Application of AFM to probe micro- and nano-sized magnetite particle interaction in Ca^{2+} solution

I.Dobryden[1], E.Potapova[2], N.Almqvist[1], H.Weber[1], A.Holmgren[2]*

[1] Experimental Physics, Department of Engineering Sciences and Mathematics, LTU, Luleå, Sweden
[2] Chemical Technology, Department of Civil, Environmental and Natural Resources Engineering, LTU, Luleå, Sweden
*) illia.dobryden@ltu.se

Natural magnetite is used for producing iron ore pellets, one of the raw materials in steel production. The quality of produced pellets depends on many factors, including the properties of the magnetite concentrate fed to pelletization. To be able to minimize the effect of the variations in feed properties on pellets quality, investigation of magnetite particle interaction with a focus on the surface properties is required. Atomic force microscopy (AFM), using the colloidal probe technique, is a suitable tool for measuring such particle-particle interaction *in situ*. Natural particles are usually of micro-sizes (m-s) and have different sizes and shapes, which complicates an accurate investigation of particle interaction with AFM. To overcome such difficulties, synthetic nanoparticles are used instead. Process water chemistry is one of the factors affecting magnetite surface properties. Partial dissolution of calcite and apatite minerals, present in iron ore, results in high Ca^{2+} concentrations in the process water, which has been shown to have a major effect on the charge of the magnetite particles [1, 2]. The aim of this study was therefore to investigate forces and aggregation between magnetite particles, of micro- and nano-size (n-s), in Ca^{2+} solutions at various pH values.

The spherical monodispersed magnetite nano-sized particles, with a diameter of approx. 10 nm, were synthesized by the precipitation technique [3]. Measurements were performed for m-s probe/m-s layer and m-s probe/n-s layer systems. Natural magnetite particles of 10-30 µm size were glued to NP-S cantilevers (Digital Instruments/Bruker, Santa Barbara, CA) with a measured spring constant of 0.12 N/m. Nano-sized particles were deposited on the glass slides by dip-coating. Roughness (Ra) of the n-s layers was measured with AFM and was about 10 nm for areas $1\times1\mu m^2$, a representative high-resolution image is shown in Figure 1. Particle interaction was similar for m-s and n-s magnetite particles at pH 4 and 6. At pH 10, the interaction behavior was different due to probable surface modification of
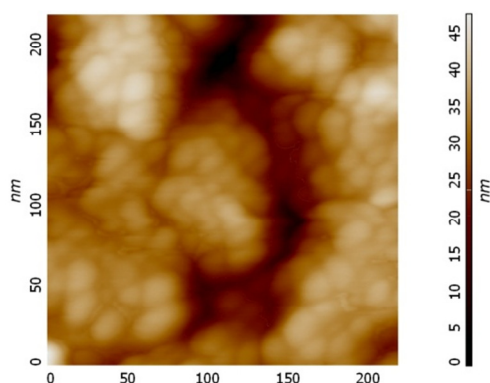

Figure 1. AFM height image of a magnetite nanolayer formed by dip-coating. The average roughness value, Ra, is 10 nm.
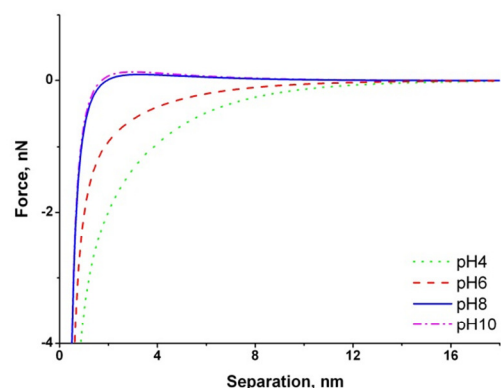

Figure 2. Force curves between a SiO_2 probe and n-s magnetite layer in 1 mM $CaCl_2$ solution simulated with the DLVO model.

natural magnetite particles by ions from process water. The adhesion force for both interacting systems was measured, see ref. [4] for a detailed description of the results. To verify that ζ-potential measurements could be used to predict the interaction between charged particles (in this case silica and magnetite) in solutions containing inorganic ions, force measurements between n-s magnetite layer and a SiO_2 spherical probe (3.5 µm in diameter) were performed and correlated with the ζ-potential results for these particles in the same solutions. Also, a DLVO simulation was performed to theoretically confirm the experimental interaction based on surface charge trends. An example of the simulated force curves is shown in Figure 2. The interaction between the probe and the magnetite surface was attractive at pH 4 and 6 but became repulsive at pH 8 and 10, which is in agreement with what could be expected from the ζ-potential results for these particles.

References

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