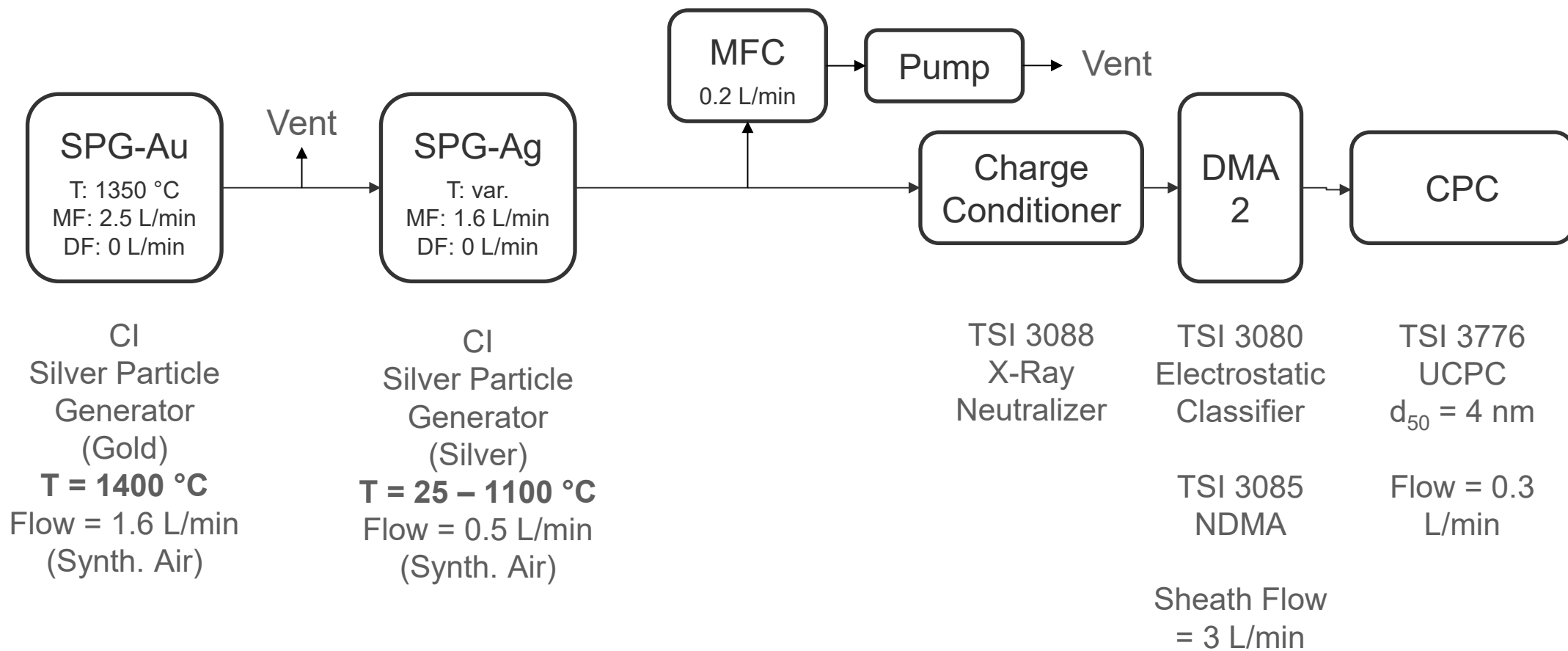
- Start with large particles to facilitate Ag pickup
- Seed Conc. $\approx 2e4 / \text{cm}^3$

