From bioinspired structure formation to particle-based metamaterials

Andreas Fery

Institut für Polymerforschung Dresden and Technical University Dresden, Germany

Metallic nanoparticles offer a number of interesting optical and electronic effects. A prominent example is localized surface plasmon resonance (LSPR), which is due to resonance excitations of the free electron cloud vibrations of the particles by light. Due to LSPR, plasmonic nanoparticles provide excellent opportunities for controlling electromagnetic near-fields at optical frequencies, which has led to a wide range of applications in various fields such as surface-enhanced spectroscopy, light harvesting, or photonics.

While much of the research has been devoted to understanding nanoparticle synthesis and tailoring their LSPR at the single-particle level [1-3], the ordering of particles at different length scales opens another powerful route to optical and electronic functionality due to novel collective plasmonic excitations arising from plasmonic coupling effects.

We focus on achieving such ordered particle arrays through assembly approaches. Colloidal self-assembly can indeed achieve well-defined colloidal clusters [4] and surface arrays [5] where coupling effects can be controlled. In particular, large-scale assemblies are possible in combination with biomimetic surface patterning. We discuss the underlying physicochemical principles of the assembly process and the resulting plasmonic coupling effects [6,7]. Finally, we present perspectives on how this assembly principle can be applied to metasurfaces with high field enhancement and/or ultrahigh circular dichroism [6, 8].

1. Steiner, A. M.; Lissel, F.; Fery, A.; Lauth, J.; Scheele, M., Prospects of Coupled Organic-Inorganic Nanostructures for Charge and Energy Transfer Applications. Angew. Chem. Int. Ed. 2021, 60, 1152-1175.

2. Steiner, A. M.; Mayer, M.; Schletz, D.; Wolf, D.; Formanek, P.; Huebner, R.; Dulle, M.; Foerster, S.; Koenig, T. A. F.; Fery, A., Silver Particles with Rhombicuboctahedral Shape and Effective Isotropic Interactions with Light. Chemistry of Materials 2019, 31 (8), 2822-2827.

3. Mayer, M.; Steiner, A. M.; Roder, F.; Formanek, P.; Konig, T. A. F.; Fery, A., Aqueous Gold Overgrowth of Silver Nanoparticles: Merging the Plasmonic Properties of Silver with the Functionality of Gold. Angewandte Chemie-International Edition 2017, 56 (50), 15866-15870.

4. Rossner, C.; Fery, A., Planet–satellite nanostructures from inorganic nanoparticles: From synthesis to emerging applications. . MRS Communications 2020, 10 (1), 112-122.

5. Yu, Y.; Ng, C.; Koenig, T. A. F.; Fery, A., Tackling the Scalability Challenge in Plasmonics by Wrinkle-Assisted Colloidal Self-Assembly. Langmuir 2019, 35 (26), 8629-8645.

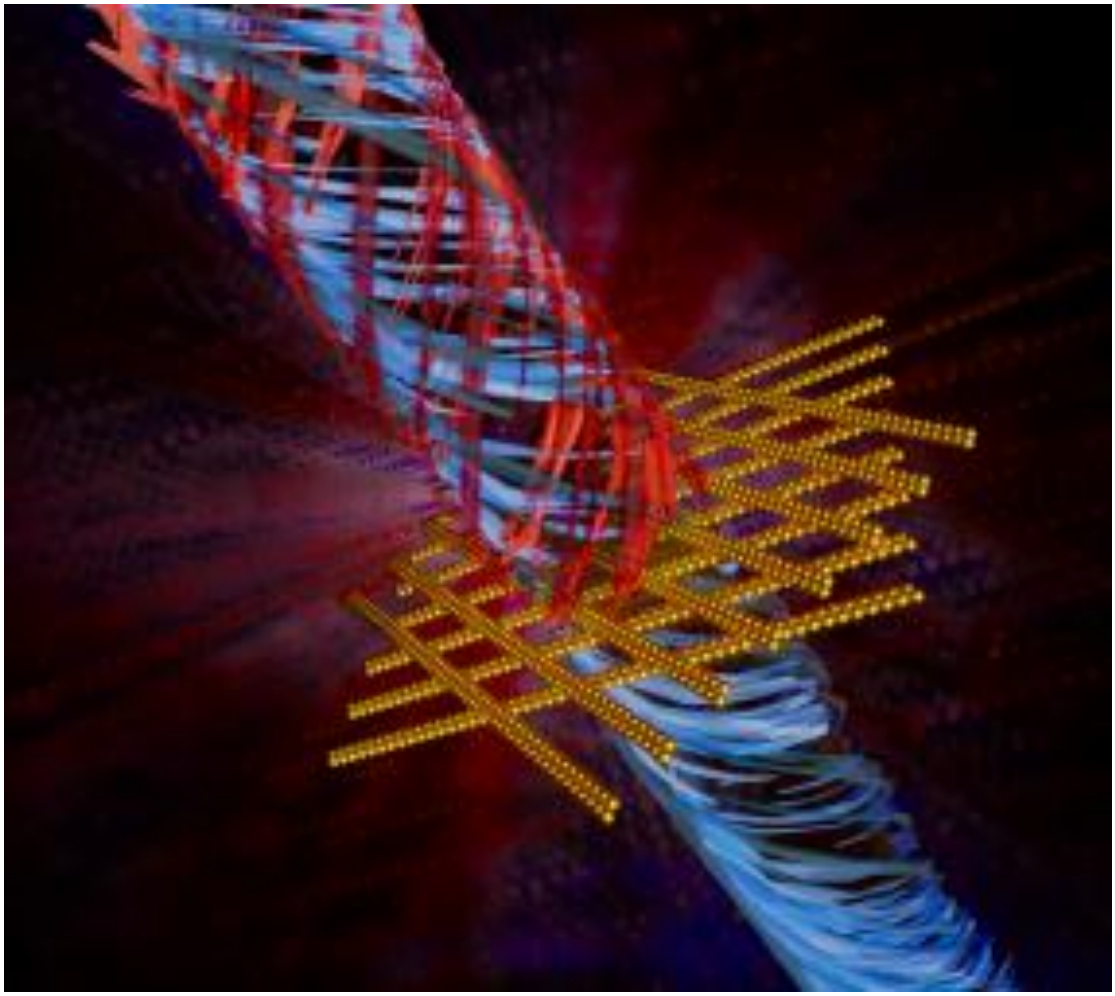
6. Mayer, M.; Schnepf, M., J.; König, T. A. F.; Fery, A., Colloidal Self-Assembly Concepts for Plasmonic Metasurfaces. Advanced Optical Materials 2018, 1800564.

7. Rossner, C.; Koenig, T. A. F.; Fery, A., Plasmonic properties of colloidal assemblies. Advanced Optical Materials 2021, 2001869 (https://doi.org/10.1002/adom.202001869).

8. Probst, P. T.; Mayer, M.; Gupta, V.; Steiner, A. M.; Zhou, Z.; Auernhammer, G. K.; König, T. A. F.;

Fery, A., Mechano-tunable chiral metasurfaces via colloidal assembly. Nature Materials 2021, 20, 1024–1028.

Figure:



Schematic of a giant circular dichroitic metamaterial, adopted from [8]