Exploring and Designing the Structure of Particles of Dried Colloidal Dispersions

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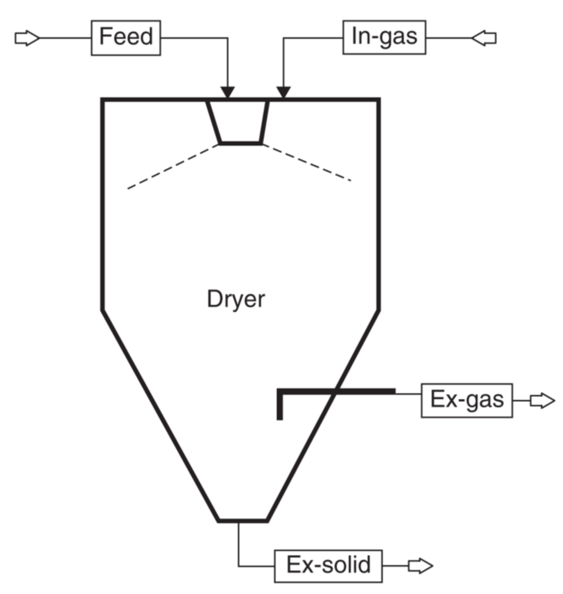
AIMS AND MOTIVATION:

Spray drying of colloidal mixtures is an efficient route to prepare particles with complex, targeted structures with enhanced functionality across a wide range of industries including pharmaceuticals, foods, and catalysts. The role of interparticle interactions within the colloid on the architecture of the dried droplet is poorly understood. Experimental approaches to probing this relationship can provide mechanistic understanding to inform models.

Two unique single droplet experimental methods will be used to emulate the processes occurring in a spray drier, allowing for in-situ measurement of drying histories and post-drying structural analysis.

The morphological influence of three core parameters will be investigated:

1. Colloidal stability (i.e. propensity for agglomeration)
2. Frictional interactions (by tuning particle roughness)
3. Size distribution for targeting stratified structures



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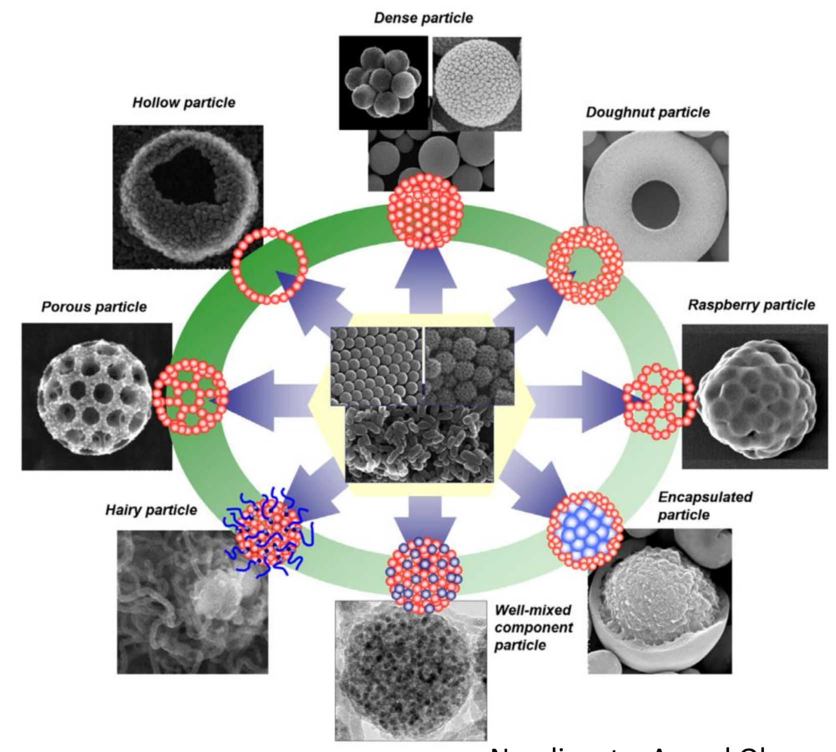

