

Shear Banding in drying colloidal films studied with μ -SAXS

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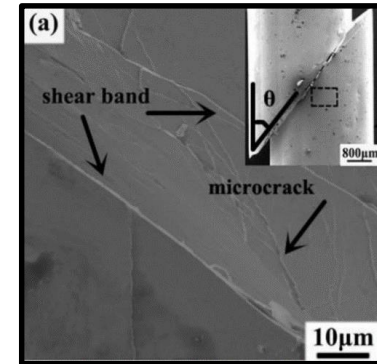
Web: www.nottingham.ac.uk/~ppzmis

Relating Plastic Deformation to microstructure

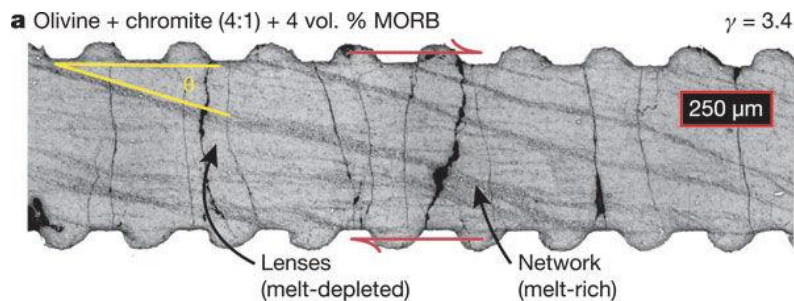
Plastic deformations do not always occur uniformly

Shear may become localised into thin bands of material

How is this related to sample microstructure?



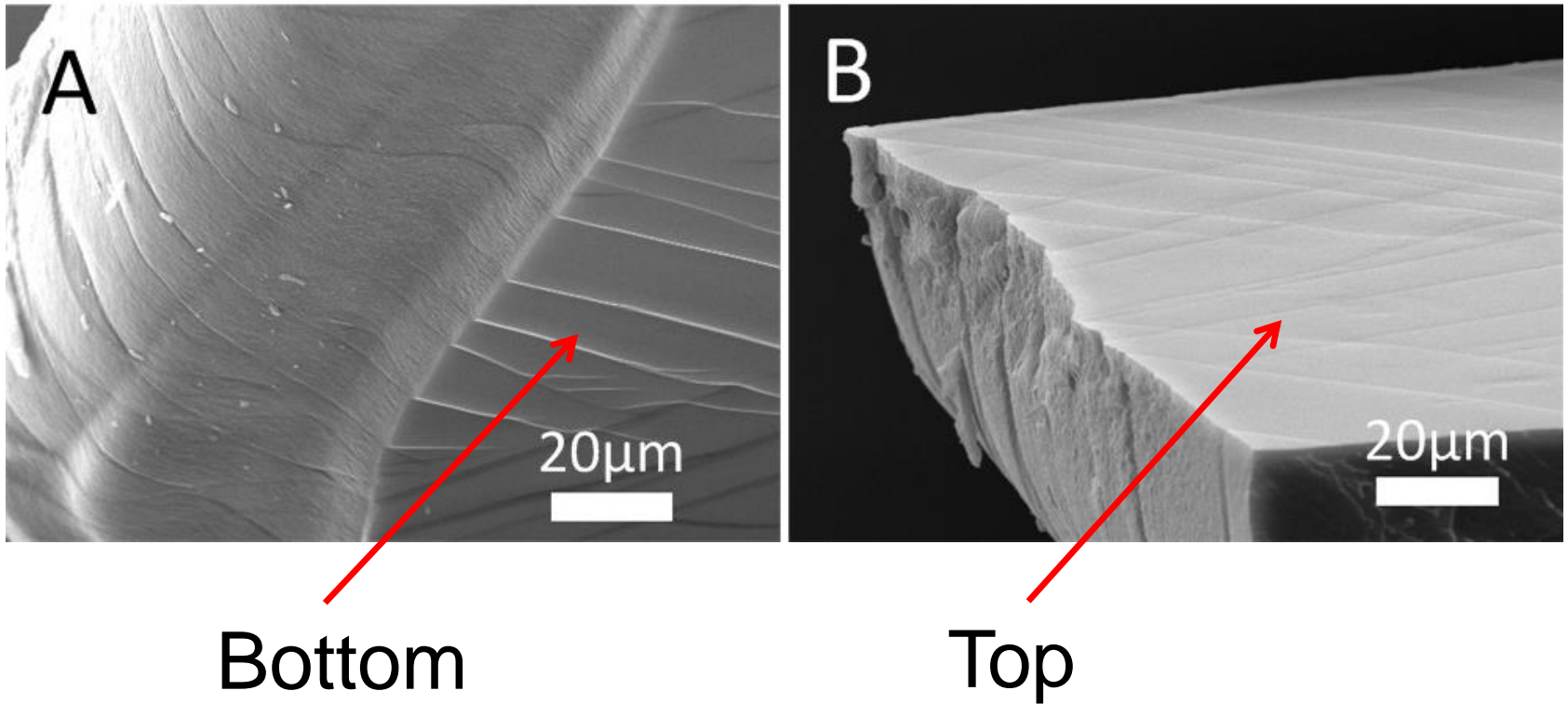
[Wang et al 2015]