No change to usual, homogeneous condensation Ag-PSD observable

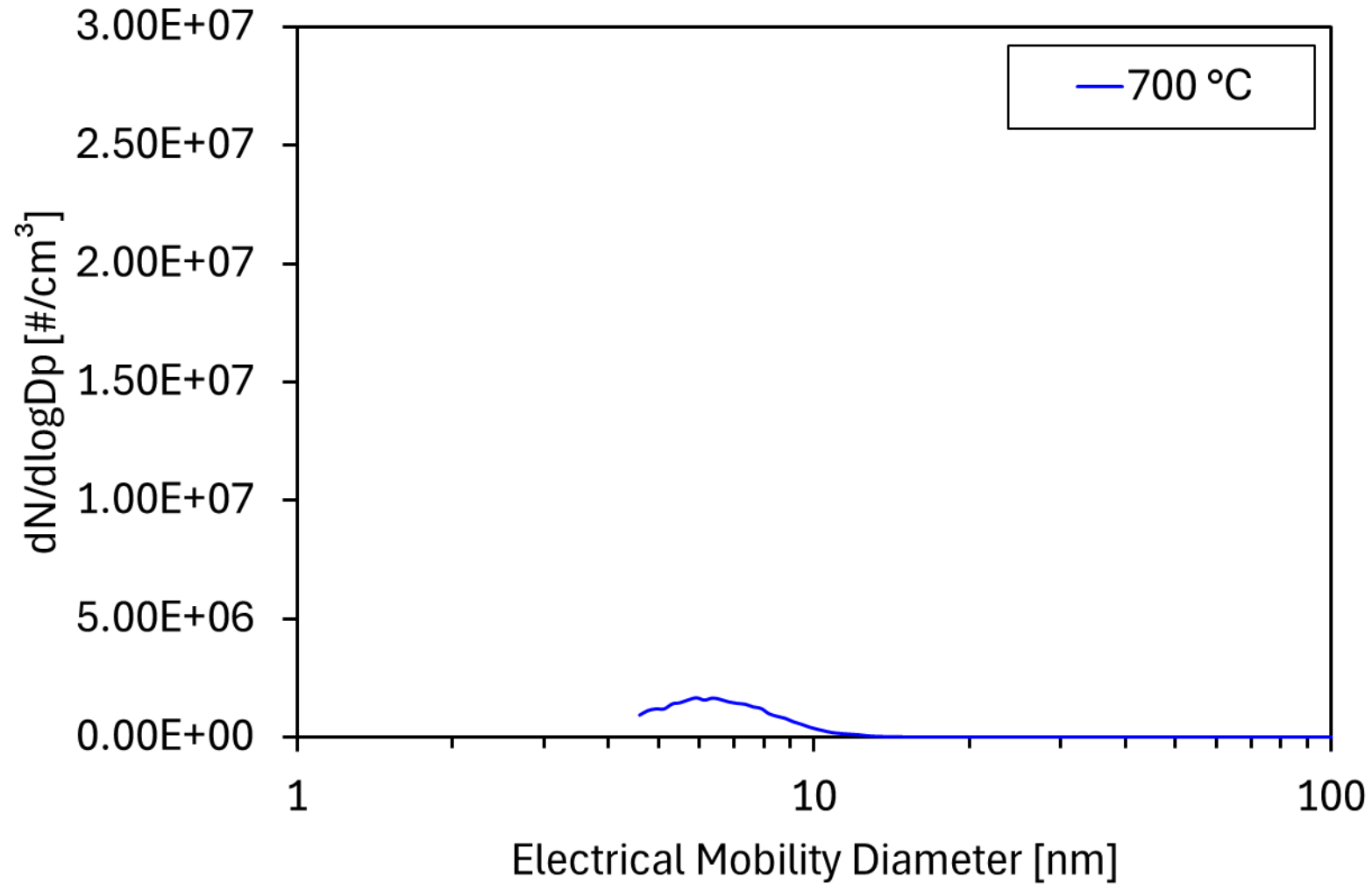
Discussion of the setup and results

- Seed particle concentration might need to be higher to suppress homogeneous condensation
- Seed particles might need to come closer to the silver vapor phase (decrease tube distance)
- Heterogeneous condensation might need more time (decrease flow rate through SPG-2)
- Longer “condenser” necessary (difficult to implement)
- “Condenser” temperature needs to be actively controlled (difficult to implement)

