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Casimir free energy of dielectric films: Classical limit, low-temperature behavior and control

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Abstract

© 2017 IOP Publishing Ltd. The Casimir free energy of dielectric films, both free-standing in vacuum and deposited on metallic or dielectric plates, is investigated. It is shown that the values of the free energy depend considerably on whether the calculation approach used neglects or takes into account the dc conductivity of film material. We demonstrate that there are material-dependent and universal classical limits in the former and latter cases, respectively. The analytic behavior of the Casimir free energy and entropy for a free-standing dielectric film at low temperature is found. According to our results, the Casimir entropy goes to zero when the temperature vanishes if the calculation approach with neglected dc conductivity of a film is employed. If the dc conductivity is taken into account, the Casimir entropy takes the positive value at zero temperature, depending on the parameters of a film, i.e. the Nernst heat theorem is violated. By considering the Casimir free energy of SiO 2 and Al 2 O 3 films deposited on a Au plate in the framework of two calculation approaches, we argue that physically correct values are obtained by disregarding the role of dc conductivity. A comparison with the well known results for the configuration of two parallel plates is made. Finally, we compute the Casimir free energy of SiO 2 , Al 2 O 3 and Ge films deposited on high-resistivity Si plates of different thicknesses and demonstrate that it can be positive, negative and equal to zero. The effect of illumination of a Si plate with laser light is considered. Possible applications of the obtained results to thin films used in microelectronics are discussed.

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Keywords

Casimir free energy, dc conductivity, dielectric films, Nernst heat theorem

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