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NANOCRYSTAL PRODUCTION

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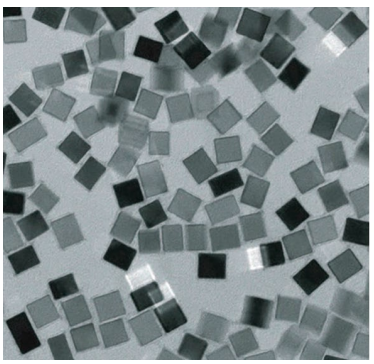
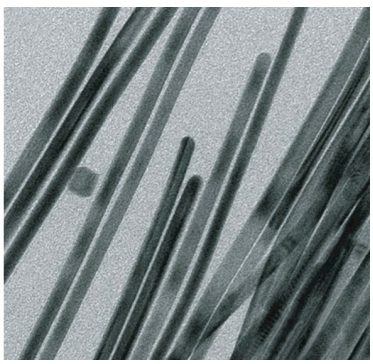
The distinctive physicochemical properties of noble-metal nanocrystals (NCs) are commonly exploited in catalysis, photonics, sensing and medicine. However, the applications of NCs are often limited to small-scale lab studies because the continuous and scalable production of uniform NCs required for larger-scale applications remains challenging. Now, writing in *Nano Letters*, Younan Xia and co-workers report the design of a device for the fully automatized synthesis of uniform noble-metal NCs. The device combines a droplet reactor with a new unit for the separation of silicone oil and water, and cross-flow filtration.

The high surface-area-to-volume ratio of NCs differentiates them from their bulk counterparts and makes their physicochemical properties very sensitive to the particles' shape and size, which are thus important parameters to control. Synthetic methods that allow fine control over the shapes and sizes of NCs are routinely used in lab studies. However, scaling the process up by increasing the batch size leads to non-uniformity in NCs, which is undesirable for technological applications. Other approaches that use microfluidic and millifluidic droplet reactors, in which the reactive solution is divided into a series of droplets, afford uniform NCs but still require manual purification and separation of the NCs, such that it is challenging to automate the production process.

Droplet reactors have been explored for the synthesis of NCs based on Pd, Au, Ag, Pt and Rh. Droplet reactors are typically fabricated from a polymeric tube in which silicone oil transports aqueous droplets, each containing a mixture of the reactants. When passing through a heated zone, reaction is initiated and crystallization begins. The reaction time depends on tube length and flow rate of the carrier (silicone oil). "This approach still requires laborious processes for the separation of the aqueous reaction phase from the oil, and centrifugation for the collection of the nanocrystals," comments Xia. "These requirements forced us to consider a new design of the droplet reactor for the automated production of NCs by incorporating on-line water–oil separation and NC purification components."





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The upgraded droplet reactor features design concepts from different scientific fields. The new water–oil separation unit, for example, consists of a perforated polytetrafluoroethylene (PTFE) tube. The different surface tensions of oil and water result in the oil passing through the pinholes in an oil-coated box, and the aqueous phase continuing to the purification unit. In the new design, cross-flow filtration — normally used for protein purification — is used to ensure NC uniformity. Thus, when the solution containing NCs of different sizes flows through a tubular filter, particles larger than a certain size (or molecular mass in the case of proteins) are retained while the unwanted components, such as solvent, capping agents, unreacted precursors and by-products, are filtered away.

"We envisage an on-demand nanocrystal synthesis system, in which simply switching on the device and choosing parameters it will be possible to obtain a colloidal suspension of uniform particles," explains Xia. It seems that the newly developed droplet reactor is not too far from this goal. So far, the device has been successfully used to produce uniform Pd nanocubes of different dimensions as well as anisotropic nanoparticles such as penta-twinned Pd nanowires. It now remains to test the performance of the droplet reactor and on-line separation and purification capabilities for the production of other nanoparticles, including quantum dots, oxide semiconductors and even organic compounds.

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ORIGINAL ARTICLE Niu, G. et al. A droplet reactor system capable of automation for the continuous and scalable production of noble-metal nanocrystals. *Nano Lett.* https://doi.org/10.1021/acs.nanolett.8b01200 (2018)