[Katz et al 2006]

[Hudleston et al 2015]

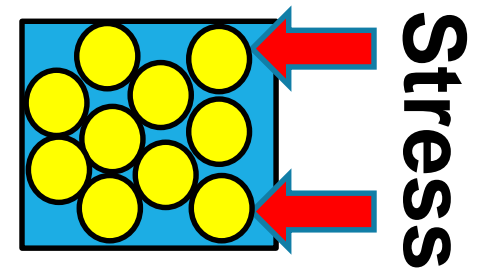
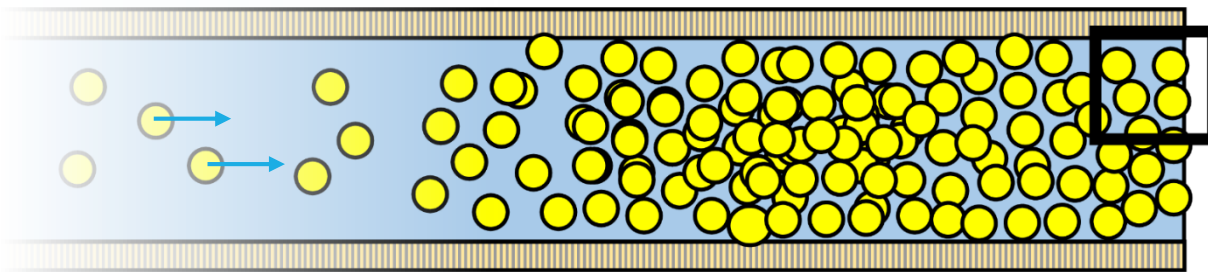
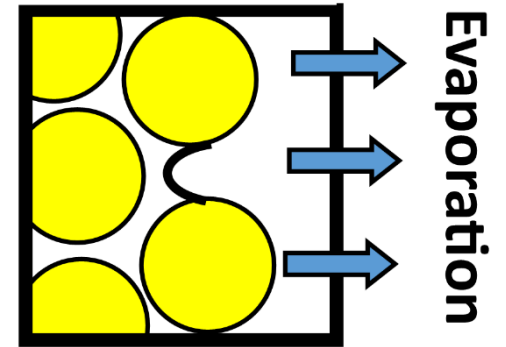
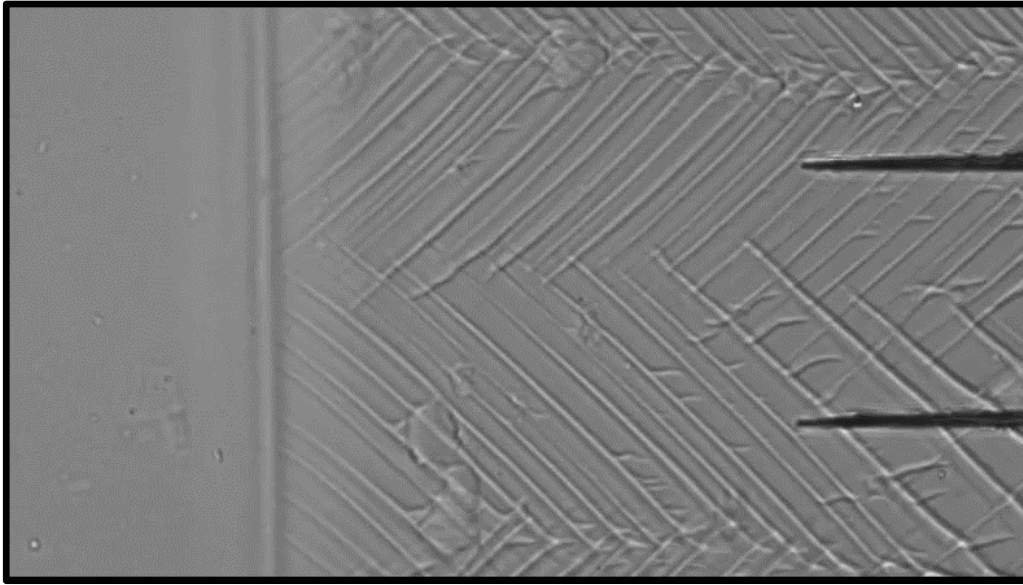
Shear bands in a colloidal film



“Shear banding in drying films of colloidal nanoparticles”

