Self-assembly of Colloidal Superballs Under Uniform Compression

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Colloidal **superballs** undergoing uniform compression tend to form **structures** that gradually change dependent on the shape parameter.

Motivation

Understanding the relationship between the shape of a colloidal building block and the structure of a self-assembled material is important for the development of novel materials by self-assembly. Assembly of colloidal superballs under compression, attained from drying colloidal dispersion in a capillary, reveals a several phases of structural assembly.[1] Uniform compression can then help to comprehend the relationship between shape and assembly for novel functional materials.

Hierarchical Assembly

Superballs

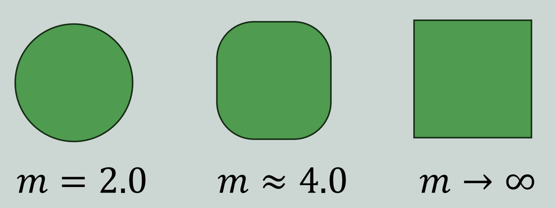
Shape-dependent Assembly

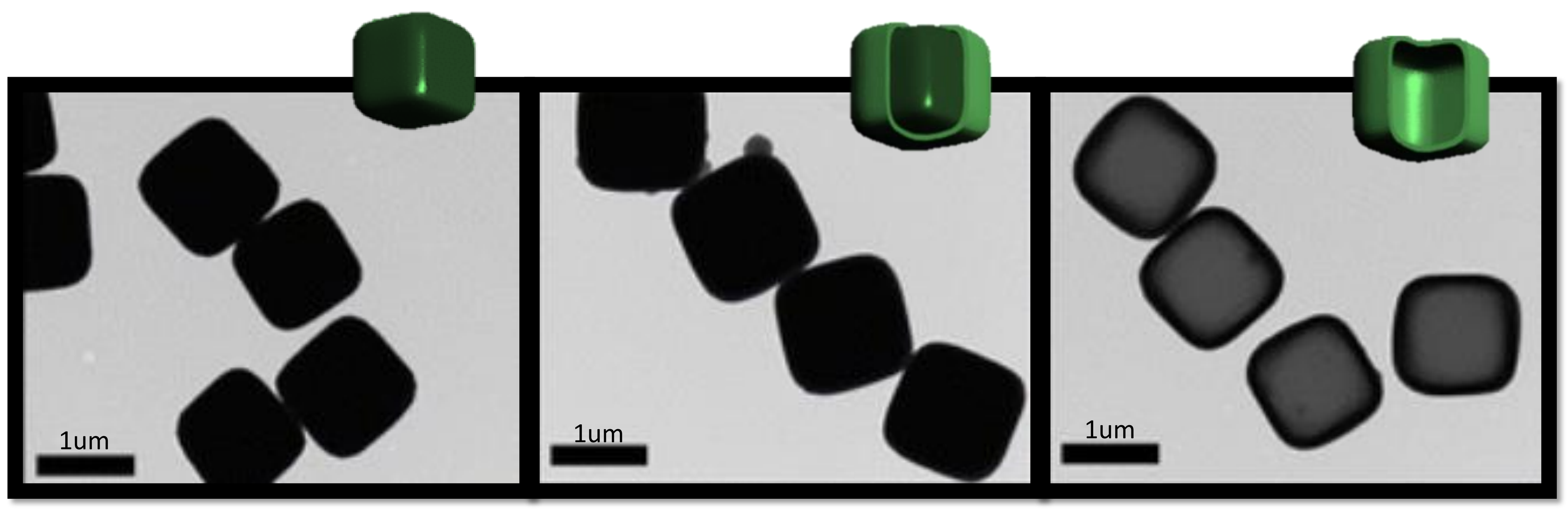
Compression Method

The shape of a superball

Colloidal superballs can be tuned to specific shapes from a sphere to a cube via a rounded cube. Non-magnetic superballs are fabricated by coating hematite superballs[2] with silica and etching out the hematite core[3,4].

