AFM Research

Measuring Forces Between ALFA-Al2O3 Surfaces using the Atomic Force Microscope

Henrik G. Pedersen, Jakob W. Høj and John Engell

Institute of Mineral Industry

Technical University of Denmark, DK-2800 Lyngby

Abstract

Direct measurement of forces between surfaces as function of distance may lead to better understanding of how particles interact in suspensions.

The Atomic Force Microscope (AFM) allow measurements of the force acting on a single colloidal particle in different solutions.

Force-distance data are presented for an AFM-probe made from a tabular alfa-Al2O3 particle and a polished sapphire single crystal.

The AFM derived surface potentials show good agreement with literature data on zeta-potentials.

Introduction

The main objective for measuring forces between surfaces is to contribute to the understanding of interactions between particles.

The net interaction between colloid particles determine whether they are dispersed or coagulated in the aqueous phase.

The direct measurement of the forces may give a better understanding compared to indirect methods such as measurement of zeta-potentials.

With the development of the Atomic Force Microscope (AFM), it has become possible to measure forces between a very sharp tip and a flat surface of a specific sample material.

Moreover AFM is a continuous procedure, which gives the possibility to measure dynamic effects such as frictional forces.

Experiments

Fig. 1A shows the principle in force measurements using the AFM.
The laser beam is reflected from the end of the cantilever probe
to the position sensitive photodetector.

The position of the sample surface is controlled
by the piezoelectric actuator.

By simultaneously collecting the voltage applied on the actuator
and the signal from the photodetector, i.e. the deflection of the cantilever,
it is possible to calculate the force acting on the probe
as a function of surface separation.

