



Program in Polymers
and Soft Matter

SEMINAR

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“Bridging the gap between molecules and nanoparticles”

The concept of “colloidal molecules” builds on the analogy between colloidal particles and molecules. For about a hundred years, colloidal particles have been used to model the behavior of atoms or molecules. Recently, this approach has been reversed: reactions between molecules are now being utilized to model self-organization of inorganic nanoparticles (NPs). In particular, polymer science offers unique strategies to address the challenges in NP assembly.

By using lessons of polymer physics and chemistry, we are developing new paradigms for NP patterning and self-assembly. For NPs end-capped with polymer molecules in a brush-type configuration, we found a striking similarity between NP self-assembly and reaction-controlled step-growth polymerization.¹ The kinetics and statistics of polymerization enables a quantitative prediction of the architecture of linear, branched, and cyclic chains of NPs and their aggregation numbers, as well as the formation of isomers, all in agreement with theory. By using a polymer paradigm, we demonstrated the ability to control the aggregation numbers in NP clusters and the strategy for the co-assembly of plasmonic NPs with different dimensions and compositions.^{2,3}

In another strategy, we solved a challenging task of NP surface patterning by utilizing thermodynamically driven segregation of polymer ligands into surface-pinned micelles, the process driven by a balance between the interfacial energy of the polymers and the free energy of stretching of the micellar ‘legs’.⁴ We achieved control of the dimensions of pinned micelles, their spatial distribution and the number of micelles per nanoparticle, all in agreement with a theoretical model. Our very recent work shows that a stoichiometric acid-base neutralization reaction between reactive brush-type polymer ligands governs self-limiting NP assembly into molecule-type clusters with precisely controlled symmetries.⁵

This work bridges the gap between chemical reactions taking place at a molecular level and NP assembly occurring at the length scale three orders of magnitude larger. It shows that the theoretical models developed for molecules can be applied to the fabrication of nanomaterials with new architectures. On the other hand, the ability to monitor NP self-assembly by imaging emerging nanostructures provides a unique way to test theoretical models developed for polymerization. Since programmable NP organization remains a major challenge, polymer-inspired self-assembly strategies have profound implications for the design of nanomaterials with applications in electronics, optics, catalysis, and chemical sensing.

References

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