On the mechanisms of colloidal self-assembly during spin coating.

Daniel T. W. Toolan,[a] Syuji Fujii,[b] Stephen J. Ebbens,[a] Yoshinobu Nakamura[b] and Jonathan R. Howse.[a]

[a] Department of Chemical and Biological Engineering, The University of Sheffield, Sheffield S1 3JD, UK

[b] Department of Applied Chemistry, Faculty of Engineering, Osaka Institute of Technology, 5-16-1 Ohmiya, Asahi-ku, Osaka 535-8585, Japan

Research program

The self-organisation of colloidal dispersions is a highly important and promising phenomenon, which has been a topic of intense scientific interest due to the applications of latex films in a wide range of applications including coatings, adhesives and inks.(1-3) A crucial stage in latex film formation is the evaporation of solvent from a colloidal dispersion, resulting in particle ordering and packing into three dimensional structures. Beyond latex film formation the self-organisation of colloids influences processes as varied as the formation of dense ring-like deposits when coffee is spilled on a surface(4) and the formation of highly ordered two and three dimensional crystalline structures known as colloidal crystals, which have potential applications as photonic band-gap materials.(5) One of the main obstacles to exploiting these exciting materials is developing and understanding fabrication strategies that allow for fine control over the complex self-assembly processes that occur, such that large, defect free colloidal crystals may be obtained, via industrially scalable manufacturing methods.

Spin-coating is a thin film production technique widely utilised for semiconductor fabrication that has since been demonstrated as a facile method for the production of highly uniform colloidal crystal thin films.[11-16] The technique involves depositing a colloidal dispersion onto an optically flat substrate that is then rotated at high-speed (1,000 – 10,000 RPM). Fluid thinning occurs due to both shear forces and evaporation of the dispersant, resulting in the formation of a dry film within a matter of seconds.[18,19] However, the rapidly rotating sample and high evaporation rates make performing studies *in situ* challenging and as such the majority of studies have been performed *ex situ*, where the final ordered structure is analysed and used to produce an inferred hypothesis based upon theory and macroscopic observations.

The objective of this fellowship was to take the technique of stroboscopic microscopy, developed at the University of Sheffield to Osaka Institute of Technology in order to directly visualize the colloidal crystallisation process for the first time.

The research program was highly successful and we have been able to directly observe and identify several colloidal crystallisation mechanisms. The findings of this research have been published in Soft Matter (http://pubs.rsc.org/en/content/articlehtml/2014/sm/c4sm01711k) and are summarized in Figure 1. In addition movies of colloidal crystallisation can be found at https://www.youtube.com/user/DanielTWToolan/videos.

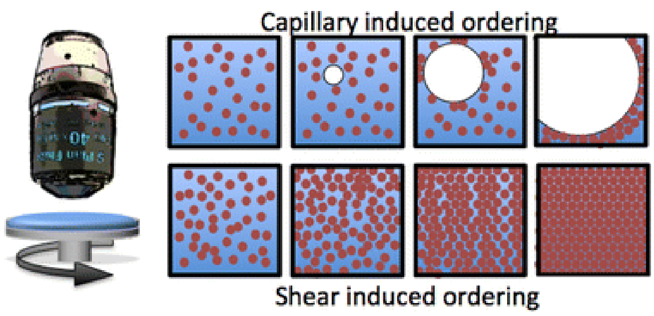

Figure 1. Through the technique of stroboscopic microscopy we are able to directly identify a number of different mechanisms by which colloids self-assemble during spin-coating.

Work in Japan

As might be expected from a research fellowship I spent the majority of my time in the lab/office, which where conveniently connected via a sliding door. As may be expected lab space is at a premium, so my entire microscopy set-up was confined to small area (see Figure 2). As the lab was on the 15th floor it did have spectacular views of Osaka.

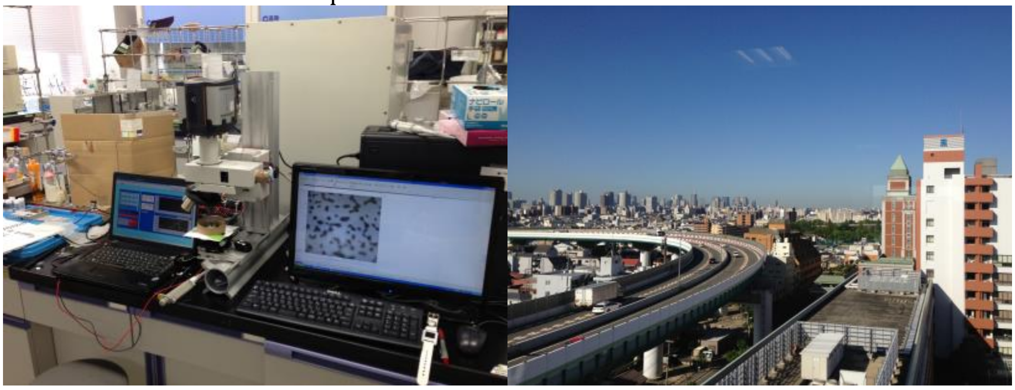

Figure 2. left) Picture of stroboscopic microscopy set-up in Japan, right) view from lab.

Advice

I really enjoyed my time in Japan and I'd recommend anyone to try and explore as much of it as possible. One of the best purchases I made was getting a (very) cheap bicycle. The public transport is fantastic but it was definitely far more fun to explore Osaka on two wheels.

References

1. Keddie JL. Film formation of latex. Materials Science and Engineering: R: Reports. 1997;21(3):101-70.
2. Keddie JL, Routh AF. Fundamentals of latex film formation: processes and properties: Springer; 2010.
3. Winnik MA. Latex film formation. Current Opinion in Colloid & Interface Science. 1997;2(2):192-9.
4. Deegan RD, Bakajin O, Dupont TF, Huber G, Nagel SR, Witten TA. Capillary flow as the cause of ring stains from dried liquid drops. Nature. 1997;389(6653):827-9.
5. Wijnhoven JEGJ, Vos WL. Preparation of Photonic Crystals Made of Air Spheres in Titania. Science. 1998;281(5378):802-4.