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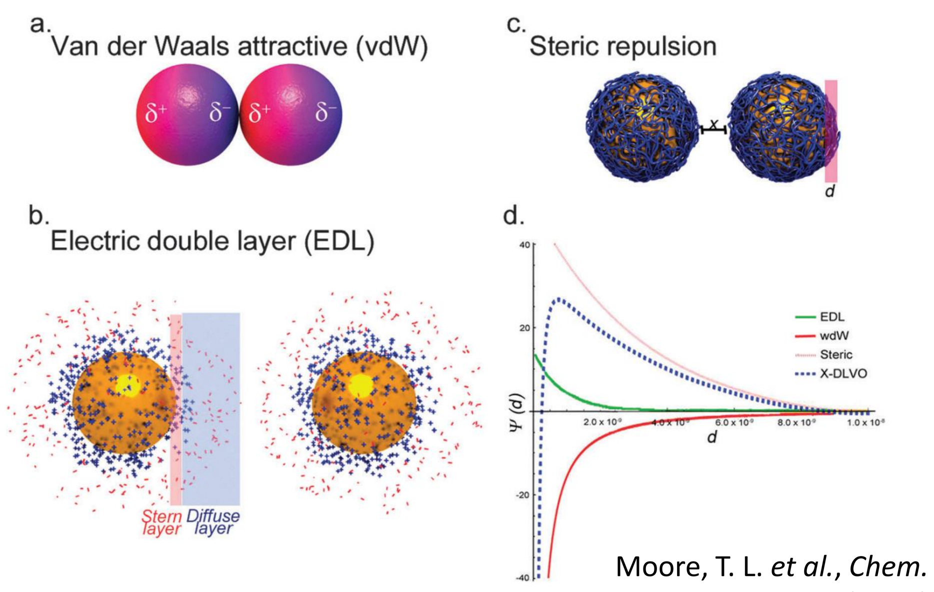
Main factors affecting particle morphology
• Formulation e.g. particle properties, colloidal stability, solvent
• Process e.g. droplet size, temperature, pressure
• Equipment e.g. droplet production, drying chamber
• Environment e.g. air humidity

TUNING INTERPARTICLE INTERACTIONS:

Colloidal stability is classically defined by the DLVO potential, a summation of the attractive (van der Waals) and repulsive (steric + electrostatic) forces. The latter will be altered via addition of electrolyte and by changing the pH.



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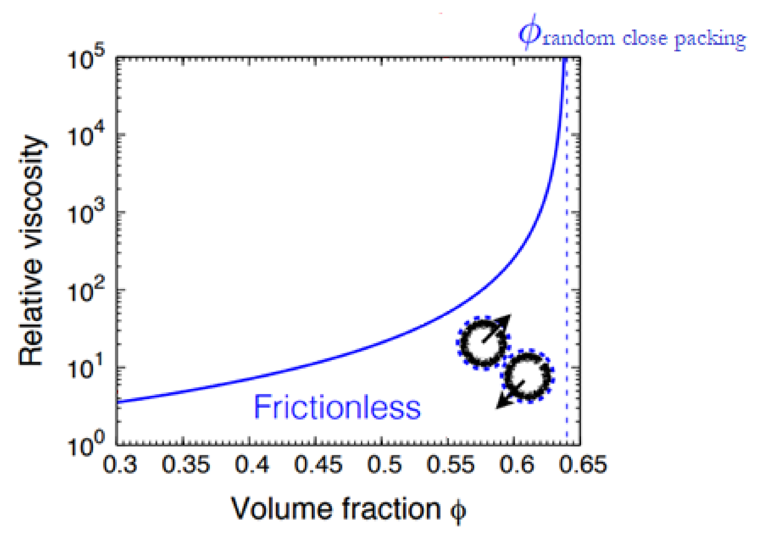
Colloidal particle roughness is known to affect viscosity at high particle volume fraction. Silica nanoparticles of varying roughness will be synthesized using electrostatically-driven adsorption.



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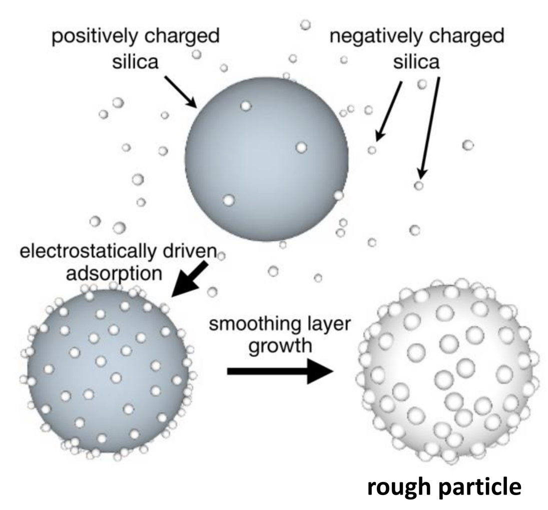