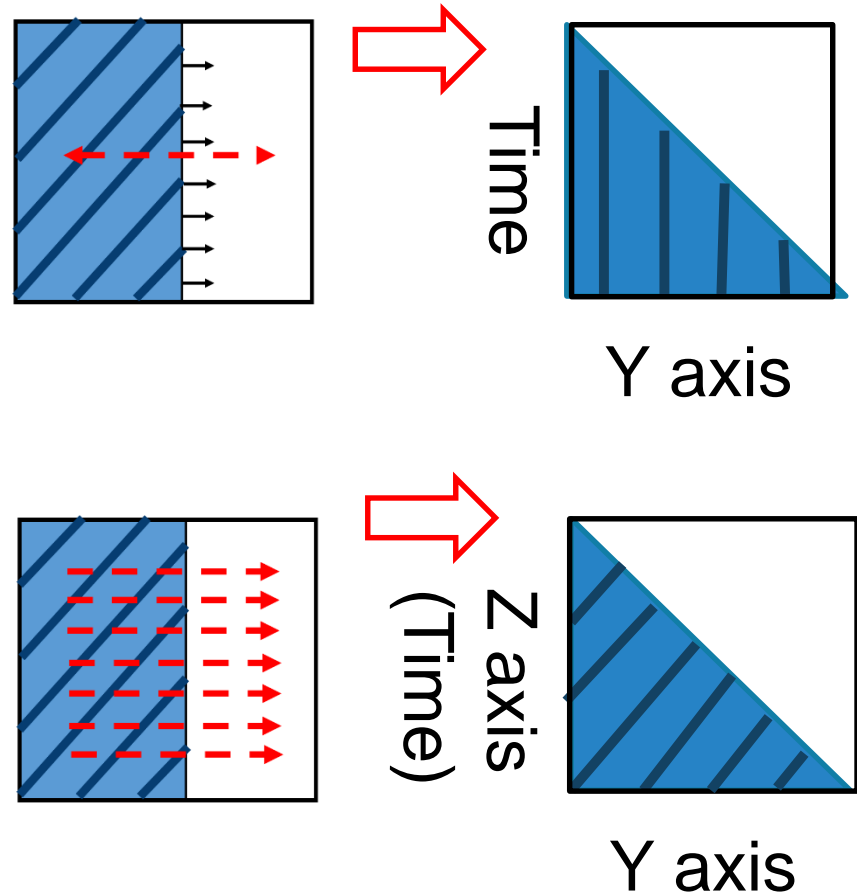
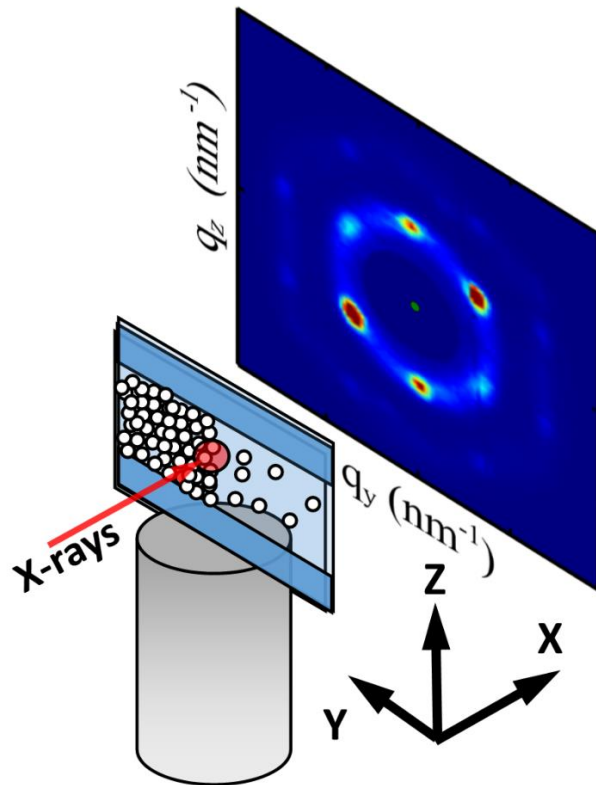
B. Yang, J.S. Sharp, M.I. Smith, ACS Nano (2015)

Drying in colloidal films



Xray experimental details

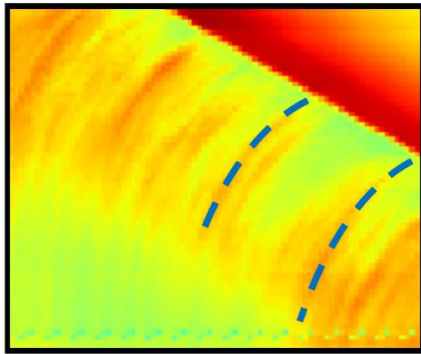
ID13 beamline at European Synchrotron Research Facility



