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# Magnetic Field-Assisted Assembly of Anisotropic Nanostructures: From Design to Application

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Magnetic field-assisted assembly has emerged as a powerful strategy for the controlled fabrication of dynamically responsive anisotropic nanostructures with tailored physical and functional properties. In this lecture, we present recent advances in the design and synthesis of magnetically assembled iron oxide-based nanostructures, ranging from nanoscale chains and rods to more complex hierarchical and hybrid assemblies. By applying external magnetic fields during synthesis and processing, individual superparamagnetic nanocrystals can be directed into anisotropic assemblies with enhanced magnetic responsiveness and collective behaviour.

We will highlight key parameters governing magnetic assembly, including particle size, magnetic moment, interparticle interactions, and colloidal stabilizations, which together determine the final morphology and functional performance of the resulting nanostructures. Stabilization strategies based on silica coatings will also be discussed, enabling the integration of these assemblies into biologically relevant environments.

Selected examples will highlight the potential of anisotropic magnetic nanostructures in soft matter systems, especially in the context of biofilm disruption [1]. Under low-frequency rotating magnetic fields, such structures act as nanoscale or microscale mechanical actuators, generating torque and shear forces that enable penetration into complex biological matrices and induce magneto-mechanical loosening of biofilms [2]. These systems represent a promising alternative or complement to conventional antimicrobial approaches, particularly for persistent and treatment-resistant biofilms.

These findings highlight the transition from passive nanoparticles to active, magnetic field-driven nanorobotic systems, opening new opportunities for non-invasive treatment strategies targeting complex biological structures. Magnetic assembly thus provides a versatile platform that connects fundamental nanomaterials design with emerging applications in biomedicine and beyond.

### References

[1] Caf et. al., ACS Nano, 2026, 20, 34-58.
[2] Kralj et. al., Adv. Healthcare Mater. 2025, 14, 2403736

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