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Conference Paper · April 2019

DOI: 10.1364/OMA.2019.AW1E.2

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Determination of surface binding properties using rotational optical tweezers

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Abstract: Rotational optical tweezers uses circularly polarized light to rotate birefringent microparticles. Normally, if the particle is trapped far away from a surface, the rotation rate only goes to zero when the tweezers laser power is turned to zero. However, we find that if one traps close to a surface, the rotation rate goes to zero even at finite tweezers laser powers for some type of substrates. We suspect this to be due to binding between the substrate and the birefringent particle, keeping in mind that the hydrodynamic drag for this mode of rotation cannot increase beyond 1.2 times the drag away from the surface. We use this to probe some surfaces and find that there is no binding for hydrophilic ones but hydrophilic ones particularly tend to show a power threshold beyond which the birefringent particle starts rotating. We also place the particle on the threshold and observe ”stick-slip” kind of rotational behaviour.

OCIS codes: 000.0000, 999.9999. [8-pt. type] For codes, see http://www.osapublishing.org/submit/ocis/

Optical tweezers is a very versatile tool for micromanipulation. The rotational degree of freedom in a birefringent microsphere has been well exploited to rotate a variety of particles using circularly polarized light. However it is generally believed that the rotation rate in the x-y degree of freedom (where z is the axis of light impinging on the particle) goes to zero if the particle is trapped too close to surface on account of infinite drag. We find that this statement is incorrect [1] because the drag in this mode of rotation is bound to 1.2 times the value far away from surface. Yet when we place our rotating particle close to some types of surfaces, it ceases to rotate at finite laser powers. We suspect that this is because of binding to the surface and explore the behaviour for many different types of surfaces. For hydrophoblic surface like a PDMS surface coated on glass, there is no sticking especially when the liquid crystalline birefringent microspheres are used. Hydrophilic surfaces, on the other hand, tend to show a sticking behaviour at finite laser powers. We also observe stick-slip behaviour just above the surface threshold.

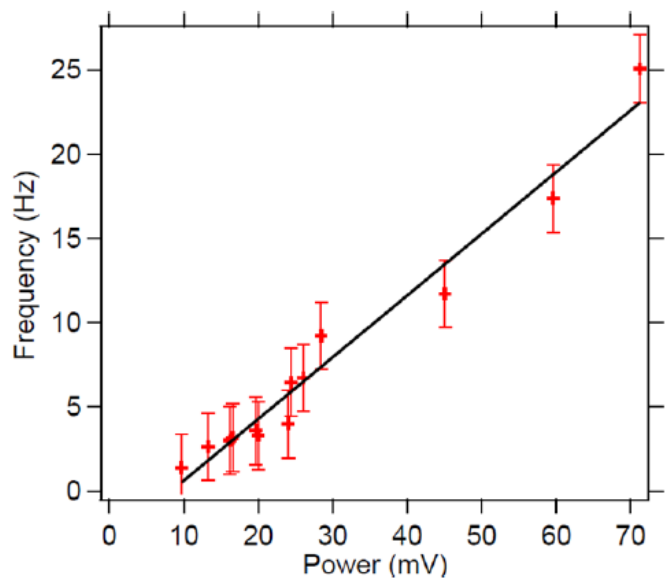

Fig. 1: The rotation rate of a birefringent particle goes to zero close to a hydrophilic (regular glasss slide) surface at non-zero laser powers due to binding.

This can be used to quantify various types of surfaces and the leading order binding mechanisms. We find a regular glass surface mildly hydrophilic and has a low threshold, but when Chitosan substrate was used, the threshold increased significantly, inspite of the fact that chitosan is less hydrophilic than glass. We suspect that this happens because chitosan is a well-known biopolymer and has adhesive properties particularly in the presence of water at a pH of 7.

We study the stick-slip and find that the waiting time distribution can be used to ascertain the potential barrier of the washboard that the particle sees while rotating. We find a value of 0.78 k_BT which is slightly higher than 0.5 k_BT obtained from the equipartition theorem. The threshold shows that hydrophilic binding energy is about 40 k_BT.

We also try to study the adhesion properties of a surface of a CHO cell. We find that there is no threshold like in the previous cases. However, the rotational drag on the system is almost a factor of 5 larger than in glass. We suspect that to be non-specific binding with the cell surface. There is a set of lipid bilayers on the cell membrane which have hydrophilic-hydrophobic-hydrophobic-hydrophilic kind of conformation such that the outer surface is hydrophilic. It has been reported in some of the earlier works as well [2] where specific binding to the surface has been probed.

Thus we show that the rotation of a particle in optical tweezers stops at finite laser power due to surface binding and show an application of the effect to ascertain surface properties. We find that for some bio-surfaces (like CHO cells), the threshold ceases to exist and yet the rotational drag appears to have a value much larger than that for regular glass.

3. References

[1] Q. Liu and A. Prosperetti , "Wall effects on a rotating sphere", J. Fluid Mech., **657**, 1 (2010)

[2] A. Pralle, E.-L. Florin, E. H. K. Stelzer and J. K. H. Horber, "Photonic force microscopy: A new tool providing new methods to study membranes at the molecular level", Single Mol., **1**, 129, (2000).