1 μ m spot size < feature size

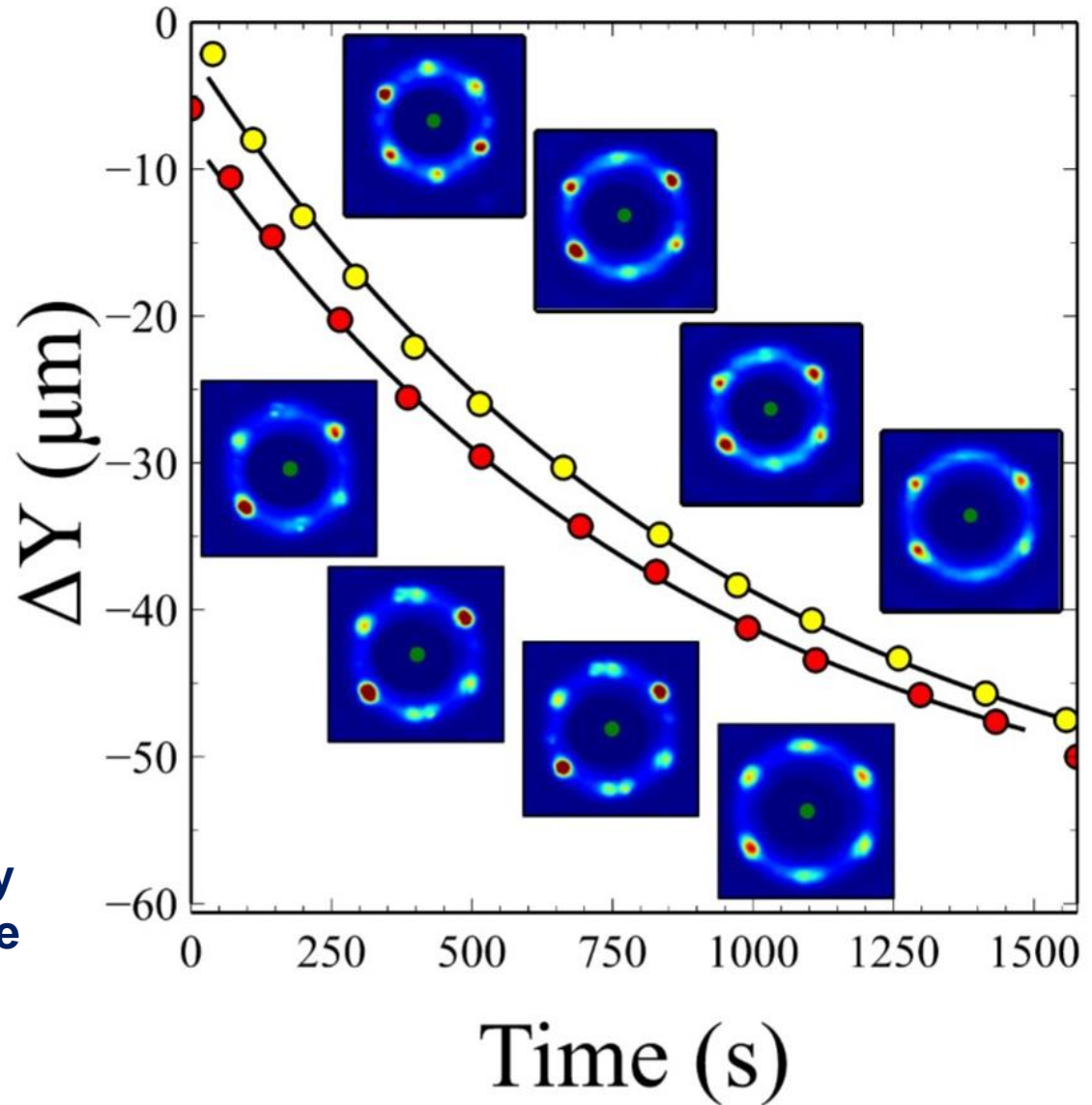
Dynamic measurement of changing microstructure

Transition region shows curves of correlated intensity

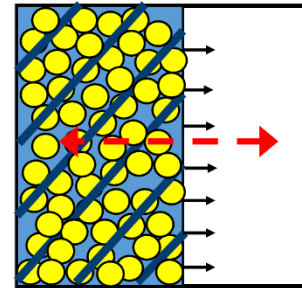
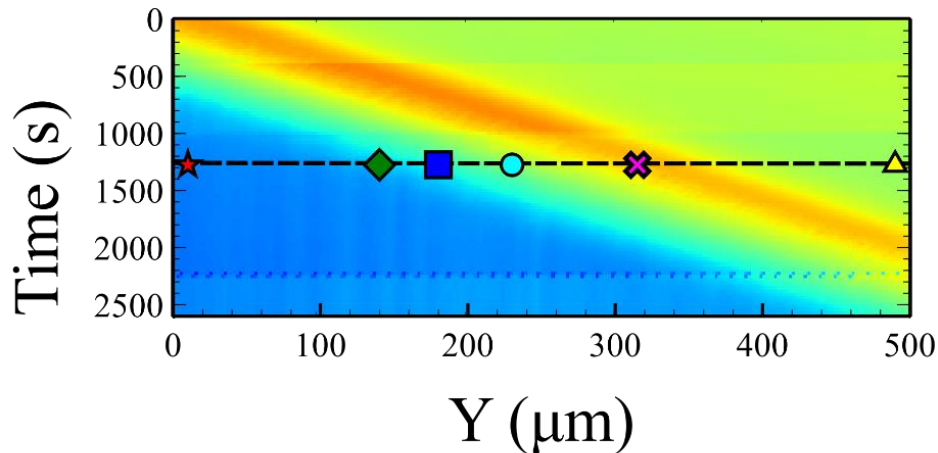


Inhomogeneities in scattering patterns follow these trajectories

μ -SAXS can track small groups of particles as they undergo compaction in the film



