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Nanomanipulating and sensing single particles interactions with combined atomic force microscopy optical tweezers (AFM/OT)

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Materials containing suspended micro- or nanoparticles serve a wide variety of purposes and they are used in several applications. In all the colloid system applications it is necessary to maintain the particles well dispersed and to avoid the formation of aggregates. It is for this reason that it is absolutely necessary to know the particle-particle interaction forces at the nanoscale.

The equilibrium state and the hydrodynamic properties of colloid systems in aqueous medium are affected by several environmental parameters. The addition of salt influences stability of colloids [1]. An explanation for this fact was given by the Derjaguin-Landau-Verwey-Overbeek (DLVO) theory, describing the surface charges at interfaces. This theory assumes that the interaction force between two particles is due to the sum of the electrostatic double-layer repulsion and the van der Waals attraction [2].

In order to study the effects of surrounding liquid properties on the stability of single particles from a new point of view, we have designed, developed and calibrated a combined atomic force microscopy/optical tweezers apparatus (Figure 1) [3]. This high resolution imaging instrument is capable to confine micro- and nanomaterial and to quantify force in the femtonewton scale.

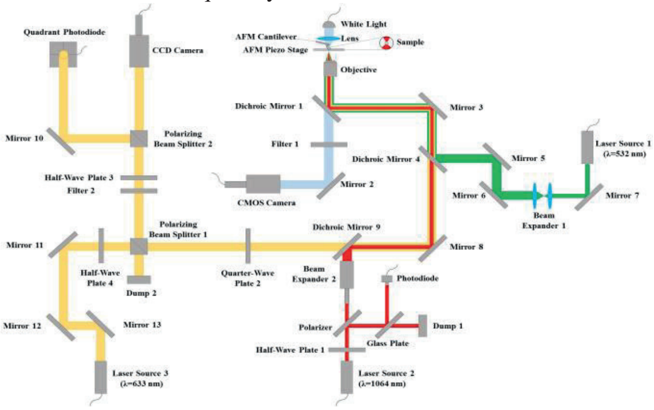

Figure 1. A sketch showing the scheme of atomic force microscopy and optical tweezers (AFM/OT) setup.

Moreover, one of the most interesting applications of the proposed apparatus is to use optical tweezers in order to manipulate single objects (e.g. nanomaterials and cells). The main achievement of the optical trapping nanomanipulation is to develop a selective nanomaterials sorting process with the aim to purify samples and to study the properties of single selected nano-objects. Nanomanipulation can also be useful to organize, assemble and locate complex hierarchical structures composed through optical tweezers manipulation.

In the first experiment, the AFM/OT system (Figure 2) was used to isolate a 1.0 µm polystyrene particles into a microfluidic well using the dragging force of the trapping laser. Subsequently, a custom-made AFM colloidal probe cantilever in which a single fluorescent 5.5 µm particle was glued to the end of a tip-less AFM cantilever was used to quantify the interaction force between two polystyrene particles.

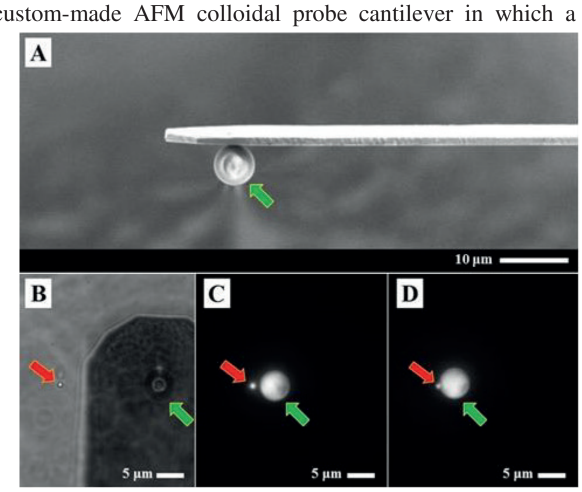

Figure 2. A SEM micrograph of the 5.5 polystyrene particle mounted on the tipless AFM cantilever using AFM as a manipulator (A). A 1.0 µm polystyrene particle was trapped a few micrometers from the cantilever (B), then the probe was translated in the trapped particle direction (C) and finally the particle glued to the cantilever approached the surface of the trapped particle (D).

The experiment was carried out by approaching the trapped particle with the AFM particle probe at a constant velocity (200 nm/s) in pure water and recording the optical tweezers output signals with the resolution of ±100 fN. The same experiment was repeated in 10^{-5} M and 10^{-3} M KCl solutions in that order. The obtained data (Figure 3) confirm that the behavior of colloidal systems observed experimentally agrees with the theoretical predictions. In pure water, long range attraction is clearly measured, whereas small short range repulsions are still not strong enough to overcome the attractive component in the analyzed range.