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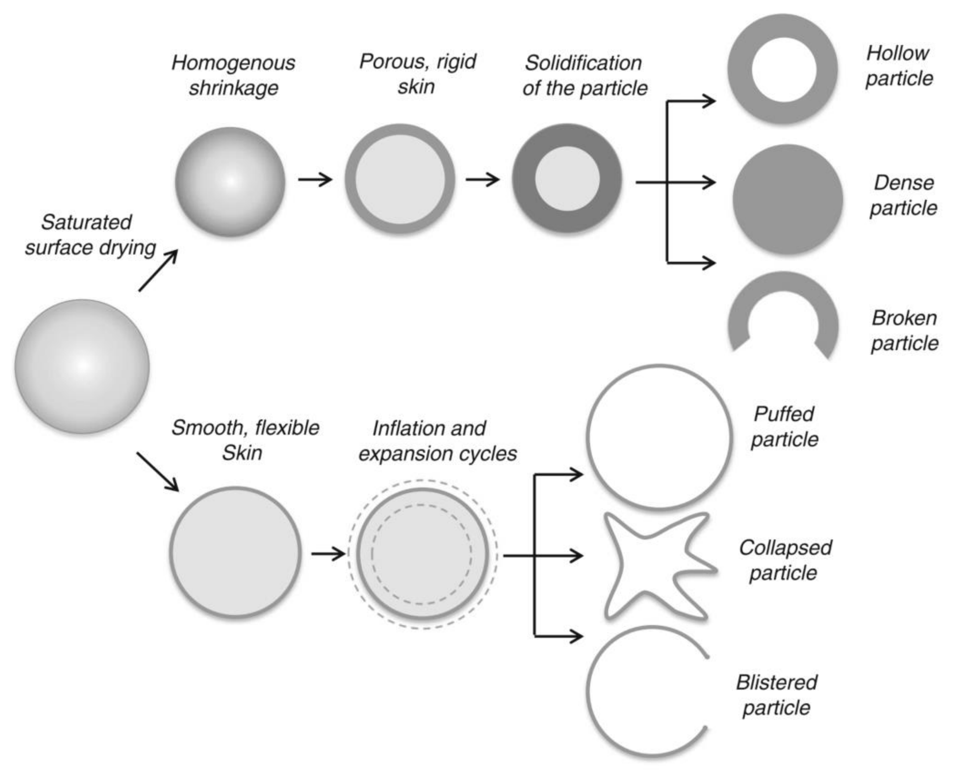
DEVELOPING THE THEORY:

The specific morphology attained upon drying a colloidal droplet depends on the sol–gel–jammed-'solid' transition at the droplet surface, the forces driving these changes, and the response to these forces (with regards to mechanical stresses and subsequent shape deformation). Attractive capillary forces between particles are understood to play a role in driving this transformation. By investigating whether particle aggregation and particle shape affect morphology, a stronger theoretical understanding can be built.



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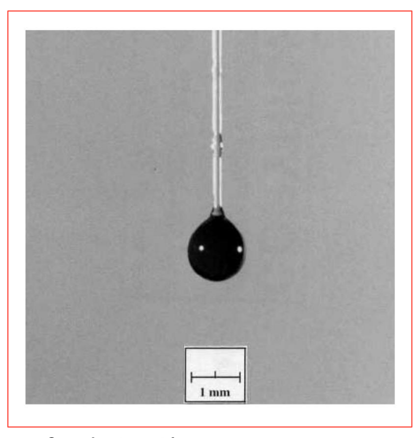
Empirical Approaches	Deterministic Approaches
• Characteristic drying curve	• Continuous species transport (CST)
• Reaction engineering	• CST with a population balance
• Peclet number analysis	

A range of drying models have been developed and will be tested against experimental findings.

EXPERIMENTAL TECHNIQUES:

1. Droplet suspended on thermocouple filament with mass balance



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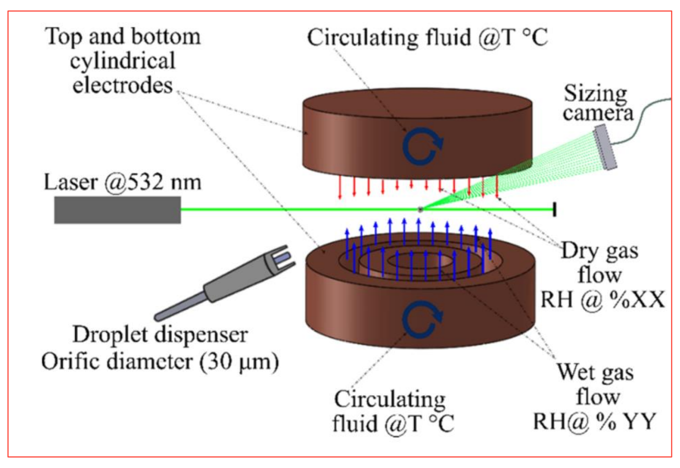
2. Electrodynamic balance