Plastic deformations with amorphous microstructure

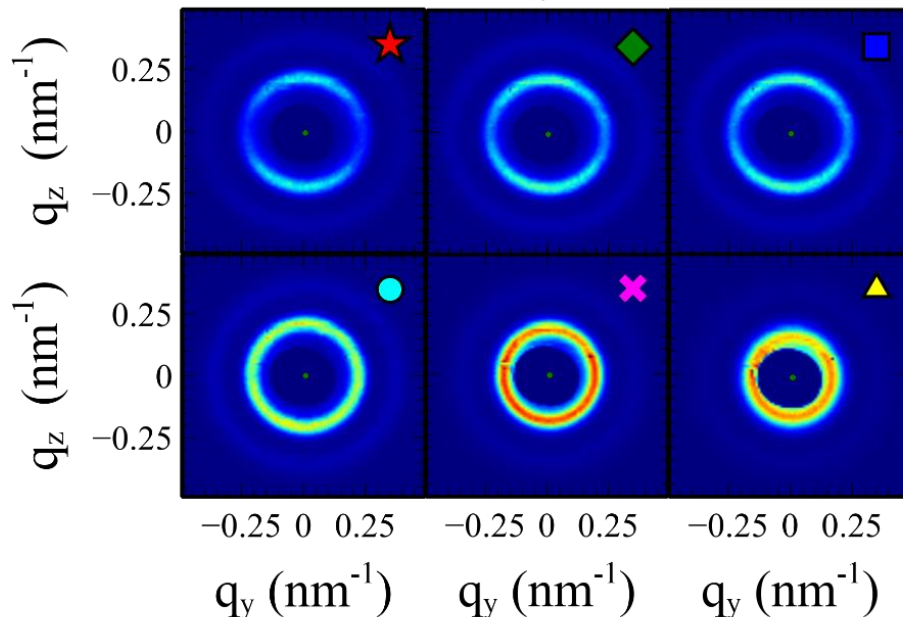


30wt% Ludox in water

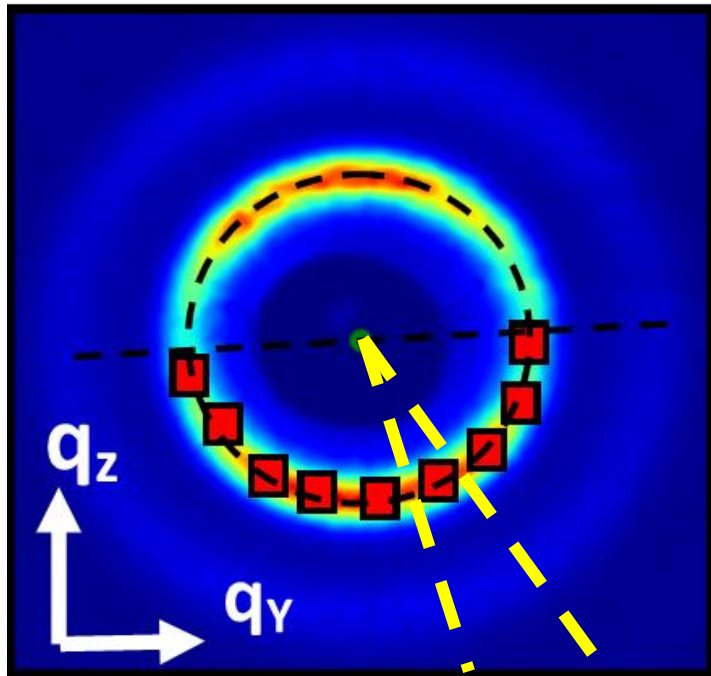
Drying Front Velocity
 $0.24 \mu\text{m s}^{-1}$

