Simulating The Influence Of The Casimir Effect On The Current Density In Amorphous Materials

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Abstract: In the production process of ceramic floors whose base is the raw ceramic material, the previous but important controls are made on the parameters of temperature, pressure of having pressed, humidity, apparent density and particle - size. These controls are made on raw samples by different methods in order to determining the electric properties like conductivity, permittivity, and polarization, other at the same time with: pressed degree, apparent density (AD) and mechanical resistance. In the following development, a simulating theoretical method is presented to calculate influence of the Casimir effect on the density current in amorphous structures used in the production process of tiles for ceramic floor technique.

Index Terms: Apparent density (AD); conductivity; mechanical resistance; polarization; relative permittivity thermal density current.

1. Introduction

In the production process of tiles for ceramic floor and in many other cases, related with the study and characterization of loamy material, the necessity arises of making previous controls of the most outstanding parameters as: a) grade of humidity of the samples [1]; b) temperature of having cooked; c) pressure of having pressed and d) apparent density (DAP), to enunciate some. These controls are made on raw samples by different methods, as the most recent [2], with the objective of determining the behavior of electric properties as: a) conductivity; b) electric permittivity; c) grain dimensions [3], and others. Presently work the experimental results of the behavior of absorption and thermal emission are shown of more than 100 samples of raw ceramic material (test tubes) whose chemical composition and grade of relative humidity is detailed in the table 1. The most important thermal properties in the dielectric materials, is the permittivity and that for compound loamy it is complex, since its calculation and determination is a problem of multiple phases (air, dilutes, solid), such and as it reports it [4] a rigorous physical model that describes the behavior of the relative permittivity and, for this class of atomic systems, it is extensive and it requires of a good calculation machine and enough available time, however, the experimental method is a good tool that has the scientists to determine the most approximate value to the theoretical value of this fundamental parameter.

Table 1
Chemical composition of ceramic materials

Components	Composition for mass %
SiO_2	63
Fe_2O_3	4 - 5
K_2O	1,8 - 2
Al_2O_3	28
$Ti_{0,1}O_2$	0,5
Otros	1,5
Relative humidity 5 - 7 %	

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Non alone empiric models of determination exist, of ε, but of the electric conductivity σ, electric susceptibility χ and apparent density DAP, for compound multiphase and thermal density current, like for the case that occupies us. In agreement with the experimental data, the basic principles of the electromagnetic theory, the form of absorption and emission of the light for the bodies, a theoretical relationship settled down among the grade of humidity of the test tubes study object, the temperature and the relative permittivityε.

2. Experimental procedure

2.1 Preparation stage.

They took 10 groups of samples, each one of 20 test tubes of raw ceramic material, with a participation of 5 gr of H_2O for each 100 sample gr and with a relative humidity HR between the 5 and 7% of humid base. The range of pressure of had pressed used in the process of production of the samples, went from 30 to 60 Bar.

2.2 Measurement of thermal parameters

When connecting the source of halogen light of 150 Watts, they were activated the sensors of temperature, voltage and current automatically. Every 30 seconds, they registered the corresponding data, until arriving to a maximum temperature of 360º K, then faded the source of light and they continued taking the descent data. Among the multiple properties and electromagnetic, chemical and other characteristics of registration instruments as the sensors; that can be used to analyze bioelectrical signals, this form of absorption and thermal emission of these devices. In the production process of ceramic sensor whose base is the ceramic material, the previous but important controls are made on the parameters of temperature, pressure of having pressed, humidity and particle - size. These controls are made on raw samples by different methods [1], the same thing that: compactation degree, apparent density (DAP) and mechanical resistance [2]. The another hand, the superficial and volumetrically characteristics of the sensor, are in certain advantageous form for the detection of different types of signals, since then are depending on the problem that one has and of the type of information that is wanted to analyze. The structural organization of the atoms in the sample of the sensor indicates its form and thermal behavior its answer efficiency to the stimulus. For the analytical description of the geometric elements in the volume of the sample of the amorphous material, the factors: structural and atomic dispersion, they drive to quantify the electromagnetic and thermal behavior of the structure [3]. The present work developed a theoretical method to calculate the behavior of the apparent density (DAP) and thermal current flow and the thermal conductivity of an amorphous material. The theoretical model used to determine the influence of the structural factor in the heat propagation process for ceramic material under the influence of a uniform electric field is the statistic of Maxwell - Boltzman that allows analyzing the solution of the movement equations for many bodies and their interaction. In this model is necessary to keeping in minding that, if dielectric material is a mixture of phases (air, water, solid), the electric permittivity is a different property in a different way. Since, it is subjected being to the direct action of an electric field, the polarization will be a function of: humidity, atomic structure, porosity degree, pressure and the internal energy that is in turn a function of bands structure. First of all, the one numbers of normal vibrations whose frequencies are included in the range of *w* until (*w* + *dw)*, is defined as:

$$dN(w) = \frac{w^2 dw\,\tau}{2\pi^2}\left(\frac{1}{v_1^{\,3}} + \frac{1}{v_2^{\,3}} + \frac{1}{v_3^{\,3}}\right) \qquad (1)$$