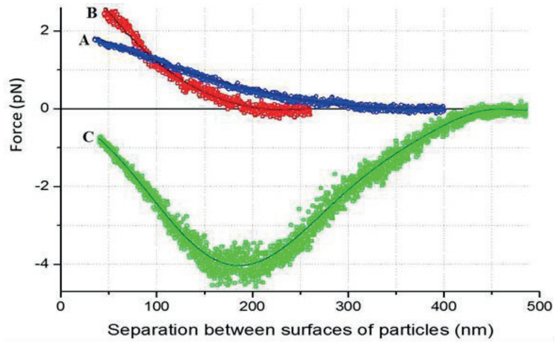

Figure 3. Force as a function of the relative distance between a single pair of polystyrene particles. The interaction force were collected varying KCl concentration: 10^{-3} M (blue circles; A), 10^{-5} M (red squares; B) and pure water (green triangles; C) at pH 7.

A completely different behavior is observed in presence of KCl, where no final attractive forces act in the analyzed range, while repulsive forces that grow exponentially with decreasing particle-particle distance are visible. In all the studied systems, no interaction forces between the polystyrene particles could be observed at distances exceeding 450 nm.

Another experiment was carried out in order to create a multi-particles structure, allowed us to prove the AFM/OT instrument capability of acting as a nanomanipulator and to scan the produced structure with the AFM probe at the same time, generating a high resolution image of the manipulated sample. In this case, the trapping laser was used as a high precision nanomanipulator while the AFM cantilever guarantees the capability to visualize the treated sample zone with high resolution. Five polystyrene particles were maneuvered and isolated from the colloidal system, then the selected particles were individually confined in a clean water microfluidic well and dragged to the glassy bottom of the channel in order to form a perfectly aligned straight line structure. The force exerted by the trapping laser is strong enough to push the particles to the glass wall and the adhesion effects allow to immobilize the particles to the substrate.

The AFM/ OT system was used to collect AFM topographies of the area selected for conducting the experiment before and after the particle deposition (Figure 4) as well as the surface of the single dragged particles.

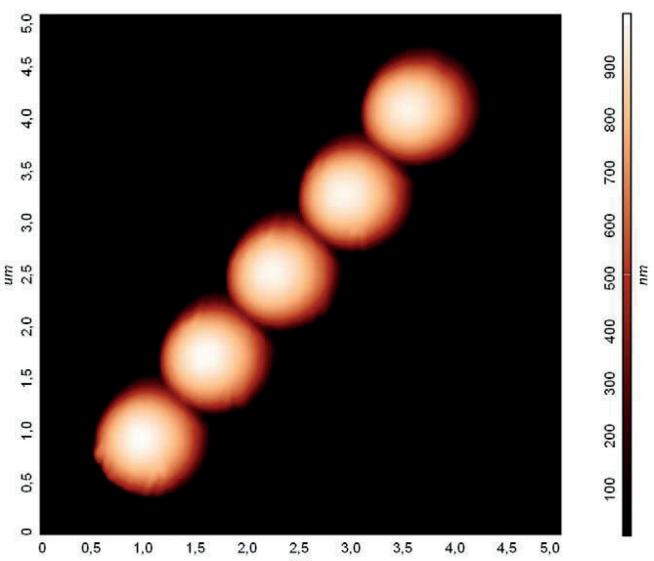

Figure 4. Topography image of the produced polystyrene particles structured immobilized onto the substrate obtained in tapping mode AFM.

This experiment allows to study the surface properties of the particles and substrates taking into consideration one single particle–surface interaction and to study such single events to characterize locally the studied materials.

Concluding, the obtained experimental results confirm the applicability of our combined system to study single particles interaction forces. It is shown that the polystyrene particles colloid systems are more stable in a 10^{-3} M KCl solution, than a 10^{-5} M KCl solution and that is, in turn, more stable than the same system in water. Furthermore, we have proved the instrument capability to manipulate single polystyrene particles and simultaneously study the sample surface properties by using the hybrid double probe AFM/OT system.

References

[1] C. Chassagne et al., *Colloids Surf. A*, 440, 208 - 216, 2014.
[2] J. A. Marotoet al., *Colloid. Polym. Sci.*, 276 453 - 458, 1998.
[3] F. Pierini et al., *Meas. Sci. Technol.*, 27, 25904 - 25915, 2016.

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