

Nanofluids on solid substrates

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FOREWORD

Nanofluids on solid substrates

Guest Editor

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In the mid-nineties Andres *et al* [1] showed that when Au nanoparticles were cast from a colloidal solution¹ onto a flat substrate (MoS₂), highly ordered particle superlattices could form. Since that pioneering experiment, significant inroads have been made into developing an understanding of the complex and intriguing physical processes underpinning the assembly of nanoparticle and nanorod arrays at the solid–liquid, liquid–air, and liquid–liquid interfaces. In addition to an intense research effort devoted to controlling the degree of close packed order in colloidal nanoparticle arrays [2], there have been a variety of demonstrations of the exploitation of solvent dynamics to generate long-range (micron scale) patterns including rings [3, 4], networks [5], and quasi 1D lines with controllable widths and spacings [6]. This latter aspect of the assembly of nanostructured systems, i.e. the understanding and control of non-equilibrium dewetting of nanofluids, forms a central theme of this special issue of *Journal of Physics: Condensed Matter*.

As pointed out by Thiele *et al* [7] elsewhere in this issue, Reiter's original work on polymer films [8] stimulated a large number of studies of pattern formation in dewetting systems. A considerable number of groups focussed on the question of how the dynamics of the dewetting process affect the self-organised morphology of a polymer film. Particular attention has been paid, for example, to the issue of whether hole formation in a dewetting polymer film is due to a conventional nucleation-and-growth mechanism, a spinodal process, or some combination of the two [9]. Similar questions regarding the roles of nucleation- and spinodally-driven solvent dewetting in nanofluid systems have been tackled, first by Ge and Brus [10], subsequently by Rabani *et al* [11], and increasingly by other groups (including our own).

The vast majority of work in the area of dewetting-induced pattern formation has, however, been concerned with non-volatile fluids. Nanofluids, where a non-volatile solute (the nanoparticle/nanorod) is dissolved in a volatile organic or inorganic solvent, are much less studied but have proven to have fascinating dewetting behaviour. This is a burgeoning and exciting area of research and the papers on nanofluid-surface interactions collected here provide the reader with an insight into the state of the art in the field.

Real space (e.g. scanning probe and optical microscopy) and reciprocal space (e.g. x-ray scattering) techniques of course complement each other well in the analysis of pattern formation in nanostructured systems and an interesting mix of these techniques features in the papers on nanofluids selected for this issue. Robel *et al* use grazing incidence small angle x-ray scattering (GISAXS) to address the important question of the thermal stability of 2D gold nanoparticle lattices, finding significant differences in the kinetics depending on whether the samples are annealed in air or in vacuum. In an elegant experiment involving a hybrid polymer-nanoparticle system, Roth *et al* use GISAXS to monitor how a wettability difference affects the drying of an aqueous Ag nanofluid, providing key insights into the spatial correlation of the Ag nanoparticle layer along the wettability gradient.

¹ The term 'nanofluid' is increasingly used to describe a colloidal solution/suspension of nanoparticles or nanorods in a solvent.

Both Nobile *et al* and Byun *et al* in this issue exploit what is sometimes called the ‘coffee ring’ effect to impose anisotropic ordering of nanorods and nanoparticles, respectively. The ‘coffee ring’ effect arises from the slip-stick motion of the contact line of the solvent due to the pinning of the solutes (i.e. the nanoparticles/nanorods). This effect is used to particularly good effect by both groups to produce smectic liquid crystal-like ordering of nanorods (Nobile *et al*) and, via an elegant ‘sphere-on-flat’ geometry, extremely well-ordered lines of iron oxide nanoparticles with a controllable spacing (Byun *et al*).

Finally, Govor *et al* and Thiele *et al* [7] focus on the formation of fingering/branching instabilities in dewetting evaporating thin films. The latter group uses phase separation of two immiscible fluids, a complex coupled system, to drive an instability which gives rise to branching patterns of polymers and rings/chains of nanoparticles. They make the important point that there are significant—and potentially very useful—differences between the diffusion coefficients of nanoparticles on a thin fluid layer as compared to a solid substrate. The combination of solute concentrations, relative volumes of the solvents, and surface/interface free energies provides a wide parameter space for exploration and exploitation. In addition to elucidating the key physics underlying the formation of branched aggregates of nanoparticles during solvent evaporation, Thiele *et al* [7] put forward novel theoretical methods (including a density functional theory approach) to model the dynamics of dewetting nanofluids.

The scope of the contributions in this special issue covers both review material and new research results. The papers provide an important ‘snapshot’ of the state of the field as of mid-2009 and I’m confident that they will stimulate further research into how the dewetting of nanofluids can be exploited so as to produce, simply and quickly, novel 2D and 3D nanostructured assemblies.

To conclude, I would like to thank all of the authors for their contributions and the editors and staff of *Journal of Physics: Condensed Matter* for their help in producing this special issue.

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