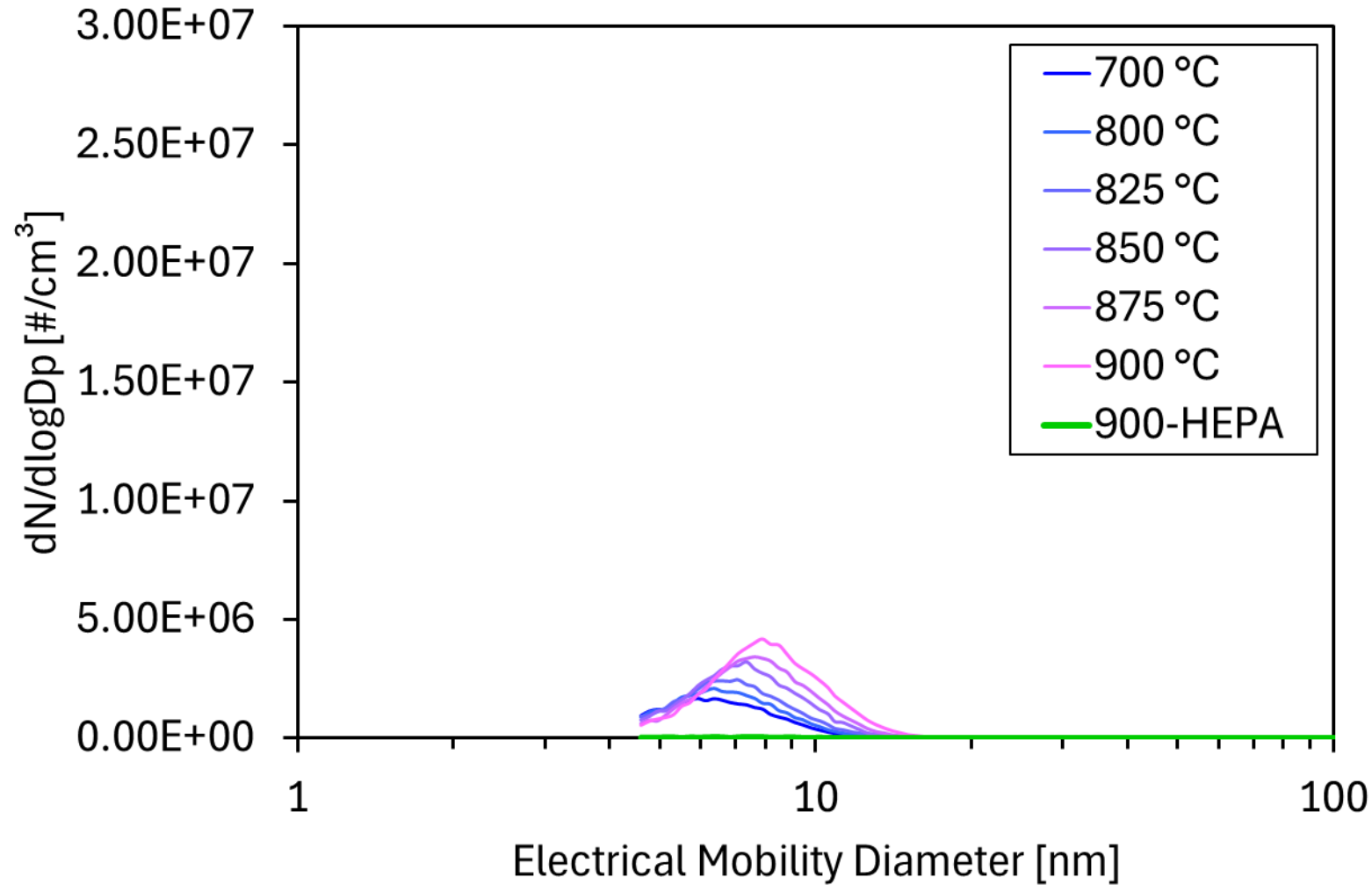
Experiment III – Polydisperse Au Seeds



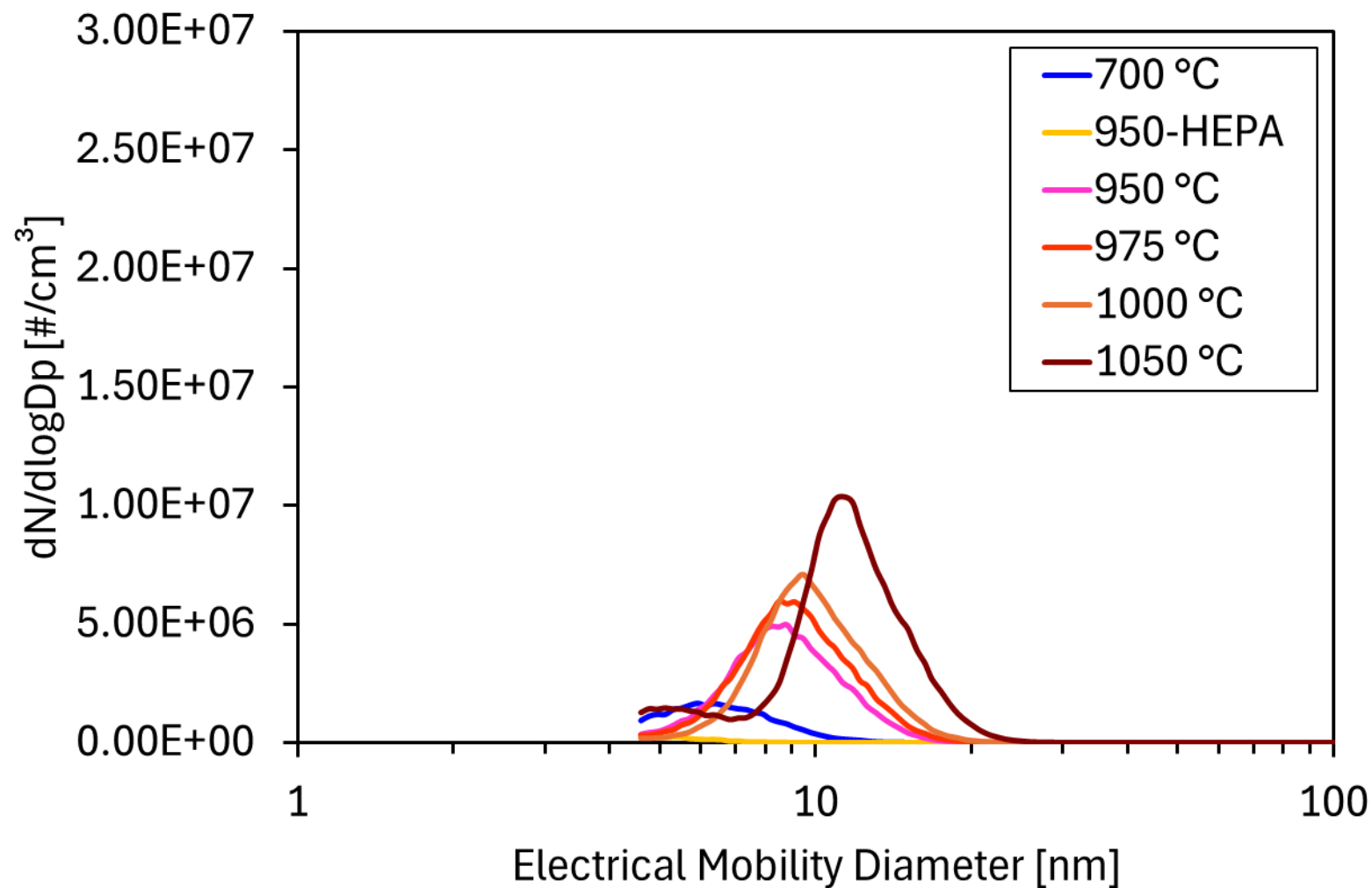
Experiment III – Polydisperse Au Seeds



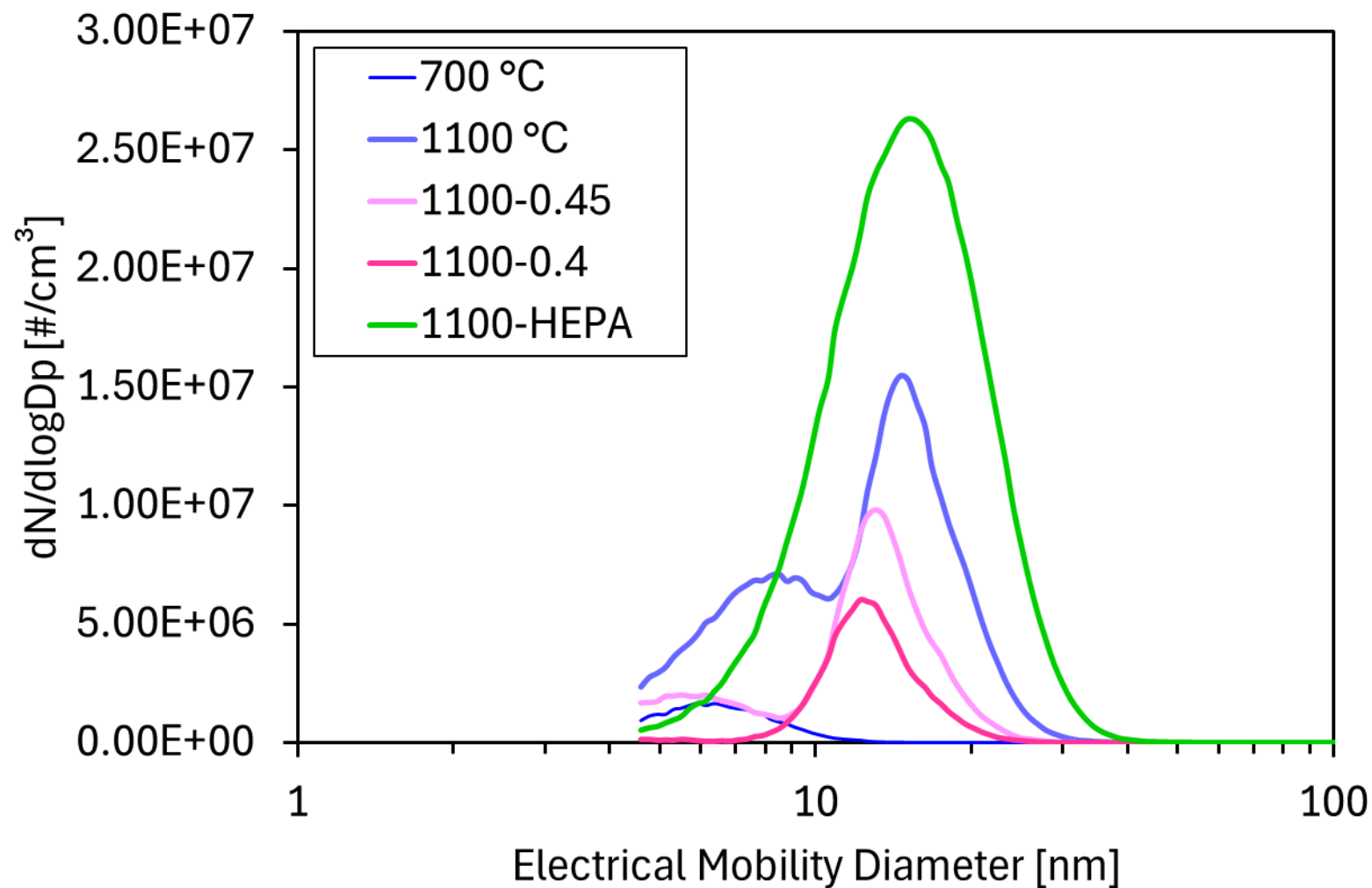