Where: v_1; v_2; v_3 - are velocities of longitudinal, transverse and *Z* directions respectively; τ - volume of unit cell. But, the function of dipole number distribution formed in the raw ceramic; it can be considered as a Boltzman distribution that depends on the external field applied, in the following way:

$$n(z) = a\left[\frac{-\sqrt{z}}{b}\exp(-bz)\left(z + \frac{3}{2b}\right) + \frac{3\sqrt{\pi}}{4b^{\frac{5}{2}}}\,erf(\sqrt{bz})\right] \qquad (2)$$

Where: $a = \frac{2n_o}{\sqrt{\pi}}\left(\frac{V_T}{KT}\right)^{\frac{3}{2}}\left[(k-1)\varepsilon_o\right]^{\frac{3}{2}}\left(\frac{Cu}{N}\right)^3$; $b = \frac{V_T}{KT}(k-1)\varepsilon_o\left(\frac{Cu}{N}\right)^2$;
$z = E^2\left(\frac{V}{m}\right)^2$; $erf\left(\sqrt{bz}\right)$ - error function

In the previous equation, V_T – corresponds to total volume of the sample, including air, water, and solid; *K* – is the Boltzman constant; *T* – is the absolute temperature in Kelvin. In the theoretical model that we proposed the molecular polarizability α_m is a function of grain structural deformation. It is due to the compactation form and of orientation caused by the external field applied, that is:

$$\alpha_m = 4\pi\varepsilon_o S(w)\Delta_g + \frac{P_m V_T\, p}{3KT} \qquad (3)$$

Where: *S(w)* – structural factor of grain, this factor was calculated in [3]; P_m – molecular polarization; *p* – electric dipolar moment; *w* – oscillation frequency of the dipoles formed in a crystalline net; Δ_g – volume grain average (m^3). The first term in (3), corresponds to polarizability for structural deformation, and the second term, is the polarizability for orientation caused by the external electric field.

$$P_m = Hn(z)\alpha_m E - P_C \qquad (4)$$

Where: *H* – sample relative humidity; *E* – internal field or molecular field (V/m); P_C – casimir polarization. Combining the equations (2) and (3) the form of the molecular polarizability is obtained:

$$\alpha_m = \frac{4\pi\varepsilon_o S(w)\Delta_g KT}{\left(3KT - Hn(z)V_T\varepsilon_{in}\right)} \qquad (5)$$

Where: ε_{in} – internal energy of bands (Jul). This fact leads to implement a minimum condition of polarization, that is:

$$n(z) > \sqrt{\frac{3P_r}{H\varepsilon_{in}}} \qquad (6)$$

Where: P_r – pressure (Pas). Keeping in mind equations (2) and (6), we can evaluate and calculate the constant of electric permittivity of the loamy material having the volumetrically relation ship (air/sample, solid/sample, water/air) that determine in certain measure the hardness of ceramic material and with the relationship:

(V_{ap}/V_m); where: V_{ap} – applied voltage (volts) and V_m – measured voltage (volts)

In consequence:

$$K^* = \varepsilon_r \frac{V_{ap}}{V_m} \qquad (7)$$

Where: K^*- dielectrically constant of the raw ceramic material. It can be defined like a lineal combination of two processes: the first one has relationship with the polarization of the ceramic samples with a degree of humidity but in presence of an external field and the second term, with the drying polarization. The calculation of the electrical relative permittivity dependent on the structural factors can determinate of the following form: Carrying out some many mathematical transformations to the previous equation, finally we have:

$$\varepsilon_m = \varepsilon_o + \frac{P_m}{E}\left(H + \frac{b(f)-1}{a(f)}\right) \qquad (8)$$

Where: *a(f)* and *b(f)* are parametrical functions. Comparing the equation (8) with the obtained for [1], it is possible to deduce an equation that describes the theoretical behavior of the RH for a raw ceramic material depending on the frequency. In this theoretical model's position, it is necessary to keep in mind that atoms located will exist outside of it lines of propagation, for that these they will be considered that reticular dispersion centers, for what the current density can calculate as a function:

$$J(r)_i = \sigma_{ij} f(r) E_j \qquad (9)$$

Where: *f(r)* - dispersion factor of grain; this factor was calculated in [3], σ_{ij} – thermal conductivity tensor; E_j - electrical field generated by the wave electromagnetic incident on the sample.

