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Biomimetic control over size, shape and aggregation in magnetic nanoparticles

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Magnetite (Fe_3O_4) is a widespread magnetic iron oxide encountered in both geological and biomineralizing systems, which also has many technological applications, e.g. in ferrofluids, inks, magnetic data storage materials and as contrast agents in magnetic resonance imaging. As its magnetic properties depend largely on the size and shape of the crystals, control over crystal morphology is an important aspect in the application of magnetite nanoparticles, both in biology and synthetic systems. Indeed, in nature organisms such as magnetotactic bacteria demonstrate a precise control over the magnetite crystal morphology, resulting in uniform and monodisperse nanoparticles. The magnetite formation in these bacteria is believed to occur through the co-precipitation of Fe(II) and Fe(III) ions, which is also the most widely applied synthetic route in industry. Synthetic strategies to magnetite with controlled size and shape exist, but involve high temperatures and rather harsh chemical conditions. However, synthesis via co-precipitation generally yields poor control over the morphology and therefore over the magnetic properties of the obtained crystals. Here we demonstrate that by tuning the reaction kinetics we can achieve biomimetic control over the size and shape of magnetite crystals but also over their organization in solution as well as their magnetic properties. We employ amino acids-based polymers to direct the formation of magnetite in aqueous media at room temperature via both the co-precipitation and the partial oxidation method. By using 2D and 3D (cryo)TEM it is shown that acidic amino acid monomers are most effective in affecting the magnetite particle morphology. By changing the composition of the polymers we can tune the morphology, the dispersibility as well as the magnetic properties of these nanoparticles.