Self-Assembly of Magnetic Superballs inside Evaporating Droplets

SARAH SCHYCK[a], JANNE-MIEKE MEIJER[b], MAX SCHELLING[b], ANDREI V. PETUKHOV[c], and LAURA ROSSI[a]

[a]Delft University of Technology, Chemical Engineering Department, Delft, the Netherlands
[b]Eindhoven University of Technology, Department of Applied Physics, Eindhoven, the Netherlands
[c]University of Utrecht, Debye Institute for Nanomaterials Science, Utrecht, the Netherlands

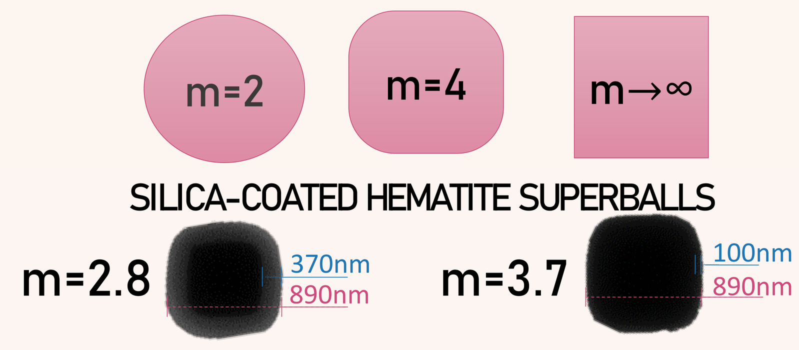
Motivation

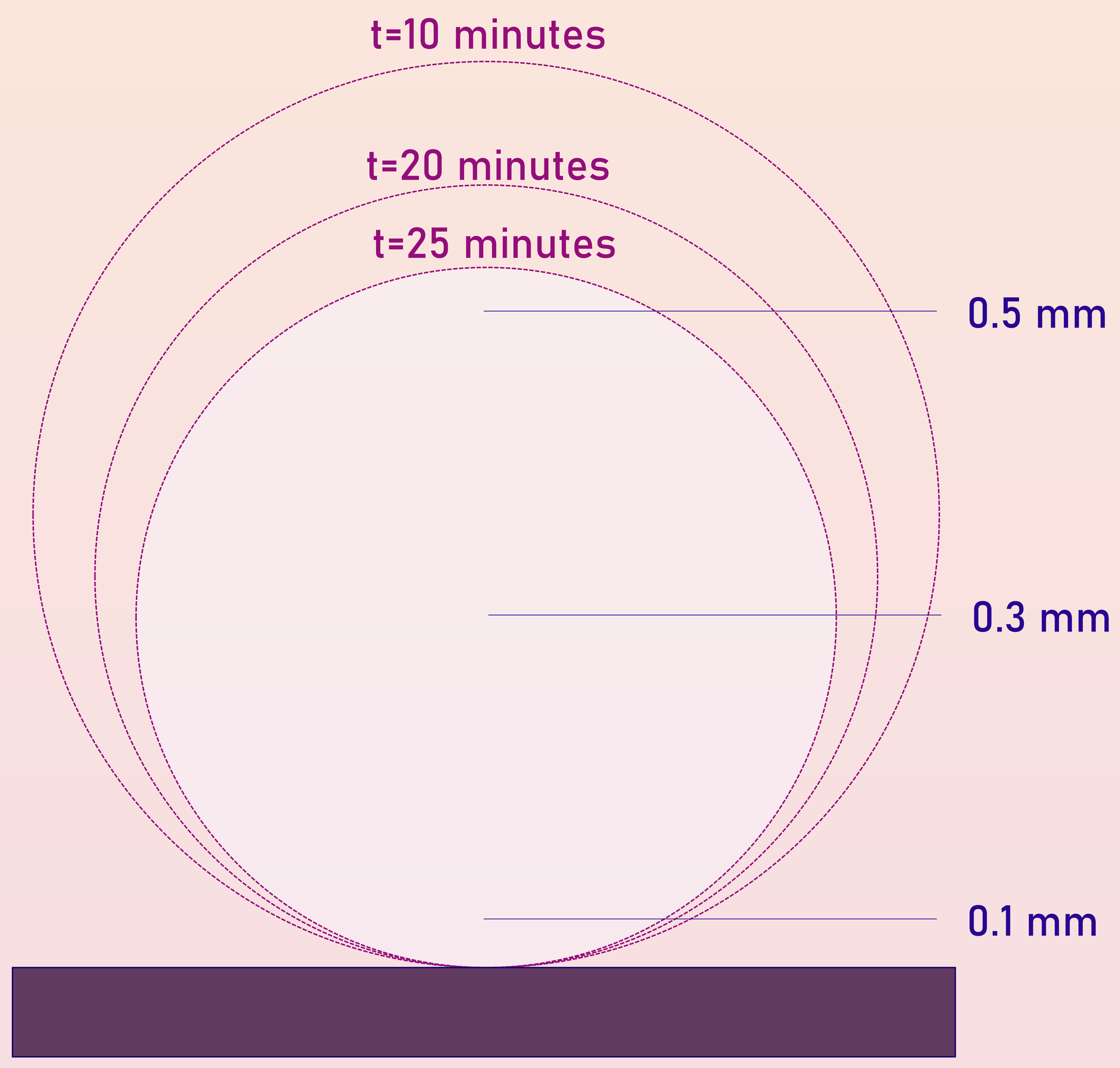
Understanding the relationship between the inherent directionality of a colloidal building block and the self-assembled structure of the particles is of both practical and fundamental interest in soft matter. Assembly of non-magnetic superballs in evaporating droplets revealed the ability to create free-standing, well-ordered macrostructures.[1] The inclusion of a permanent magnetic moment inside the superball particle result in assemblies with well-ordered and magnetic field dependent structures.[2] By utilizing both an evaporating droplet and magnetic superballs, we aim to build controllable, well-ordered macroscopic structures.