Experiment III – Polydisperse Au Seeds



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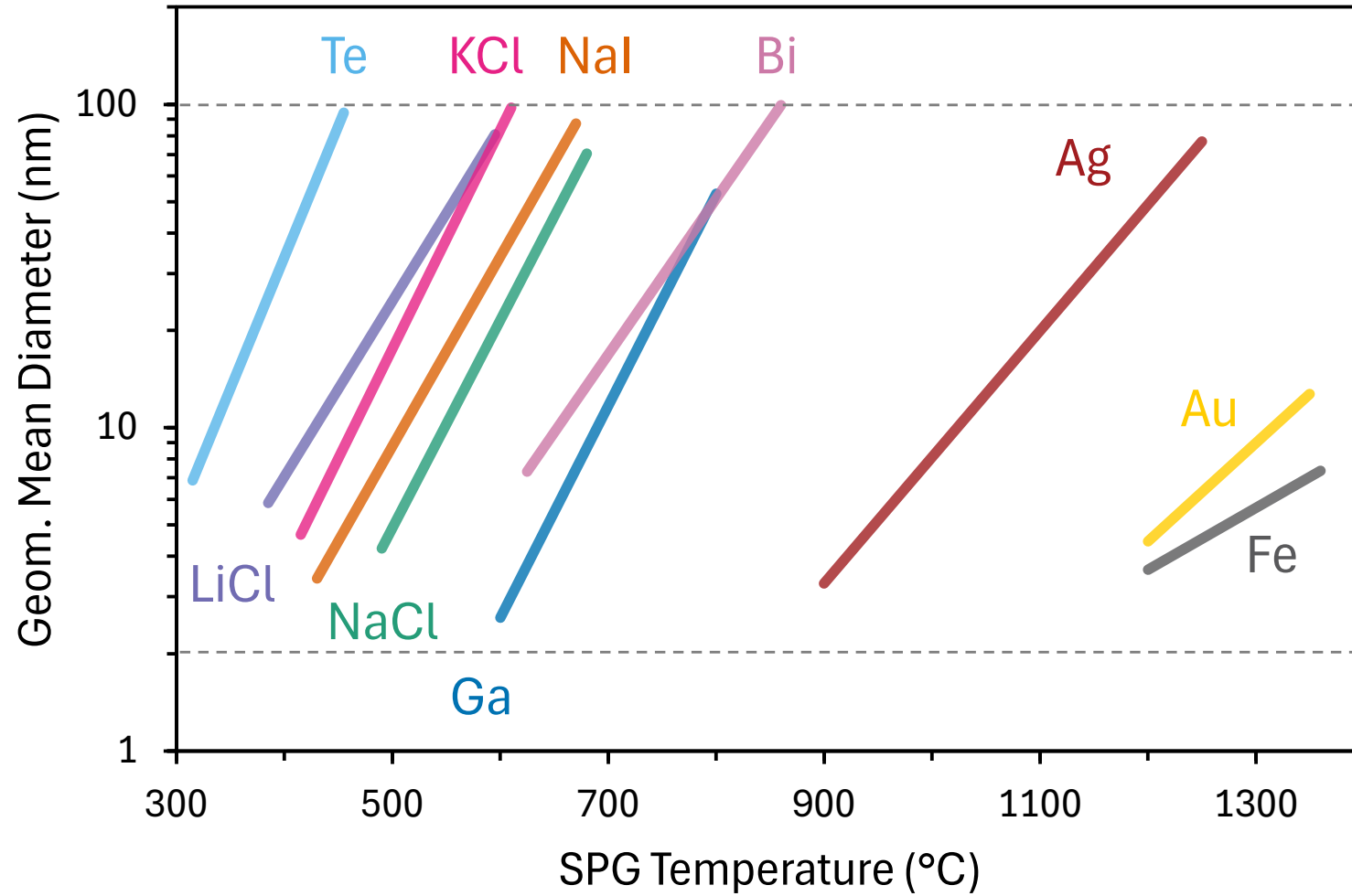
Experiment III – Polydisperse Au Seeds



Summary

- Heterogeneous condensation of silver onto gold seed particles is feasible in the Silver Particle Generator
- SPG is optimized for homogeneous condensation of silver particles – optimization for heterogeneous condensation requires mechanical changes and further experiments
 - Longer “condenser”
 - Actively controlled “condenser”-temperature
 - Seed particle loss reduction
- Morphology of resulting particles needs to be confirmed; e. g. via TEM

Thank you!

