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Measurement of van der Waal's forces between iron/iron surfaces in water by Atomic Force Microscopy

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Agglomeration of fine iron ore particles in fluidised beds used for the reduction of iron ore prompted us to assess the nature and extent of contact forces between iron particles.

We used a Nanoscope Dimension 3100 series atomic force microscope inside a fluid cell, taking due account of the magnetic effects in this ferromagnetic system to measure quantitatively the magnitude of the van der Waal's force between an iron substrate and a small iron spherical tip (see **figure 1**).

Our results compare reasonably well with calculations made using fundamental theory[1-3]. In the AFM, force distance plots were generated in order to gain an experimental value of the van der Waal's Hamaker constant for the iron system (see **figure 2**). The Hamaker constant is derived from the jump to contact distance the AFM probe makes towards the surface using the equation $A \approx \frac{3kD_j^3}{R}$, where k is the cantilever stiffness, R is the radius of the tip and D_j is the jump to contact distance. The value for A in the iron system was 3-3.3eV, compared to the theoretically derived value of 3.2-3.54eV.

Contact adhesion has been evaluated using the Schwarz general theory of contact mechanics[4]. The work of adhesion has been derived from our experimental values using this theory and the significance of the findings is discussed. **Table 1** shows the values of the work of adhesion for three different tip sizes.

The adhesion stress between an iron particle and an iron substrate is shown to be 100 – 200 Nmm^{-2}. By comparison a Tokay Gecko uses van der Waal's forces with an adhesion stress of ~ 40Nmm^{-2} to support its mass of 15 – 50 grams when climbing up vertical surfaces[5]. When viewed from this perspective it is clear that van der Waal's forces will play a significant role in the adhesion of small particles to each other during the direct reduction of iron ore..

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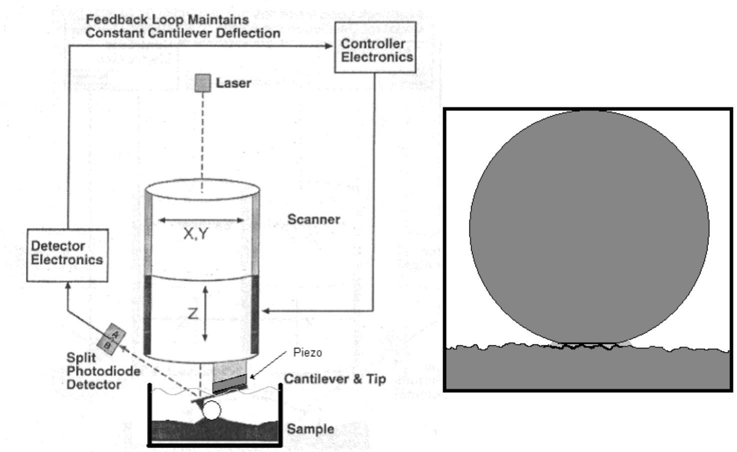

A. **B.**

Figure 1: (A) A schematic diagram of the AFM cantilever probe making contact with the iron surface. (B) A representation of the iron ball contacting the iron surface.

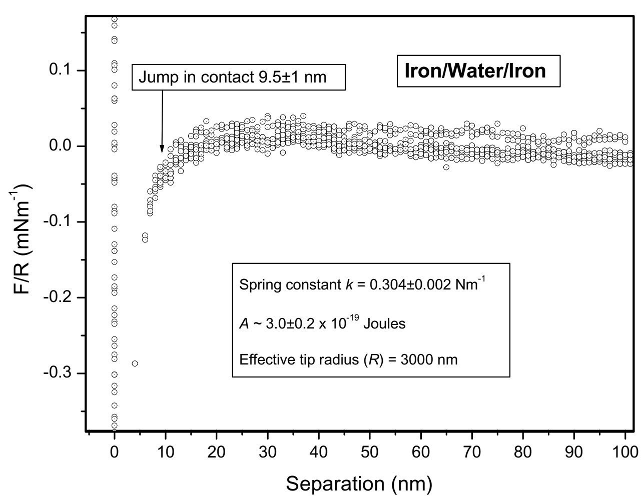

Figure 2: A sample curve of the force distance relation of a cantilever tip approaching a surface. The sharp curve down into a potential well is the point where the cantilever probe jumps into contact with the surface.

Table 1: The experimental values for the work of adhesion

R (μm)	F_{ad} (nN)	γ_w (mJm^{-1})	γ_w (mJm^{-1}) (theoretical) $D = 2.78$Å
0.1	5.66±1	18.5±1	~ 100
3	47.5±15	6.7±1	~ 100
7	171.4±2	10.4±1	~ 100

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