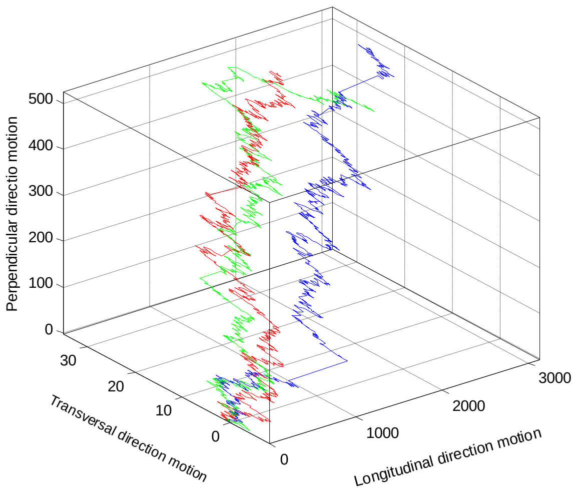

Figure 1: Behavior of the simulated current density of a raw ceramic material with the relative humidity, a) without of Casimir effect (blue trajectory) and b) with of Casimir effect (red and green trajectories)

If we make an analytic analysis of the propagation of the electromagnetic wave (EMW) in the sample:

$$\begin{cases} T(x+dx) = T_o + \nabla T dx \\ \vec{J}(y+dy,T) = \vec{J}_o + (\nabla \cdot \vec{J})dy \end{cases} \quad (10)$$

Where: ∇T - thermal gradient; $(\nabla.J)$ - divergence of the current density. Being also inclusive J a function of the temperature T, then:

$$\vec{J}(y+dy,T+dT) - \vec{J}_o = (\nabla \cdot \vec{J})dy + \nabla J_T dT \quad (11)$$

Where: (∇J_T) - thermal gradient of the current density.

But;

$$\begin{cases} dT(x+dx) = \nabla T dx \\ \vec{J}(y+dy,T+dT) - \vec{J}_o = \sigma_T \Delta \vec{E} \end{cases} \quad (12)$$

Where: σ_T - thermal conductivity of the sample; ΔE - variation of the electric field in the sample. Keeping in mind (6), we can evaluate and calculate the electric permittivity constant of the loamy material having the volumetrically relationship (air/sample; solid/sample; water/air) that determine in certain measure the hardness of the ceramic material and relationship.

In consequence:

$$\sigma_T \Delta \vec{E} = (\nabla \cdot \vec{J})dy + (\nabla J_T)\cdot(\nabla T)dx \quad (13)$$

Where: σ_T - dielectrically tensor of the raw ceramic material. If: σ_T, can be defined like a lineal combination of two processes; the first one has relationship with the polarization of the ceramic samples with a degree of humidity but in presence of an external field and the second term, with the drying polarization. The equations system (12) lead determines the behavior of the thermal current in an amorphous material, as the ceramic structure. This current can evaluate as:

$$I(T) = \int_\tau \nabla \cdot \left[\sigma_T\left(f(r)-1\right)\vec{E}\right] d\tau \quad (14)$$

Where: τ - is the integration volume and *f(r)* is the structural function factor. Then, the thermal current in the amorphous structure will be represented for:

$$I(T) = -\int_\tau \frac{\mu}{\lambda} f(r)\sigma_T \left|\vec{E}\right| d\tau \quad (15)$$

Where: $\mu = \frac{4\pi}{\lambda}\sin(\theta)$ - Parameter of structural local dispersion

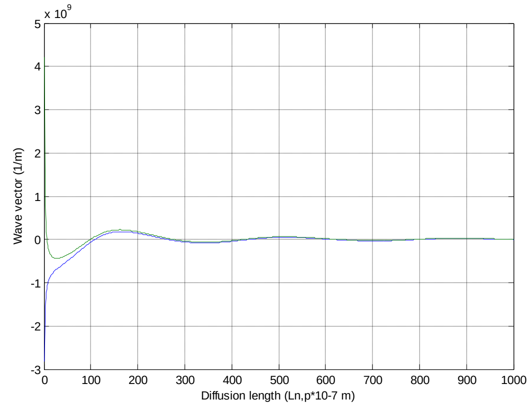

Figure 2: Behavior of the simulated wave vector of a raw ceramic material with the diffusion length without of Casimir effect (green trajectory) and with of Casimir effect (blue trajectory)

3. Conclusions

1. The Casimir effect (Figure 1) determines the density current distribution of the electric charge and also the properties of transport of the amorphous materials.

2. Recent data obtained in the laboratory of Solid State and Optoelectronic of Electronic Engineering in the Central University; demonstrate that the structure of bands of this class of materials is strongly influenced by the degree of relative humidity in the sample and the grain structure.

3. The behavior of the electric field in the granular border depends strongly on the dimensions of the vacancies and grain structure, because the conduction currents fall with the recombination in these areas.

4. The Figure (2) shows the behavior of the wave vector in ceramic materials that produce an important influence in the granular structure and the transport mechanisms.

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