Theoretical prediction of levitation due to Casimir force of plane-parallel systems made of realistic materials

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As Lifshitz predicted [1, 2], Casimir force (F_C) may be repulsive between two materials spaced by another one at nanoscale. Taking into account the influence of gravity (F_g) and the buoyancy forces (F_B), the balance of the three forces may lead to levitation phenomena which is extremely relevant in micro- and nano- electromechanical devices for controlling friction, stiction and adhesion [3]. Although the geometry sphere-plane has been widely studied [4], we consider the less analysed plane-parallel system, consisting of a thin film immersed in a fluid over a substrate.

Herein, we theoretically predict that, in thermal equilibrium at room temperature, thin films of realistic materials such as teflon, silica (SiO_2), and polystyrene (PS) immersed in glycerol, stands over a substrate of silicon at stable or unstable equilibrium distance (d_{eq}), i.e. $\overrightarrow{F_C}(d_{eq}) + \overrightarrow{F_g} + \overrightarrow{F_B} = 0$. (See Fig. 1). In addition, we analyse how that d_{eq} is affected by slight variations of temperature (T) around room temperature due to the dependence of F_C on T [5, 6].

Moreover, since the magnitude and nature of Casimir force depends on the dielectric permittivity of all the materials in the system, it is able to control the equilibrium distance by mean of the optical properties of materials that compound the system. Because of that, we studied the magnitude and stability of the equilibrium distances in two plane-parallel systems where the thin film is replaced by a film made of a hybrid material whose components present Casimir forces and equilibrium distances of opposite nature. In the first one, the hybrid material is made up of two individual thin films of different materials (bilayer system), and in the second one, it is a slab that comprise a homogeneous matrix with small inclusions inside occupying a volume fraction (f) (composite system [7]).

All these plane-parallel systems show equilibrium distances of few hundreds of nanometres that can be controlled through the thickness of each thin film and the volume fraction. The possibility of tuning the equilibrium distances makes these kind of systems a pontential ones for controlling friction, stiction and adhesion in plane-parallel geometry at nanoscale.

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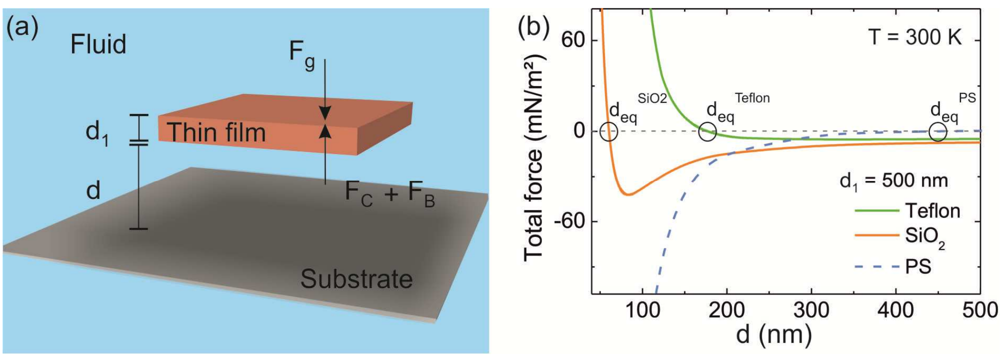

Fig 1 (a) Schematic of the plane-parallel system where d is the distance between the thin film and the substrate and d_1 the thickness of the thin film. F_C, F_g, and F_B are the Casimir, the gravity, and the buoyancy forces, respectively. (b) Force balance as function of d for a thin film of $500\,nm$ of thickness made of three different materials: Teflon (green), SiO_2 (orange), and PS (blue). The substrate and the fluid are considered to be silicon and glycerol, respectively. d_{eq} is the value of d at which the balance of the forces is zero.