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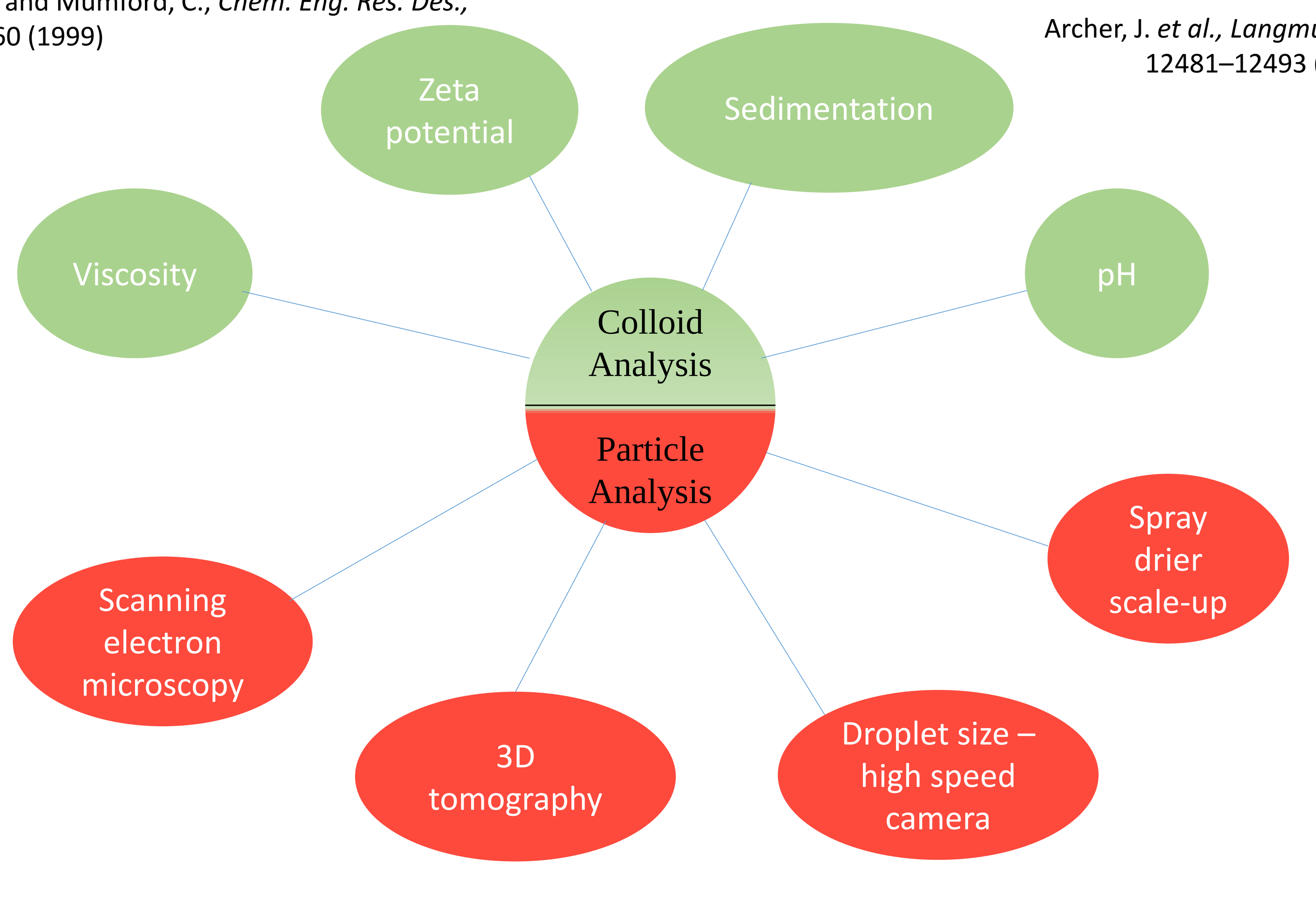

CHALLENGES AND FUTURE RESEARCH:

Challenges:

- Synthesis of monodisperse, uniformly rough nanoparticles.
- Interpreting complex mathematical models of droplet drying, and applying to experimental findings.
- Single droplet methods – isolating single parameter influence.
- Minimizing interference that single droplet methods may introduce.

Future research:

- Given the time frame of this project, it is unlikely that the morphology-influencing factors studied here will be investigated for a wide range of materials. Owing to the different types of colloidal materials found industrially, future work should look to extend this work for a wider range of materials.

RESPONSIBLE INNOVATION:

- Improved understanding of single droplet drying will be fed into models for spray drying.
- Applicable to a wide range of fields that employ droplet drying for production of powdered/granulated material.
- Developing a fundamental, theoretical understanding of droplet drying.

- Areas for potential wider impact:
  - Improved catalyst efficiency via targeted high surface-area morphologies.
  - Improved inhalation therapies for the treatment of lung problems and potentially the delivery of intranasal vaccines.
- Owing to fundamental nature of research, findings could be harnessed for the development of explosives for military use and therefore has political implications.

- All work will be carried out in accordance with EPSCR guidelines and with a goal to minimize environmental impact by avoiding the use of extraneous and harmful materials.