Dielectric Material

Introduction

A dielectric material is any material that supports charge without conducting it to a significant degree. In principle all insulators are dielectric, although the capacity to support charge varies greatly between different insulators for reasons that will be examined in this TLP.

Dielectric materials are used in many applications, from simple electrical insulation to sensors and circuit components.

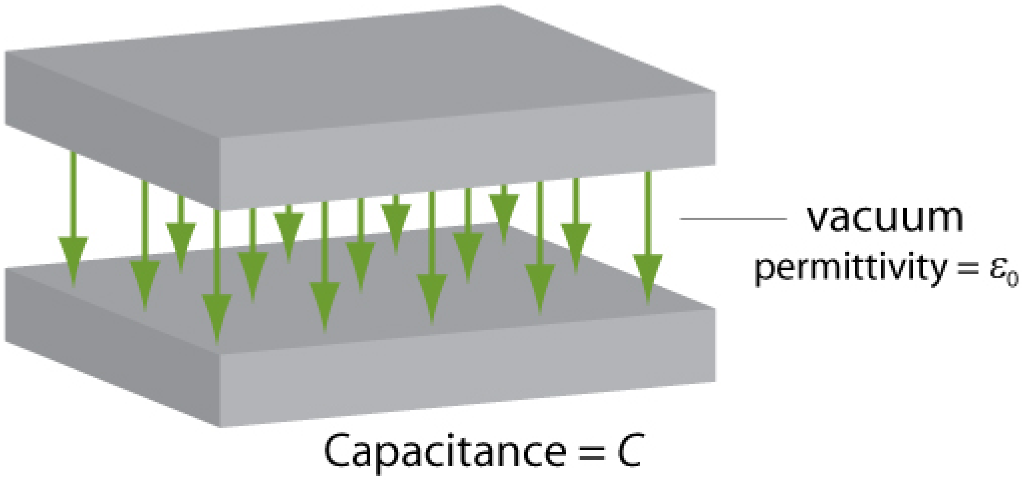
The dielectric constant

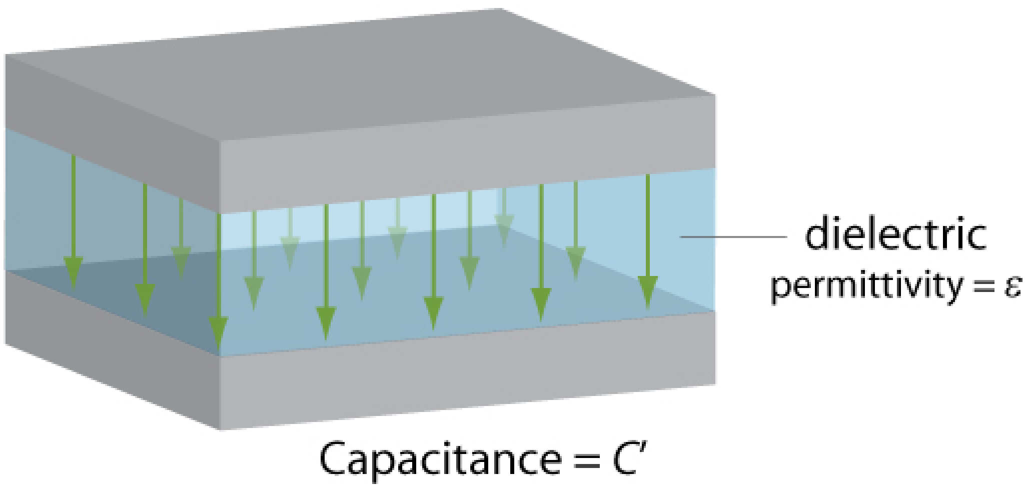
The dielectric constant of a material provides a measure of its effect on a capacitor. It is the ratio of the capacitance of a capacitor containing the dielectric to that of an identical but empty capacitor.

An alternative definition of the dielectric constant relates to the permittivity of the material. Permittivity is a quantity that describes the effect of a material on an electric field: the higher the permittivity, the more the material tends to reduce any field set up in it. Since the dielectric material reduces the field by becoming polarised, an entirely equivalent definition is that the permittivity expresses the ability of a material to polarise in response to an applied field. The dielectric constant (sometimes called the ‘relative permittivity’) is the ratio of the permittivity of the dielectric to the permittivity of a vacuum, so the greater the polarisation developed by a material in an applied field of given strength, the greater the dielectric constant will be.

There is no standard symbol for the dielectric constant – you may see it referred to as κ, ε, ε' or ε_r. In this TLP κ shall be used to avoid confusion with the absolute permittivity, which may also be given the symbol ε.

The two definitions of the dielectric constant are illustrated by the diagram below (the green arrows represent the electric field).





$$\boxed{\kappa = C'/C} \qquad \boxed{\kappa = \varepsilon/\varepsilon_0}$$

In general, the more available polarisation mechanisms a material possesses, the larger its net polarisation in a given field will be and hence the larger its dielectric constant will be.

The dielectric constant of a material and its refractive index are closely linked by the equation $\kappa = n^2$ (click here for derivation). However, care must be taken in applying this equation. It is only strictly accurate when the dielectric constant and the refractive index are measured under the same conditions. Specifically, since the dielectric constant can vary significantly with frequency (for reasons discussed in the next section of this TLP), we must measure the dielectric constant under alternating current at the same frequency that we measure the refractive index at – the frequency of visible light, ~10^{15} Hz. However, quoted values of the dielectric constant normally refer to the static dielectric constant – that is, the dielectric constant under direct current. This is often very different from the value of the dielectric constant at 10^{15} Hz.

The exception to this is for materials that possess only the electronic mode of polarisation. For these materials, the dielectric constant does not vary significantly with frequency below visible frequencies, and $\kappa_S \approx n^2$ where κ_S is the static dielectric constant.

To summarise: the equation $\kappa = n^2$ can be applied to the static dielectric constants of non-polar materials only, or to the high-frequency dielectric constants of any dielectric.

Source: http://www.doitpoms.ac.uk/tlplib/dielectrics/dielectric_constant.php