Amplifying Magnetic Responsiveness of Self-Assembled Peptide Nanostructures via Synergy of MNP-Helix and Rod-Coil Building Blocks

Self-Assembled Biomaterials Lab

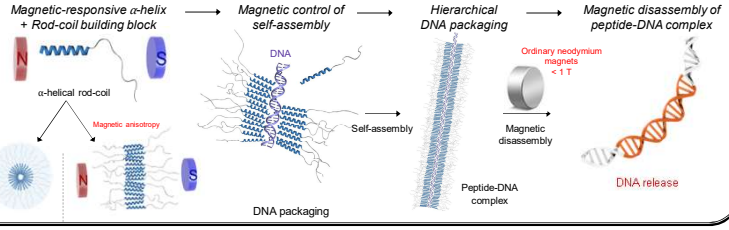
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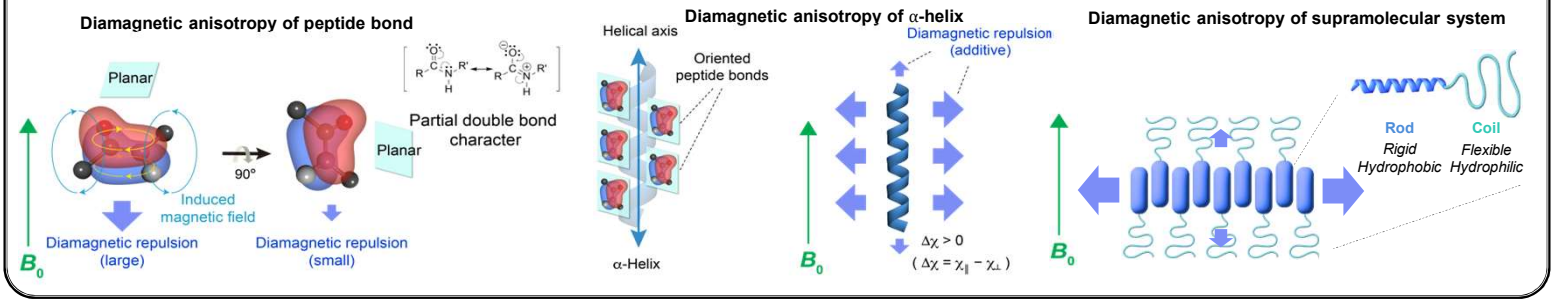
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Introduction

Organic molecules and materials are generally insensitive to magnetic fields due to their weak diamagnetism, typically requiring extremely strong fields to influence their behavior. This study presents a novel strategy to significantly amplify the magnetic responsiveness of self-assembled peptide nanostructures by leveraging the synergistic combination of perfect α-helices and rod-coil supramolecular building blocks. The core innovation involves the development of a monomeric, nonpolar, and perfect α-helix (MNP-helix) that maintains its helical conformation in the monomeric state, serving as an effective hydrophobic rod block in rod-coil amphiphiles. The design leverages the constructive addition of diamagnetic anisotropy from peptide bonds oriented parallel to the helical axis, which dramatically amplifies the overall diamagnetism of the α-helix. By utilizing the MNP-helix within rod-coil amphiphiles, we demonstrate that self-assembly processes can be controlled using relatively weak magnetic fields (0.07–0.25 T) provided by ordinary neodymium magnets. This practical magnetic field directly influences the morphology of the assemblies, leading to the formation of unique anisotropic nanostructures without the need for specialized high-field equipment. Furthermore, the study explores the integration of positively charged rod-coils that cooperatively assemble with DNA to form hierarchically ordered "artificial chromosomes." These rationally designed complexes effectively package and protect DNA from enzymatic degradation. Importantly, the packaged DNA can be released on demand through magnetically induced disassembly using a rotating magnetic field (RMF). Because magnetic fields are noninvasive and safe for humans, these magnetically responsive organic assemblies hold significant potential for advanced biological and medical applications. This work paves the way for future developments in responsive self-assembled structures, particularly highlighting their promise for DNA data storage and smart drug delivery systems.