**Faster moving front \rightarrow
Amorphous microstructure**

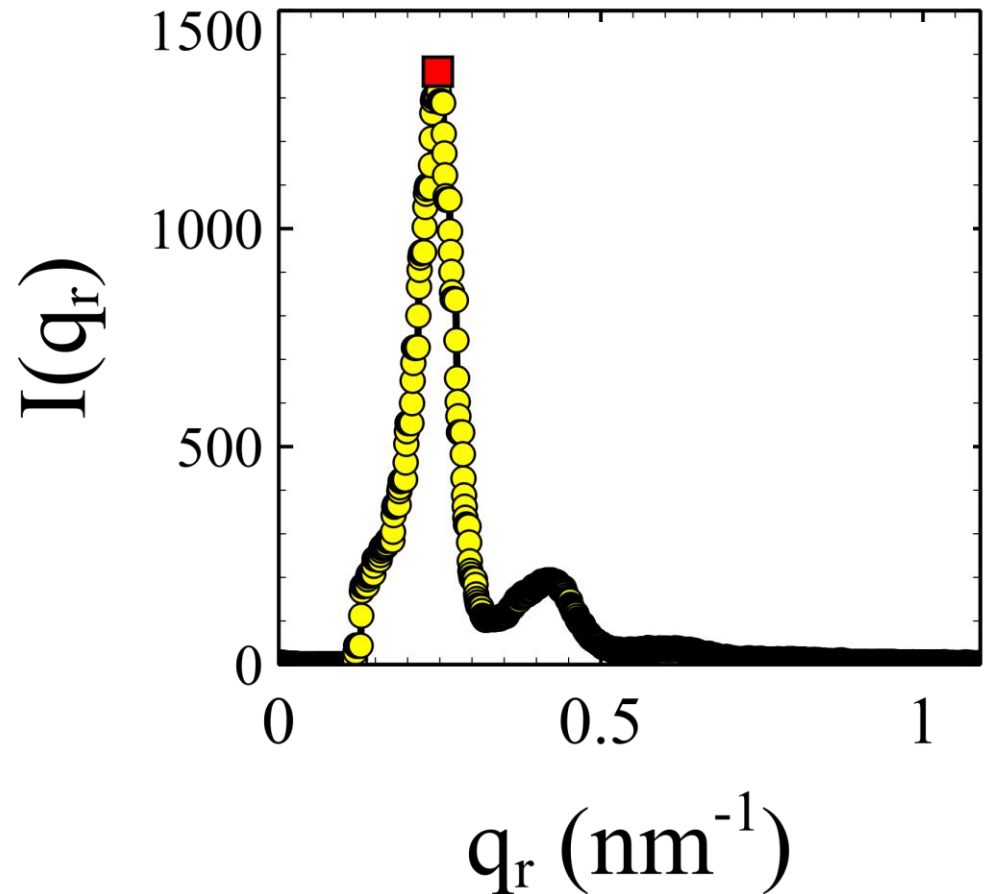
**Scattering patterns become
elliptical as film forms**



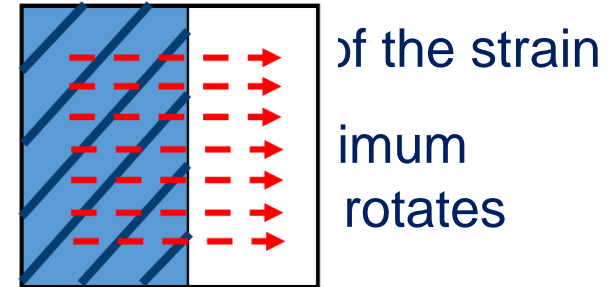
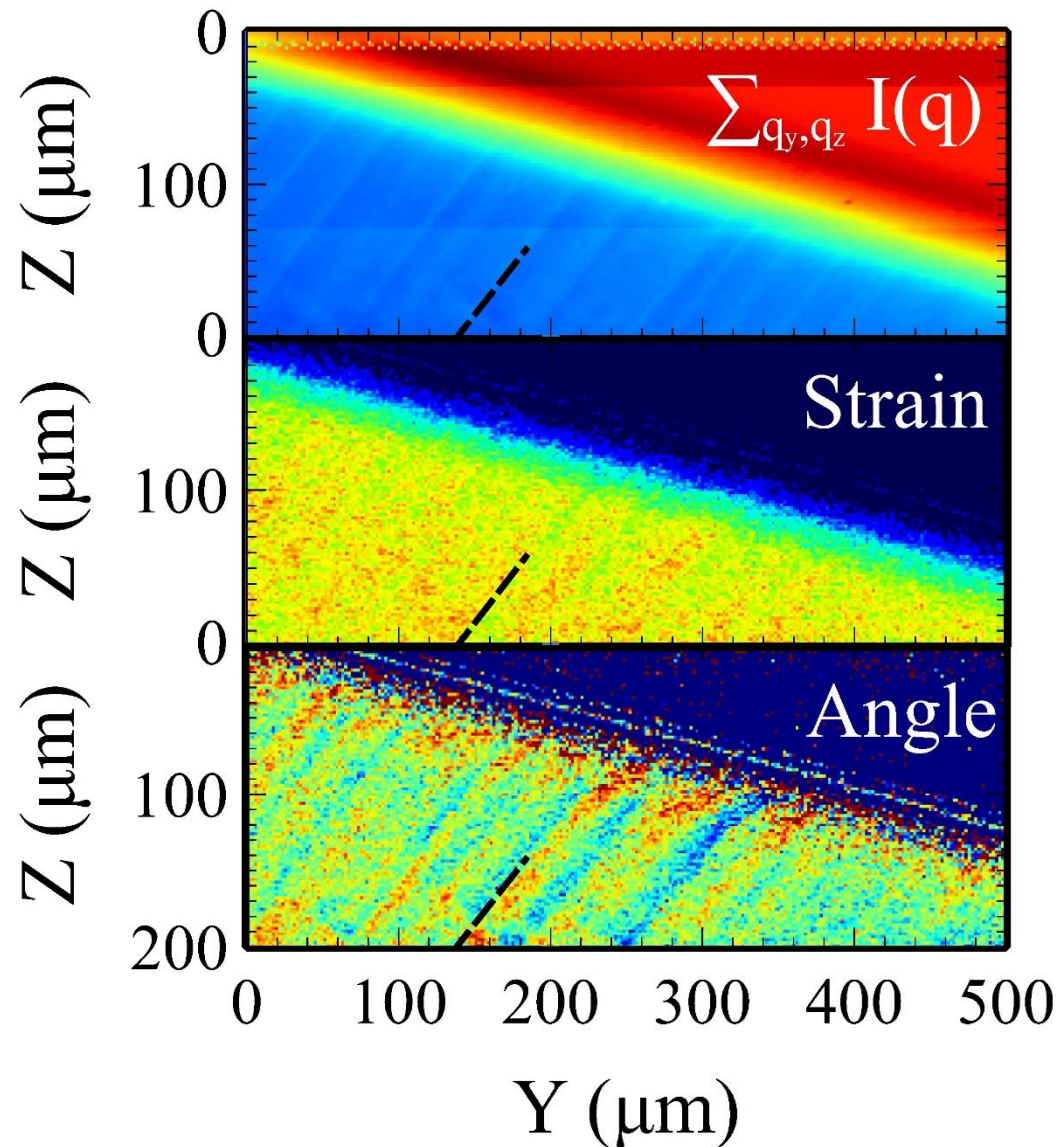
Measuring Strain in the drying film