Superball shape

Superballs are a family of shapes between spherical and cubic, via a rounded cube. Magnetic superballs are fabricated by coating hematite superballs[3] with a silica shell[4,5].

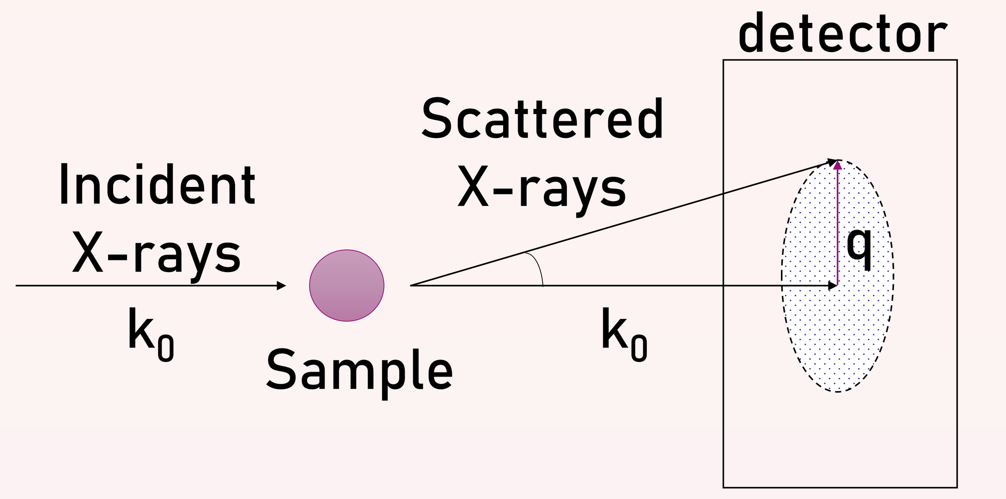
$$x^m + y^m + z^m \leq R^m$$



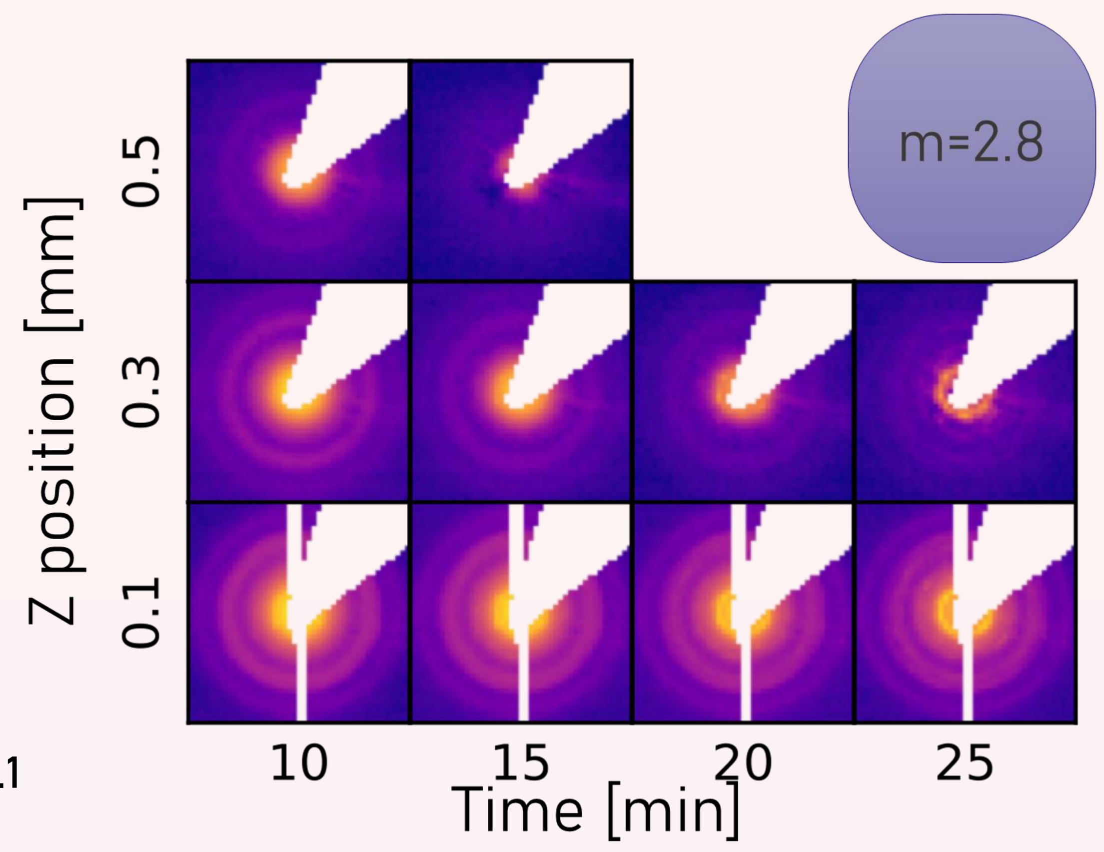


Small angle x-ray scattering (SAXS) experiments

Magnetic superball particles are assembled via solvent evaporation of a dispersion droplet. As the droplet dries, forces acting on the particles cause ordered structures to form.