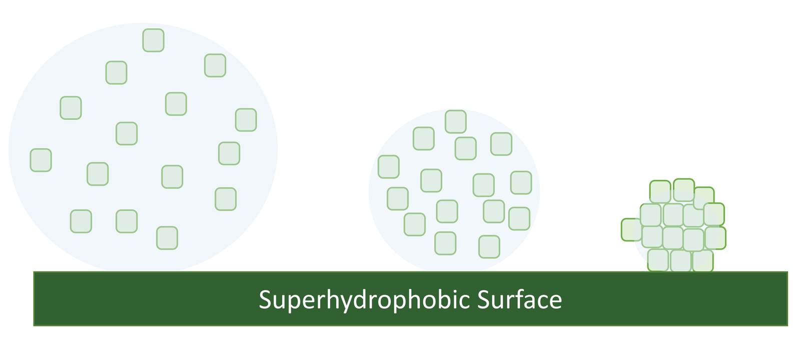
$$x^m + y^m + z^m \leq R^m$$





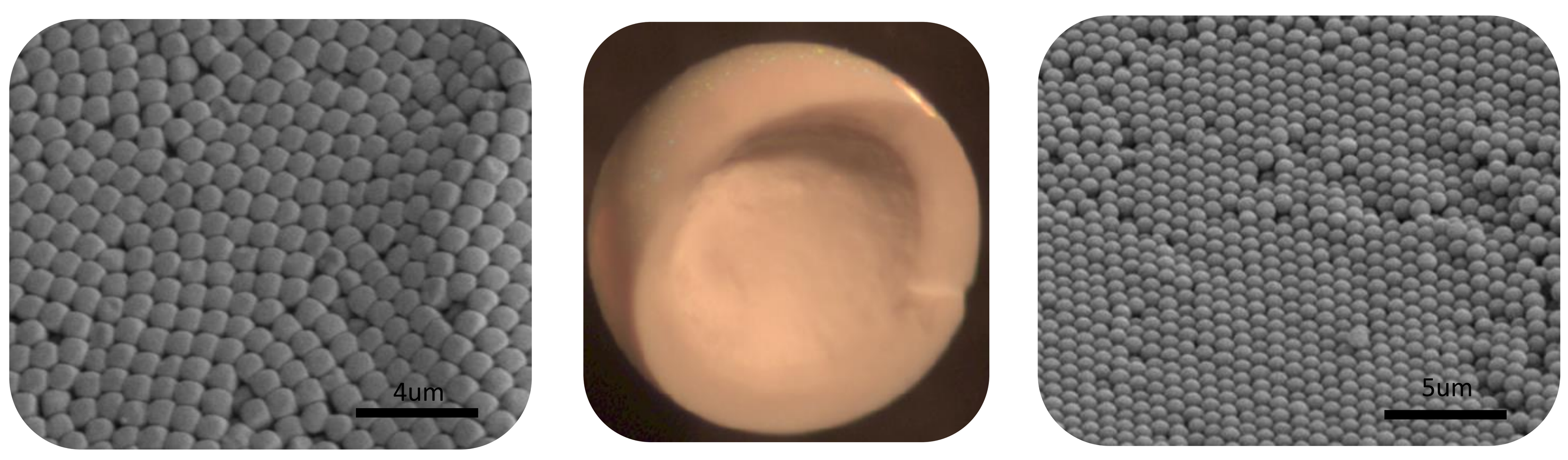
Hematite Superballs | Hematite with a silica shell | Silica shell without core

Opals are assembled under a near-uniform compression by drying a dispersion of superballs in water on a superhydrophobic plate. As the droplet shrinks, forces on the particles cause a packed structure to form.