$$\varepsilon = \frac{2}{3} \left(\frac{q_{major}}{q_{minor}} - 1 \right)$$

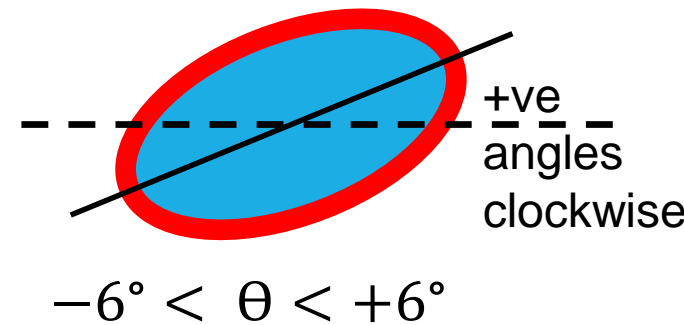


Strain in a Shear Banded Film

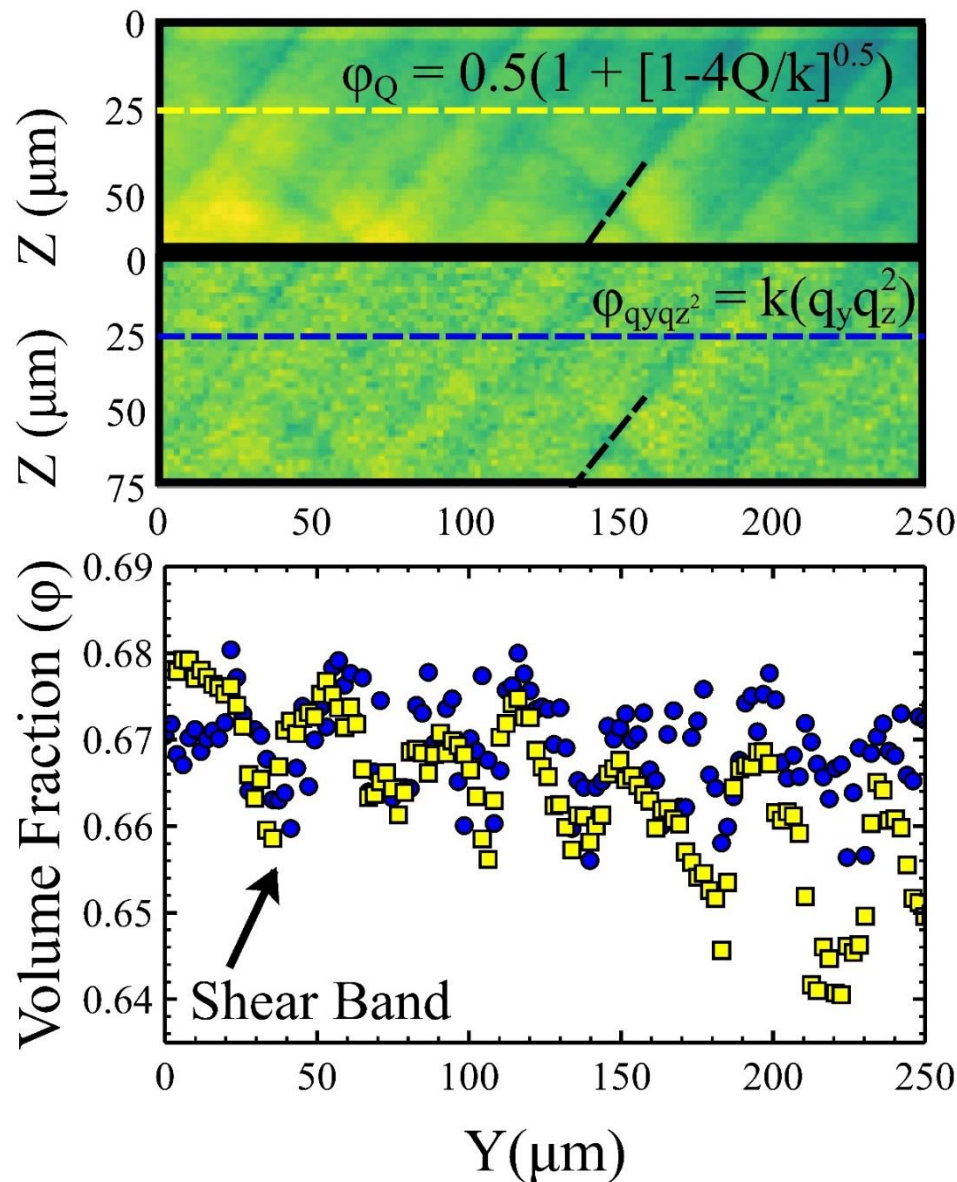


$$\varepsilon = \frac{2}{3} \left(\frac{q_{major}}{q_{minor}} - 1 \right)$$

$$3.5 < \varepsilon < 7.5 \%$$



Density Fluctuations near Shear Bands

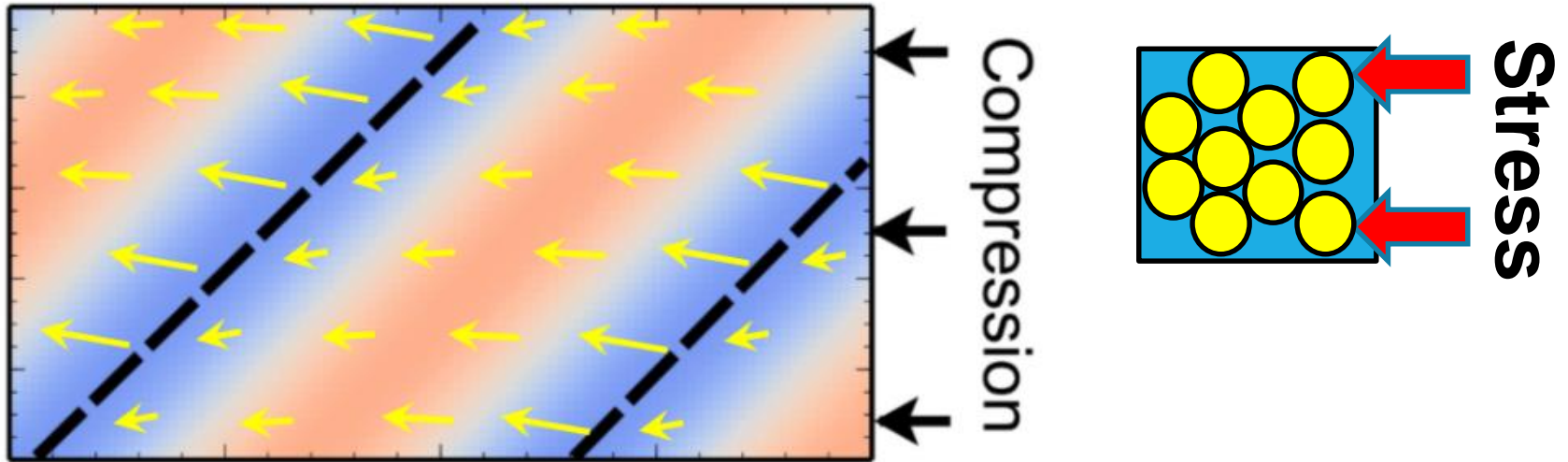


Density variations can be calculated via 2 independent methods:

1. Total scattered intensity sensitive to ϕ and scattering contrast
2. Estimated from volume of scattering ellipse

Shear bands exhibit reduction in density $\sim 2\%$

Relating strain and density