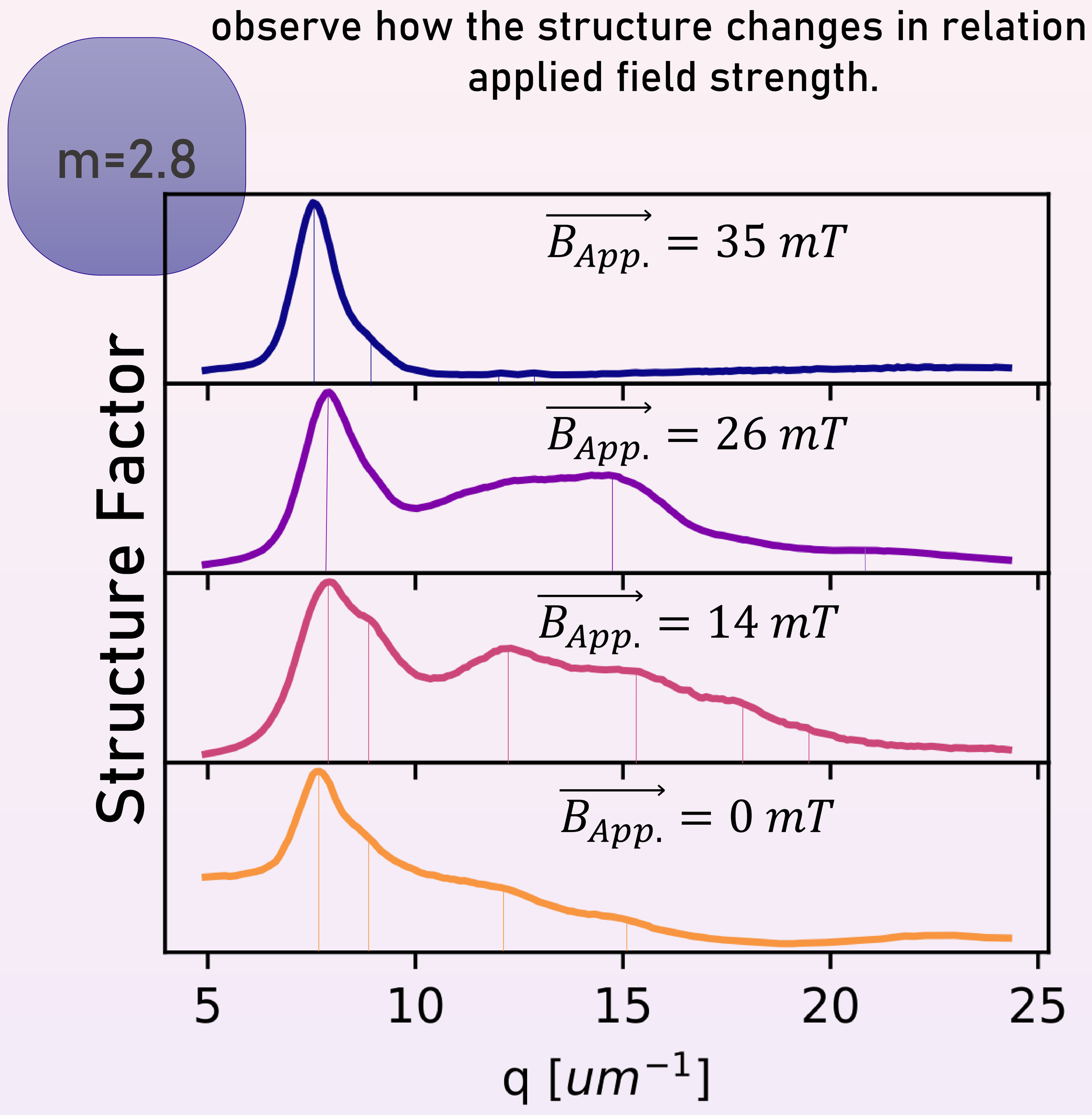


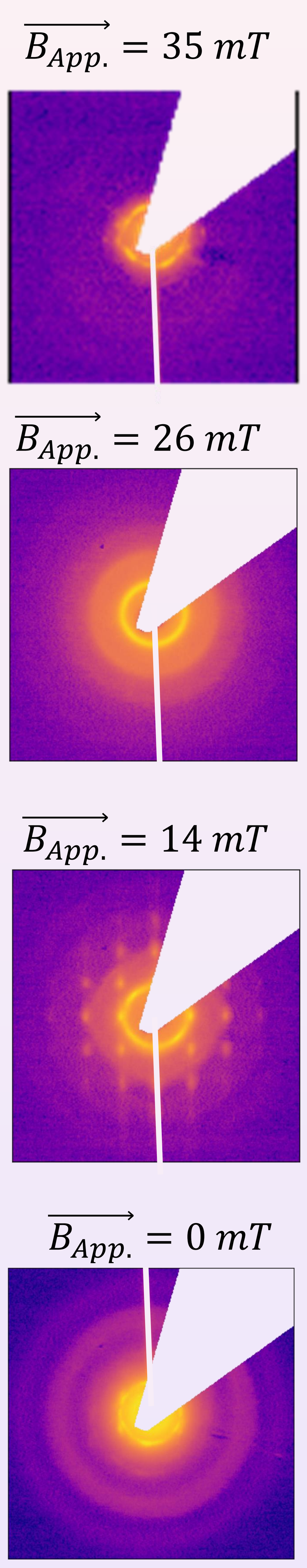
SAXS measurements are taken during the assembly process at various droplet heights (0.1 mm steps). 2D SAXS patterns confirm the shrinking of the droplet in the z-direction due to evaporation and when particle ordering appears.



