Characterization of Adhesion Phenomena & Contact of Surfaces by Soft Colloidal Probe AFM

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Supplementary data

A) RICM

In order to reconstruct the height profile of the object from the RICM images, three different approaches are possible[1]: The simple theory (considers light which enters the sample in direction normal to the plane of the substrate), the finite aperture theory (correction for finite aperture effects) and the non-local theory (correction for finite aperture effects and corrections due to curved interfaces). To get the intensity distribution over the distance r from raw data we take the average of intensity profiles over an angle φ, shown in Fig.: S1 a. For analysis of the intensity distribution we used the simple theory with correction factors for finite aperture and geometry effects[2]. To obtain the correction factors, we imaged glass beads (Polysciences Inc., Warrington, PA) on a glass surface in RICM mode. We recorded 10 glass beads with a diameter in the range of 30-50 µm and extracted the intensity profile, see Fig.: S1 b. Using the profiles, we reconstructed the shape of the beads and compared it to the calculated shapes (R by measuring their size with light microscope), and determined the correction factors corresponding to our experimental setup presented in Fig.: S1 c.

B) Optical lever sensitivity

In order to accurately determine the force from cantilever deflection the optical lever sensitivity is required. However, since we attached soft probes on the cantilevers, we cannot use the standard procedure in order to measure the optical lever sensitivity, i.e. force-distance measurements on a hard substrate to obtain the cantilever deflection from the z-piezo displacement. Here we use the spring constant of the cantilever, which was measured before, in combination with the Thermal Noise Method to determine the optical lever sensitivity[3]. The determination process is shown in the following flow chart:

1. detection of spring constant of cantilever (without soft probe) $\Rightarrow k_c$
2. detection of sensitivity of cantilever with soft probe onto a hard substrate $\Rightarrow S'$
3. Thermal Noise Method with soft probe on cantilever $\Rightarrow k_c'$
4. if $k_c' \neq k_c$ change sensitivity and go back to 3.
   if $k_c' = k_c \Rightarrow$ sensitivity of the current setup

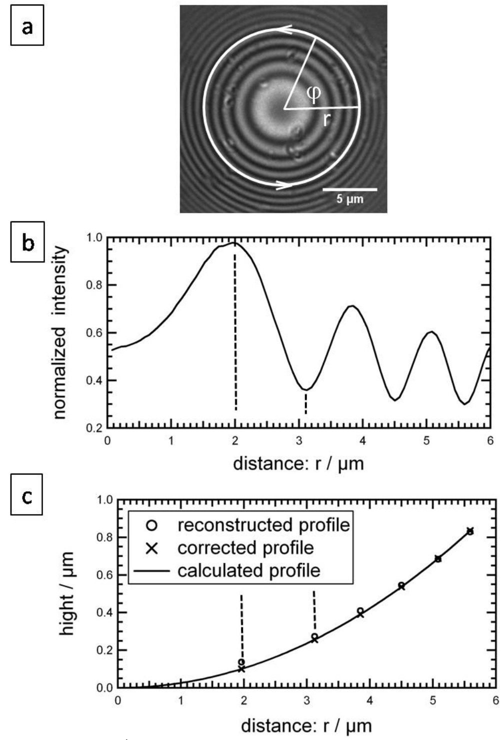

Fig. :S1 evaluation of the RICM immages: (a) RICM immage of a glass bead, (b) extracted intensityprofile, (c) reconstruction of profile

In liquid the Thermal Noise Method cannot be used due to high damping[4]. In this case, we detect the optical lever sensitivity by using the standard procedure, i.e. force-distance measurement on a hard substrate, but avoiding deformation of the colloidal probe. This can be done by approaching the very tip of the cantilever apex onto a sharp edge, not touching the soft colloidal probe. Any steep lithographic surface can be used as a sharp edge, here we use a cantilever chip (CSC38, µ-mash, Estonia) glued onto a glass surface.

C) Force spectroscopy mode

In addition to the JKR approach shown in the main text, the soft colloidal probe setup also allows to obtain the adhesion from AFM force-distance curves. Form force-distance curves as shown in Fig.: S2 we determine the work of adhesion W_{adh} (area of the force curve under the baseline[5]). Simultaneously we measure the contact radius a of the adhesion area at maximum load via RICM. The adhesion energy per unit area w can then be calculated according to dividing W_{adh} by πa^2.
For statistics, we detect the force-distance curves in mapping mode, defining a 100 µm^2 grid on the substrate with at least 64 data points. Afterwards, the force-displacement measurements are done on each point of the grid. For the hydrophilic system in water we found w_{water} = (0.9 ± 0.1) mJ/m^2, and in air w_{air} = (40 ± 10) mJ/m^2. For the hydrophobic probes in water we obtained w_{water} = (45 ± 10) mJ/m^2 and w_{air} = (11 ± 5) mJ/m^2 in air. These values agree well with values reported in the literature. The capillary force is a line effect, so in air w in units J/m^2 represents a reference value.

Notes and references

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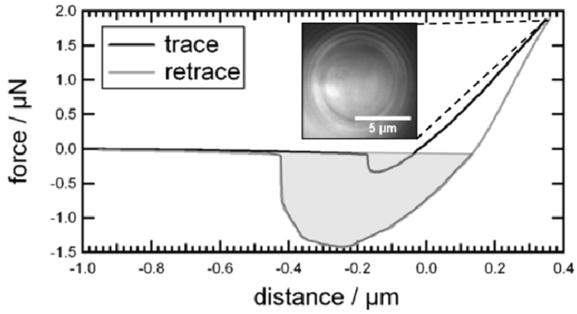

Fig.: S2 Analysis of the thermodynamik work of adhesion: collect force distance curve, evaluating work of adhesion W_{adh} (gray area) and measuring simultaneously the particle – surface contcat area at maximum load by micro interferometry (RICM).