Chain-like structures composed of ferromagnetic nanoparticles cross-linked with enzyme molecules and their enzymatic activity under external magnetic fields

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We create chain-like structures composed of ferromagnetic nanoparticles cross-linked with α-amylase and investigate their enzymatic activity under external magnetic fields. We immobilize 3,4-dihydroxyphenil acetic acid on the surface of iron nanoparticles, the average diameter of which is approximately 100 nm. We then mix the particles with N-Hydroxysuccinimide (NHS), 1-Ethyl-3-(3-dimethylaminopropyl) carbodiimide, hydrochloride (EDC) and α-amylase under a dc magnetic field. The ferromagnetic particles form chain clusters along the field direction due to the dipole-dipole interactions and the self-organized cluster structures are fixed by cross-linking via α-amylase. We next investigate the enzymatic activity of α-amylase in the clusters under external magnetic fields. The activity of α-amylase in the clusters increases under a high-frequency ac magnetic field caused by the heat generation of the particles. The enzyme reaction of α-amylase in the clusters is also encouraged under a rotational magnetic field since the probability of the collision of the enzyme with substrate molecules is increased by the rotational motion of the clusters. We show that when ac and rotational magnetic fields are simultaneously applied, the enzymatic activity is further increased compared to the above two cases.