Dispersed droplet | Concentration increasing | Structure formation

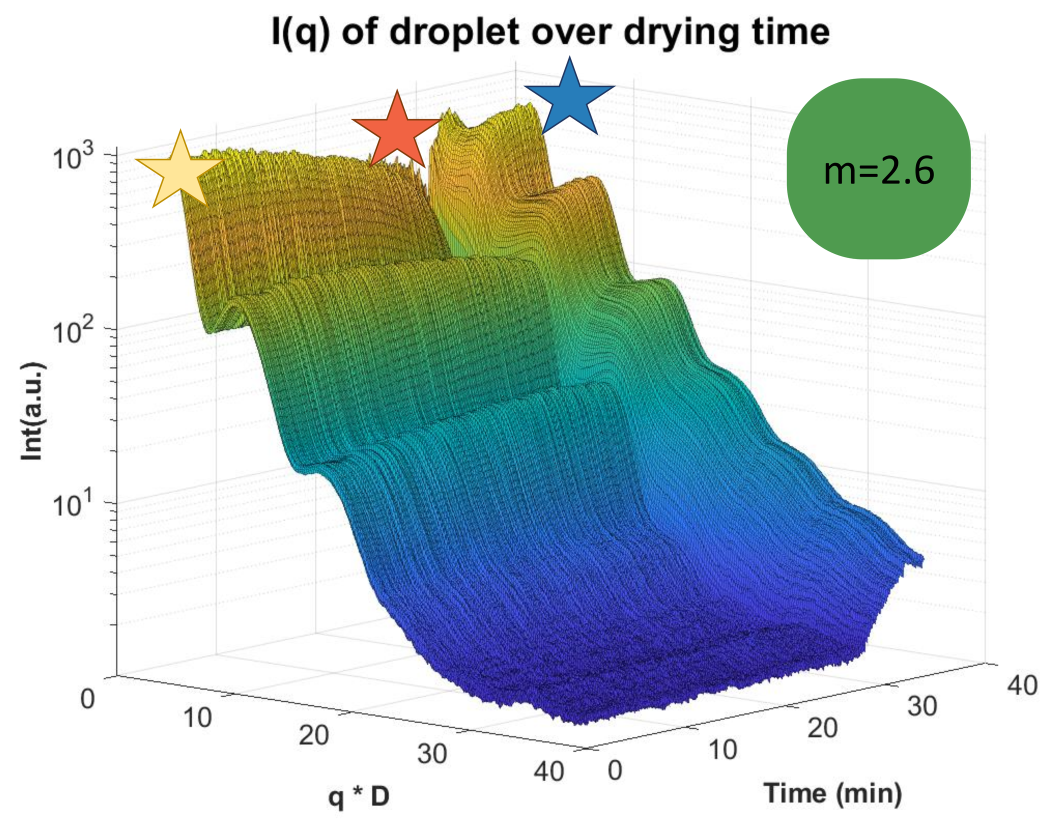
Close-packed assemblies form on the surface and inside opals made with superballs or spheres

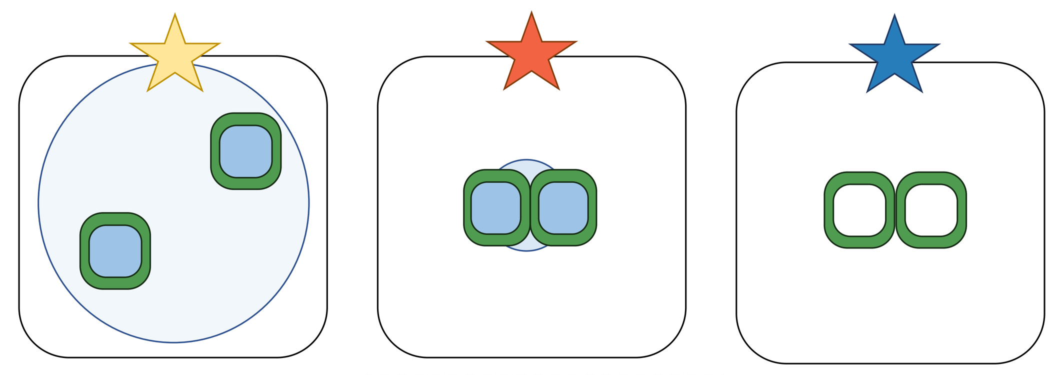


Surface of opal with superballs | Broken Opal | Inside of opal with spheres

Small Angle X-ray Scattering (SAXS)