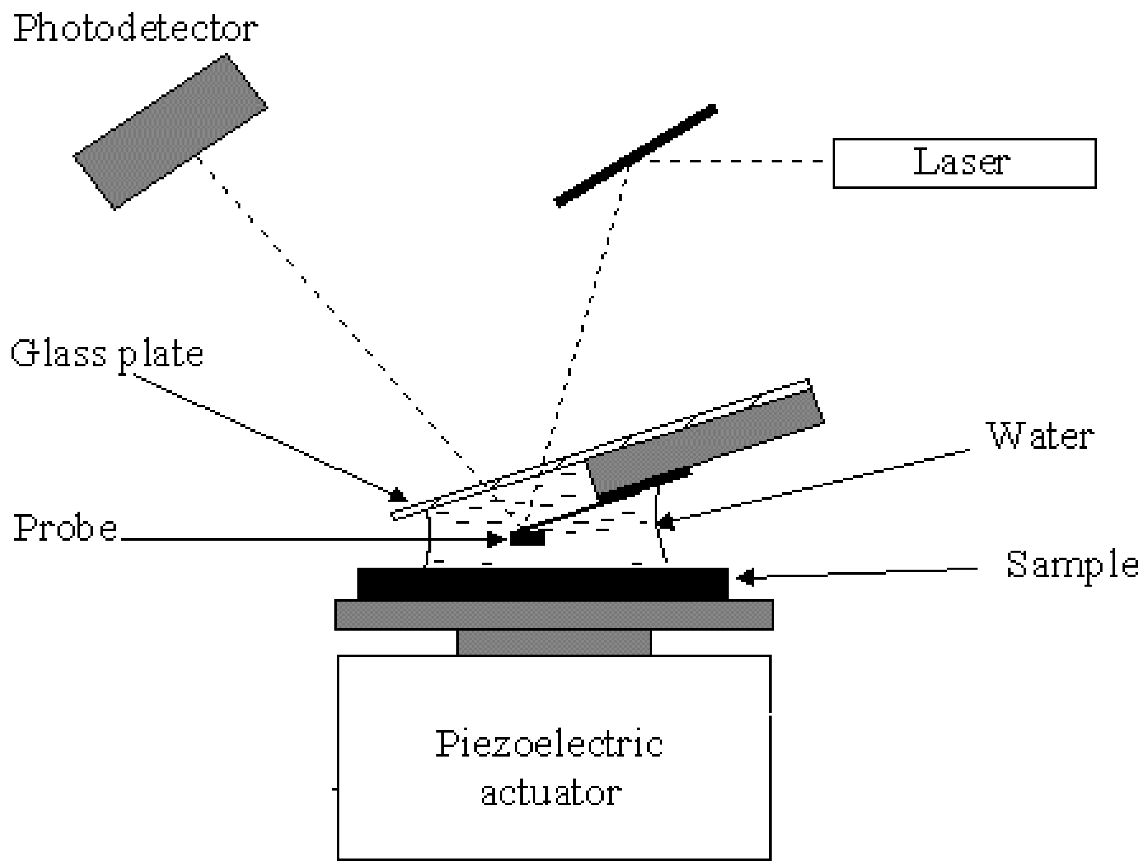

Fig 1. A: Schematics of the principle in force measurements using the AFM technique.

The measurements are performed in a drop of aqueous solution held between a small glass plate mounted on the cantilever snap-in holder and the sample surface (Fig. 1A).

The probe consists of a small tabular alfa-Al2O3 particle (15-20 µm wide, 2-5 µm high) glued to the end of a cantilever beam (Fig. 1B).

Measurements were done at pH 6, 8.5 and 9.5 in pure water and
at different NaCl-concentrations.

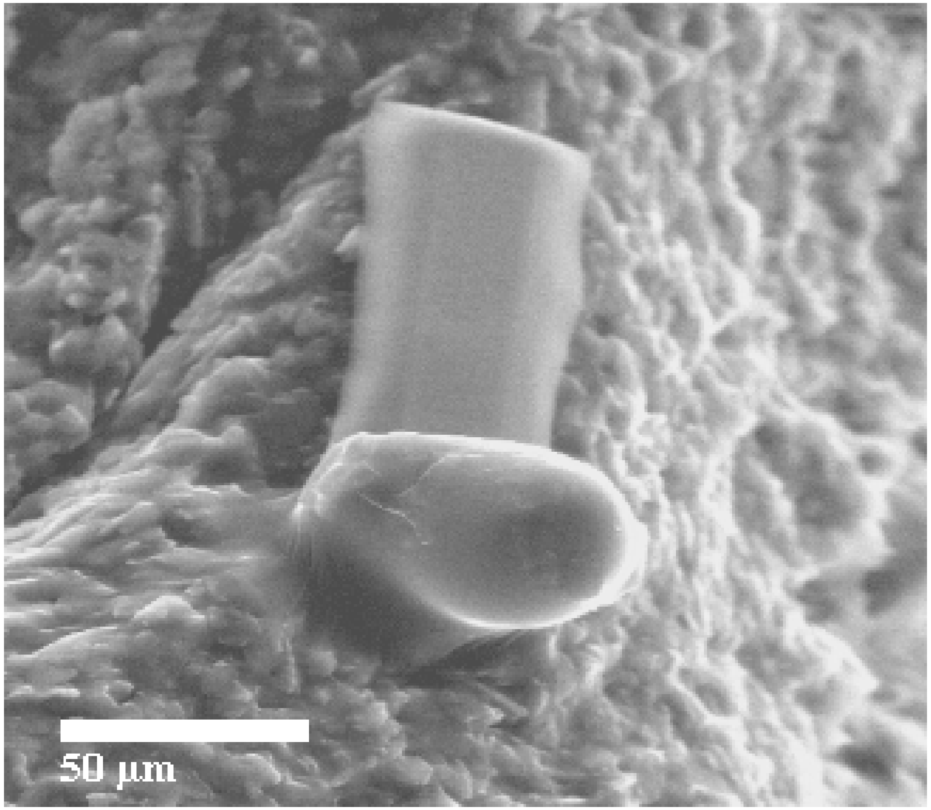

Fig 1B: SEM micrograph of a broken cantilever with a short fibre supporting the tabular alumina particle used as probe.

Results and discussion

The measured forces were compared to the DLVO theory.