Applying a magnetic field

We can apply a static magnetic field up to 35 mT to our dispersion droplets as they evaporate. We observe how the structure changes in relation to applied field strength.



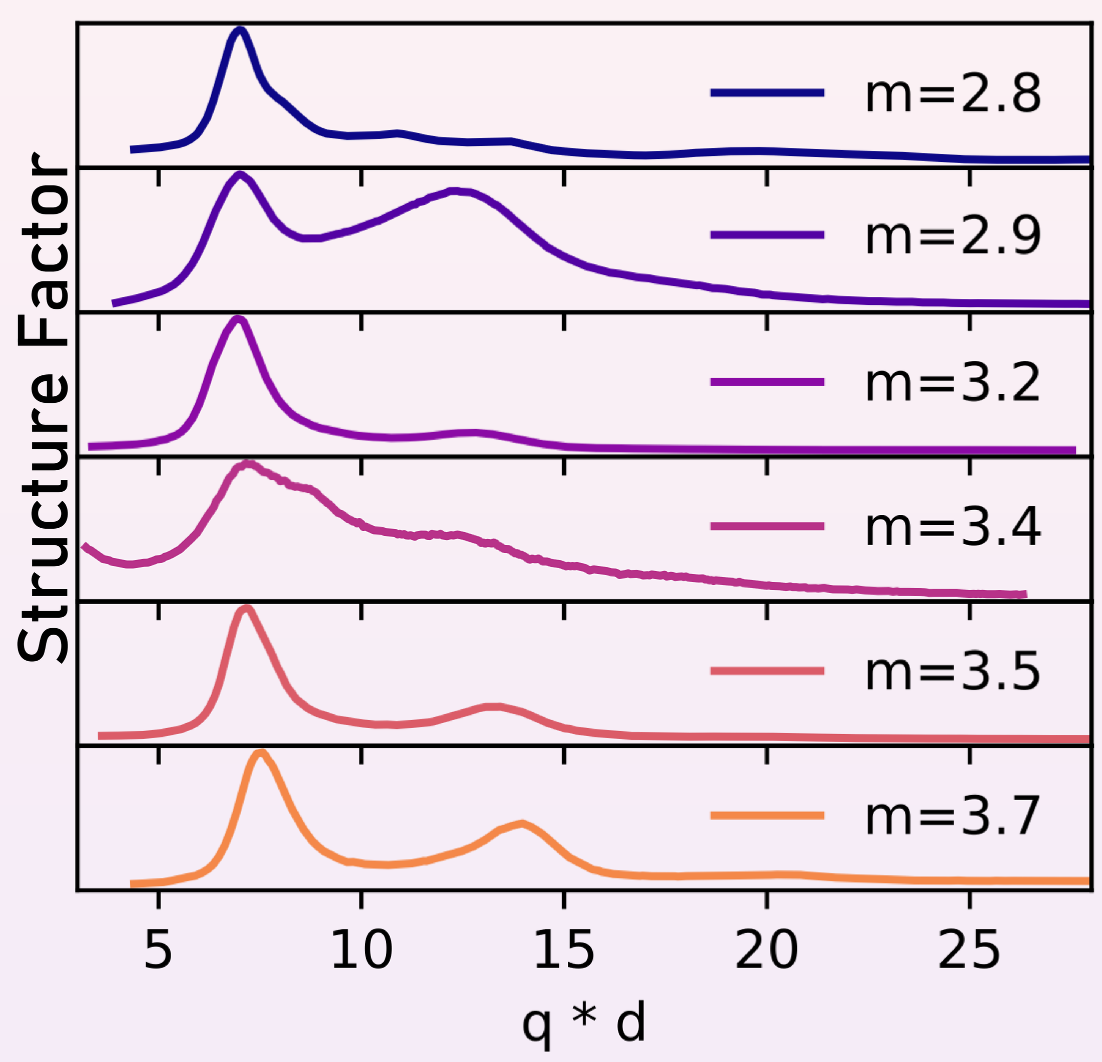


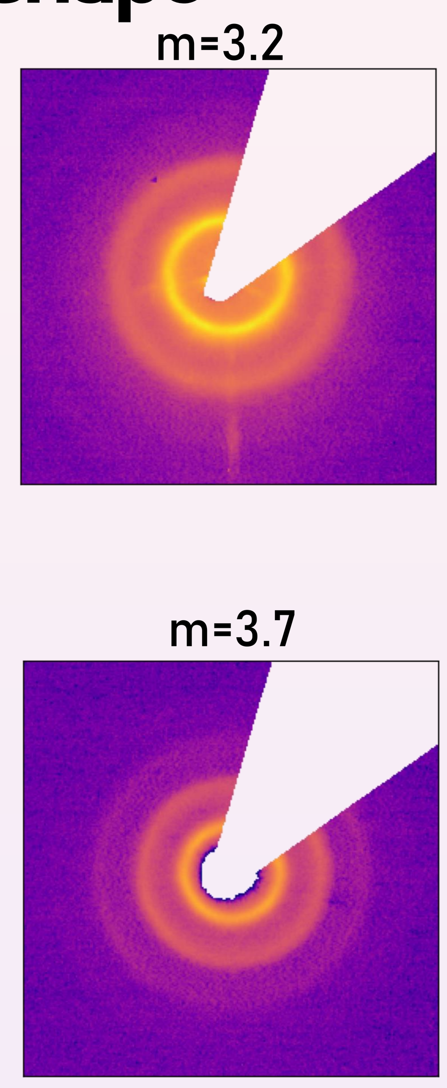
No applied magnetic field
Without an applied magnetic field, broad FCC-like S(q) rings appear during droplet drying. Faint Bragg peaks lie within these rings.

Low (14-26 mT) magnetic field
At 14 mT, the magnetic field allows the particles to orient together without hindering structure formation. Single crystalline like 2D SAXS patterns appear indicating a well-ordered macrostructure has formed.

Strong (35 mT) magnetic field
Droplets in higher magnetic fields no longer have higher order S(q) rings. The resulting assembly is then poly-crystalline with weak orientation correlation between these domains.

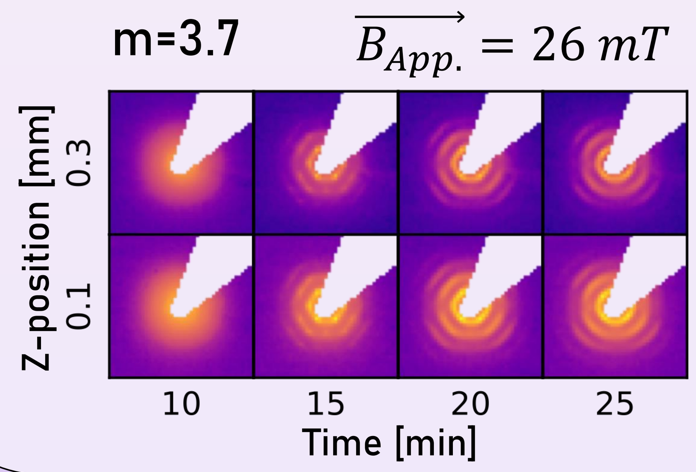
Altering the superball shape





Without an applied magnetic field, changing the shape of the superball produces assemblies with broad S(q) rings.

Controlling the structure



Well-ordered structures appear during assembly under a magnetic field for even our most cubic particles (m=3.7). Here, the structure shifts from a 6-fold, hexagonal symmetry to a 4-fold one as the droplet evaporates.

Conclusion

Macrostructures formed via magnetic superballs assembling under an evaporating droplet can be controlled. By tuning the shape of the superball and the applied magnetic field, well-ordered, free-standing macrostructures are fabricated.

Acknowledgements and References

1. Schyck et al. *JCISO*. **5**, 100037 (2022)
2. Meijer et al. *Soft Matter*. **9**, 10729 (2013)
3. 2. Sugimoto et al., *J. Coll. Interf. Sci*. **152**, 587 (1992)
4. Rossi et al., *Soft Matter* **7**, 4139 (2011)
5. Rossi et al., *PNAS* **112**, 5286 (2015)

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S.N.Schyck@tudelft.nl
@Sarah_Schyck

TUDelft