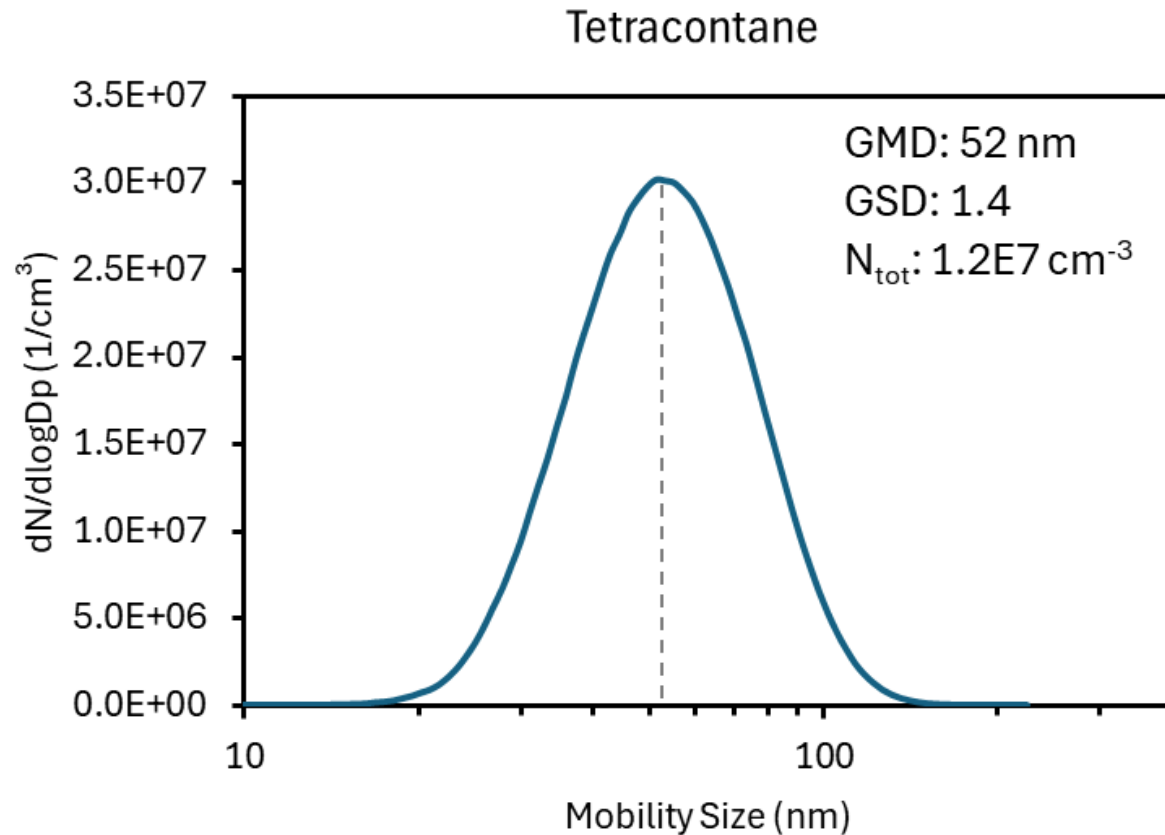


Silver Particle Generator (SPG)

- Standardize and simplify the evaporation-condensation generation method
- Precise, fast and easy control of temperature and flow
- Stable and high repeatability
- Different materials are possible
- Simple exchange of tube set



Low Temperature Materials (up to 300 °C)



- Tetracontane ($\text{C}_{40}\text{H}_{82}$)
 - PMP Volatile Particle Remover Testing
 - Testing our own Catalytic Strippers (CS)
- Plastics
(similar as Wlasits *et al.*, 2022)