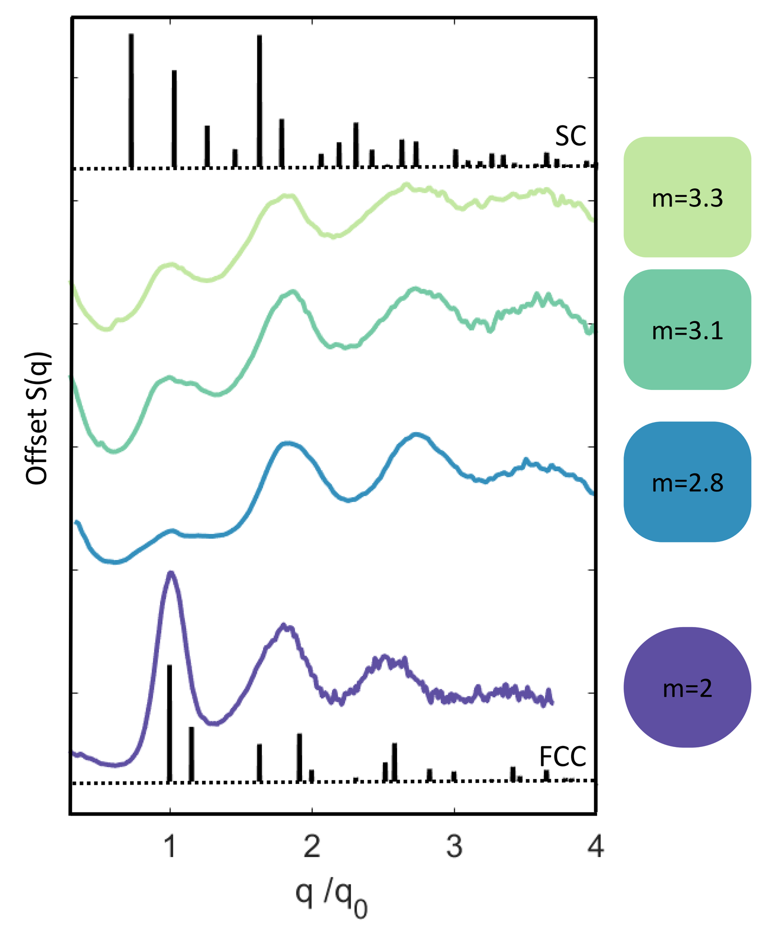
SAXS measurements of the opal formation process from superballs with various *m* values. The experiment (right) displays three distinct stages of drying which are found in all opal drying experiments.





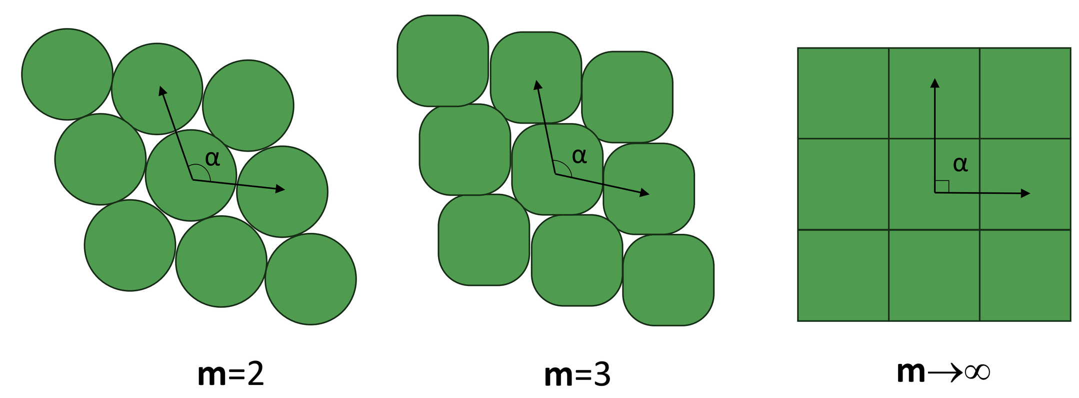
Limited particle-particle interactions | Final structure & droplet de-wetting | Dry Final Structure

The structure factor can be extracted from the SAXS before de-wetting for different *m*-valued experiments



We extract the structure factor, $S(q)$, by division of the form factor, $F(q)$. $I(q)/F(q)=S(q)$
Here, we take the initial SAXS profile to be the form factor, $I_{initial}(q) \approx F(q)$. We compare the structure factor between different droplets before de-wetting (left) by dividing q with the position of the first observed peak, q_0. The structure that forms is familiar to an angle, α, dependent rhombohedral phases that has been previously seen in 2D[1] and 3D.[5]

For superballs, the angle, α, can be related to the shape parameter, *m*. The structure smoothly transitions from a FCC-type lattice to a SC-type lattice via the change in *m*.



Conclusions

Different opals formed with various superball particles (where 2>*m*>4) have structure factors that gradually vary as the *m* value is increased. Due to the hollow nature of the superballs, uncovering the final structure of the completely dry opal requires a delicate approach.

Acknowledgements and References

1. Meijer, J., *Nat Commun*. **8,** 14352 (2017)
2. 2. Sugimoto et al., *J. Coll. Interf. Sci* . **152**, 587 (1992)
3. Rossi et al., *Soft Matter* **7**, 4139 (2011)
4. Rossi et al., *PNAS* **112**, 5286 (2015)
5. Zhang et al., *PRL*. **107**, 135701 (2011)

L.R. acknowledges the Netherlands Organisation for Scientific Research (NWO) for financial support through a Veni grant and for the provided beamtime at DUBBLE located at ESRF, Grenoble facilities .

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