

Chapter 27

On the Forces between Micro and Nano Objects and a Gripper

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ABSTRACT

The authors study the van der Waals force F_{vdW} between the gripper jaw and an object – cubical, spherical and conical in shape, situated at a distance L of closest approach from it. The generic and most general case is considered, when the materials of the working jaw of the gripper and the particle are made of different materials strongly preferring the liquid phase of the fluid being at temperature T and chemical potential m . The contributions due to the standard van der Waals, as well as of the retarded (Casimir) van der Waals interactions are considered. They concluded that F_{vdW} strongly depends on the contrast, at given fixed T and m , between the physical properties of the fluid and the material of the arms of the gripper and the particle. In addition, as expected, F_{vdW} strongly depends on the shape of the object, its size, and the distance L between it and the working jaw of the gripper. Their approach can be applied to any nonpolar fluid.

INTRODUCTION

When a particle's characteristic size is scaled down below a micrometre the role of its weight becomes negligible. When one tries to release such a neutral particle from whatever handling device surface operating on it in air or under vacuum, the particle will not drop down under the gravity

but, instead, will stick to its working surface due to the effect of the omnipresent van der Waals forces. If one charges the particle, forces vibration of the working surface, etc., the released particle might move in an uncontrollable way leaving the observation field of the apparatus that controls the performance of the operation. Having in mind the above, one shall not be surprised that handling, feeding, trapping and fixing of micro parts is still the main bottleneck in micro manufacturing and

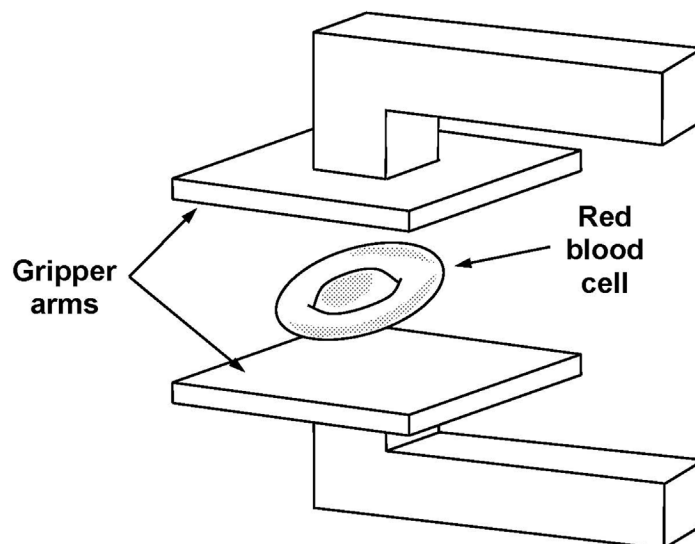
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is far from being solved today Cecil (2005). One of the main problems in the micro- and nano-assembly is the precise and reliable manipulation of a micro- or nano-part that includes moving it from a given point P_{start} , where it is to be taken from, to a point P_{end} , when it is to be placed on. One looks for further handling, feeding, trapping and fixing strategies that are still to be developed, taking into account the forces appearing at small distances between the gripper's plates and the micro object, or between the object and a surface to taken off or to be placed on (Figure 1). In addition, the environmental influences are not mastered yet – the numerous parasitic forces due to the environmental influence often make the manipulation behaviour unpredictable.

Let us remind that when a material object is situated in vacuum at a distance L from another one the changes which their presence causes onto the existing between them fluctuations of the quantum electromagnetic field leads to a strong mutual force of attraction. At molecular separations of a few nanometers or less, these interactions are the familiar van der Waals forces (Israelachvili, 1985; Persegian, 2006). However, as recognized by Casimir and Lifshitz (Casimir, 1948;

Lifshitz, 1956) at larger distances they reveal retardation effects associated with the finite speed of light. When L is of the order of a micrometer or less this force, known as the Casimir force, is the strongest force acting between two uncharged objects. While when the objects are in vacuum the net force is always a force of mutual *attraction*, in the case when they are immersed in a fluid this force, as it has been recently demonstrated experimentally by Munday et al. (2009), can be also a force of *repulsion*. The experimental study reported there, as well as the one by Hertlein et al. (2008) on the critical Casimir effect; demonstrate convincingly the correctness of the main ideas presented in the current article. One of the goals of our work is, however, to encourage further experimental studies in the field of fluctuation induced forces between objects of various geometry – spherical, ellipsoidal, cubical, conical, etc., that do not simply demonstrate the existence of the main effects considered, but that qualitatively provide information for the forces between objects of various geometry, material properties, choice of the fluid in which they are immersed, etc., as a function of the distance between them, temperature, fluid's pressure, etc.

Figure 1. Schematic view of the red blood cell manipulation by a micro-gripper



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