

From quantized vortices to nanowires: new experiments in superfluid helium droplets

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Although still in its infancy, superfluid helium droplets have now emerged as a uniquely powerful tool for the fabrication of nanoparticles and nanowires, and a number of metallic nanoparticles have been synthesized in this way, such as Ag,[1-3] Au,[1] and Ni[1] nanoparticles. In particular, the sequential addition of dopants to helium droplets eases to form core-shell nanoparticles, for example, Ag/Si nanoparticles.

At Leicester we have carried out a series of experiments on large superfluid helium droplets, inside which quantized vortices are now identified as an intrinsic feature. Starting with the addition of Ag atoms to the droplets, we have seen long chains of spherical nanoparticles on the TEM images.[4] As spherical nanoparticles do not possess anisotropy, the guiding force to align these particles can only be provided by quantized vortices in superfluid helium. Therefore, this experiment provided firm evidence for quantized vortices in large helium droplets. Following this idea we have added several other materials to the droplets including Au, Si, Cr and Ni,[5] and have exploited quantized vortices as a tool to fabricate 1D nanostructures. Finally, we report a striking observation on quantized vortices in superfluid helium droplets by TEM imaging of Ag nanoparticles deposited on a surface. The TEM images have shown scattered small particles at the vicinity of the vortex lines, suggesting multiply quantized vortices have been generated, which can survive in the vacuum for at least a few milliseconds.

References

- [1] A. Boatwright, *et al.*, *Faraday Disc.* **2013**, 162, 113.
- [2] E. Loginov, *et al.*, *J. Phys. Chem. A* **2011**, 115, 7199.
- [3] E. Loginov, *et al.*, *Phys. Rev. Lett.* **2011**, 106, 233401.
- [4] D. Spence, *et al.*, *PCCP* **2014**, 16, 6903.
- [5] E. Latimer, *et al.*, *Nano Lett.* **2014**, 14, 2906.