The full expression for the force per unit area between two plane as function of surface separation (*D*) in a 1:1 electrolyte (NaCl) is:

$$\frac{F(D)}{Area}\left(\frac{\mathrm{N}}{\mathrm{m}^2}\right) = F_{doublelayer} + F_{vdw} \qquad \text{Eq.1}$$

$$= 1.59 \cdot 10^8 \cdot c \cdot \tanh^2\left(\frac{e\psi_0}{4kT}\right) \cdot \exp(-\kappa D) - \frac{A_{\nu=0} \cdot f_{screen} + A_{\nu>0} \cdot f_{ret}}{6\pi D^3}$$

where *c* is the electrolyte concentration (moles/l),
kappa is the inverse Debye screening length (nm^{-1}),
0 is the apparent surface potential (mV),
A=0 and A>0 are the contributions to the Hamaker constant form zero and finite frequencies respectively;
fscreen. and *fret* are correction factors.

The area normalized force between the probe and a sapphire crystal is shown in Fig. 2 as function of surface separation.

The theoretical calculations of the force-distance curve indicate that the experimental data overestimate the true curves considerably. This is most likely due to a slight misorientation of the tabular particles or to surface roughness.

Fig. 2 shows the expected exponential decay.

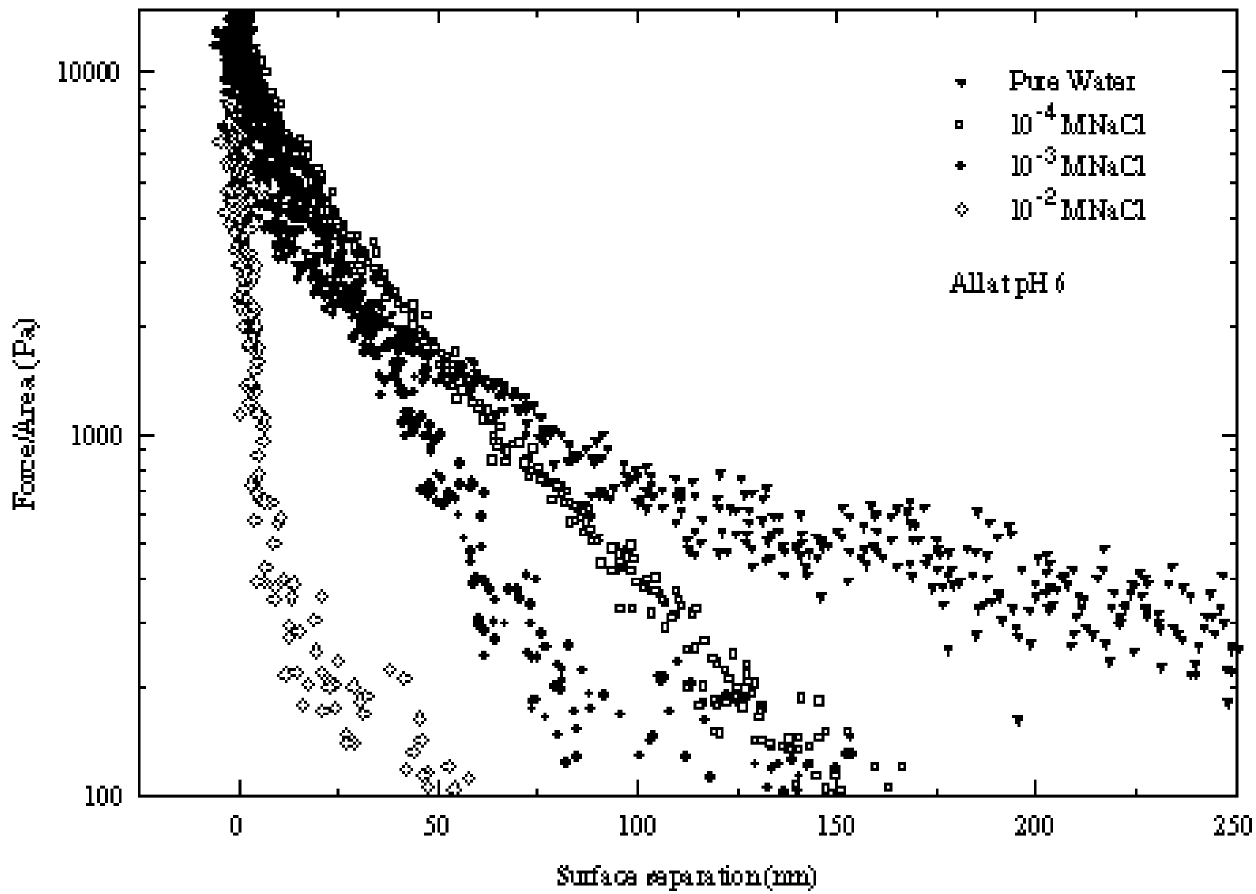

Fig. 2. Area normalized force (Pa) measured as function of surface separation (nm) between a alumina particle and a sapphire crystal at different NaCl concentrations at pH 6.