- **Strain direction changes rapidly near shear band resulting in shear of material**
- **Strongest shear correlates with a reduced density**

Conclusions

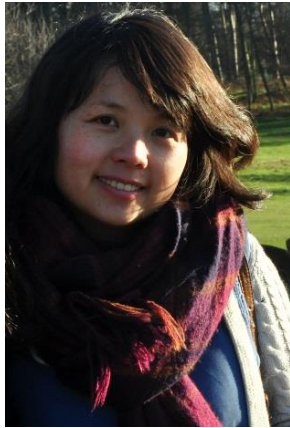
Crystalline Samples:

- Observed sudden ordering transition followed by gradual deformation and compaction
- Individual collections of particles can be tracked as they deform

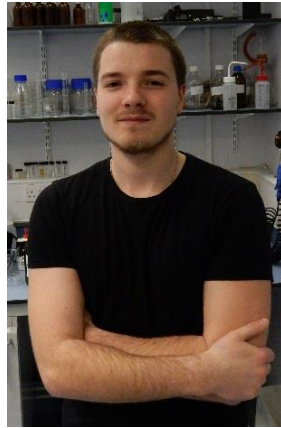
Amorphous Samples:

- Display strong shear localisation of the strain
- Particle Density fluctuates by $\sim 2\%$ due to shear banding

Acknowledgements



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Burghammer

