Geometry and material dependence of the Casimir force on nanostructured silicon surfaces

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The Casimir force is usually regarded as an extension of the van der Waals (vdW) interaction between molecules in the retarded limit. By dividing two solid plates into small elementary constituents and summing up the vdW force, it is possible to recover the distance dependence of the Casimir force between them. For smooth curved surfaces, the Casimir force is often calculated using the proximity force approximation (PFA) when the separation is small. However, the PFA breaks down when the deformation is strong. In fact, one important characteristic of the Casimir force is its strong dependence on geometry. The Casimir energy for a conducting spherical shell or a rectangular box has been calculated to have opposite sign to parallel plates. Whether such geometries exhibit repulsive Casimir forces remains a topic of current interest.

We performed an experiment to demonstrate the interplay between geometry and finite conductivity effects for the Casimir force [1]. A micromechanical torsional oscillator is used to measure the interaction between a gold sphere and a silicon surface with an array of nanoscale, rectangular corrugations. The measured Casimir force is found to deviate from the PFA by up to 10%, in good agreement with calculations based on scattering theory. Our results show that the optical properties of the material must be included in the calculation of Casimir forces between structures of non-conventional shapes, due to the non-trivial interplay with geometry effects.

![Image](image_url)

Figure 1: (a) Cross section of the nanoscale rectangular trenches on a silicon surface. (b) Schematic of the experimental setup (not to scale) including the micromechanical torsional oscillator, gold spheres and silicon trench array. (c) Ratio \( \rho \) of the measured Casimir force gradient to the force gradient expected from PFA. The solid line is the prediction from scattering theory that includes both geometry and finite conductivity effects. The dashed line represents calculations assuming perfectly conducting surfaces.