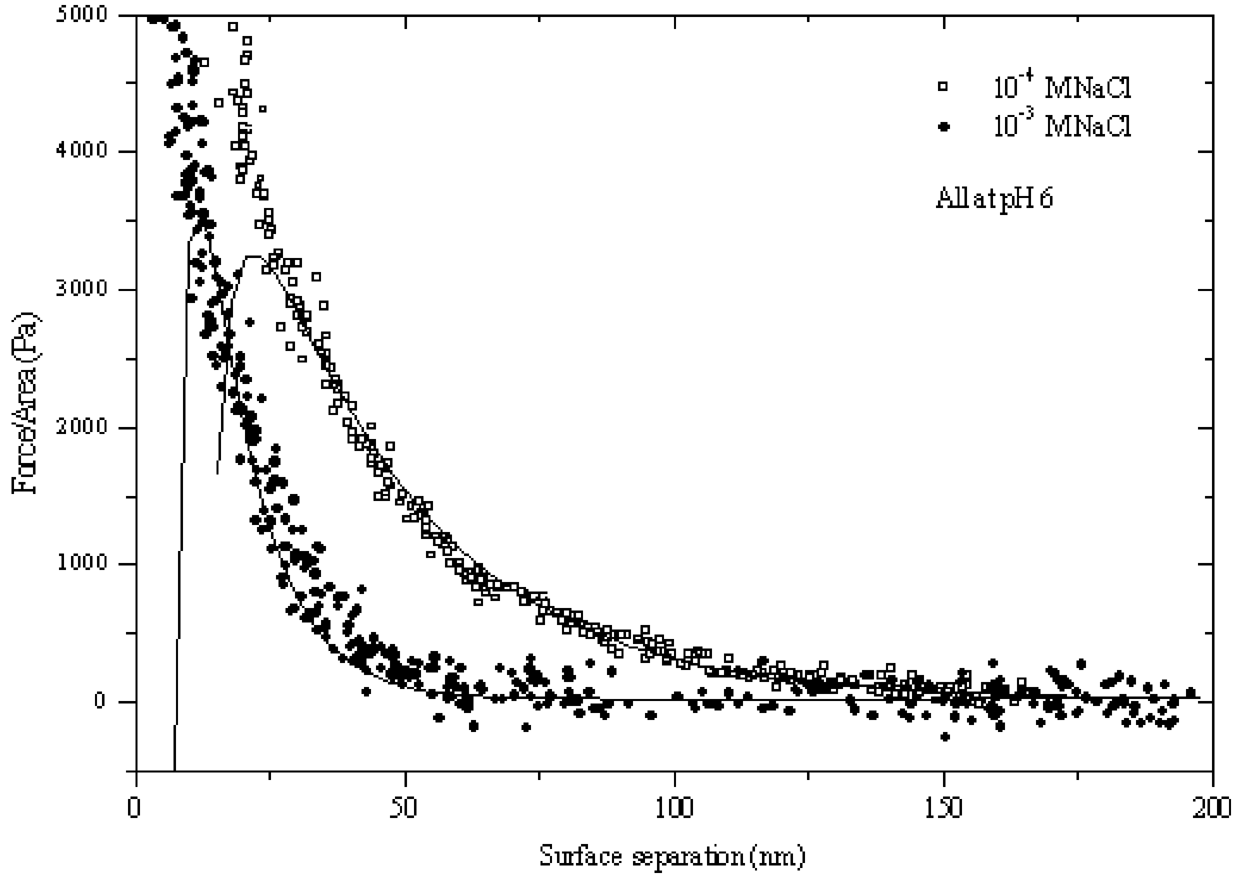

Fig. 3. Fitting of Eq. 1 to experimental data using the apparent surface potential (0) and the point of zero distance (*D*0) as variables. 10^{-4} M: psi0 = 81 mV, 1/ = 30.4 nm, *D*0 = -5 nm. 10-3 M: psi0 = 37 mV, 1/ = 9.6 nm, *D*0 = -5 nm.

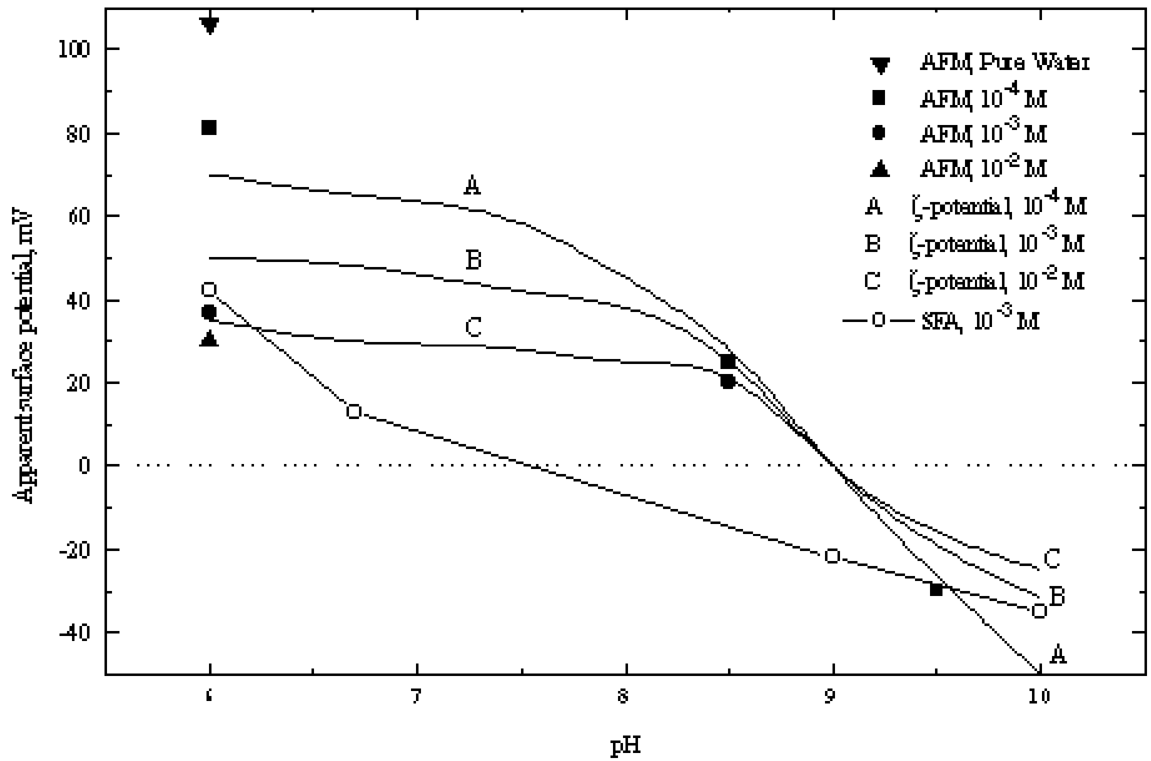

Fig.4. Apparent surface potentials of alfa-Al2O3 surfaces as a function of pH for different NaCl-concentrations as obtained from AFM force measurements. For comparison, zeta-potential curves for alfa-Al2O3 are given

CONCLUSION

The present AFM measurements illustrate the capabilities of this method.

The ability to measure forces acting on single colloidal particles using a rather simple method is of great interest for ceramic processing.

The present AFM derived apparent surface potentials show good agreement with litterature data on zeta-potential for alfa-Al_2O_3.