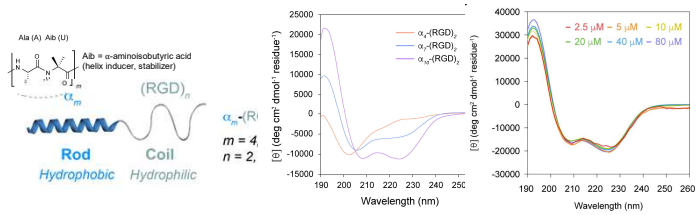


Magnetic anisotropy in organic molecules

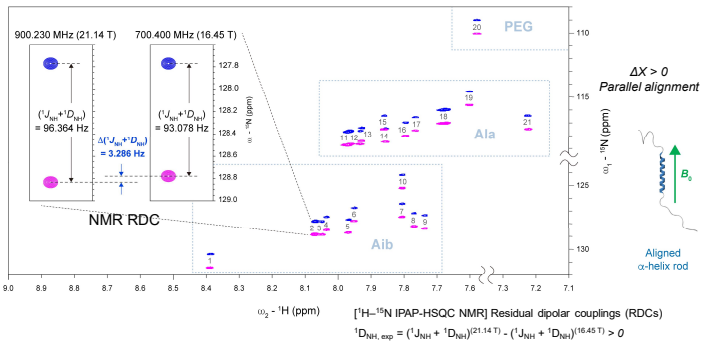


Magnetic-responsive self-assembly of α-helical rod-coils

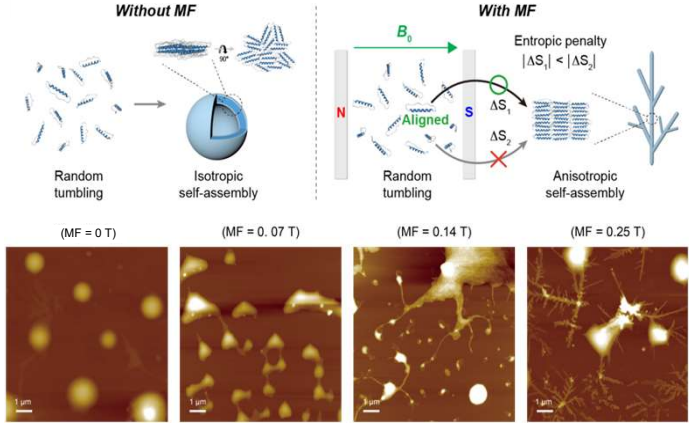
Monomeric, Nonpolar, Perfect α-helix (MNP-helix)



Magnetic alignment of MNP-helix (α_{10})

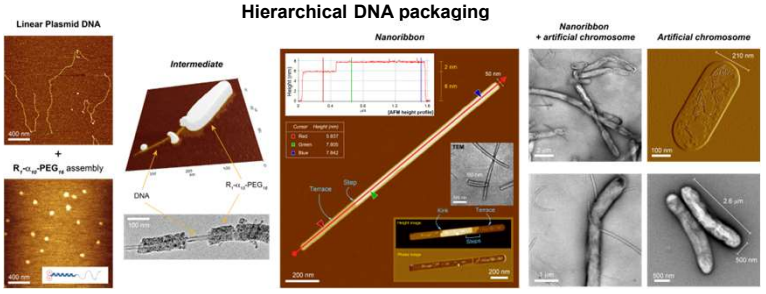


Effect of magnetic field strength on self-assembly

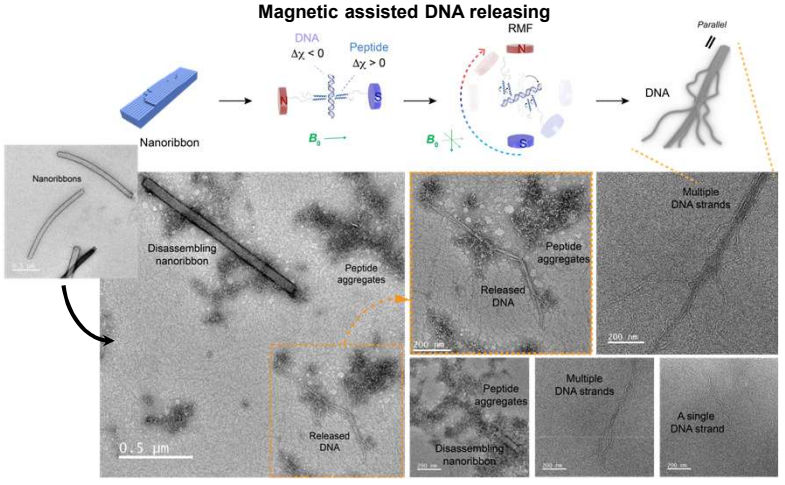


Magnetic control of self-assembly and disassembly

Hierarchical DNA packaging



Magnetic assisted DNA releasing



Reference

· "Magnetic control of self-assembly and disassembly in organic materials." ***Nature Communications,*** 14 (2023): 3081.