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A Review of Different Measurement Techniques of Dielectric properties and Subsequent Applications

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ABSTRACT: In the current paper attempt is made towards introduction of some dielectric material properties. Introduction to different dielectric principals as well as dielectric properties with relevance to Agricultural products by use of Measurement techniques with frequencies in the range from (Radio to Microwaves) low to high are also discussed. Identified reference to these properties and possible applications in different research works carried so far are also summarized in this paper.

Keywords: Dielectric properties; Dielectric Permittivity; radio frequency and Microwave Measurements and Agricultural Products.

INTRODUCTION: Today's age is the age of Food processing. It is also an age of packaging of the Food. We specifically find industrial applications pertaining to these. The Dielectric properties related to these agricultural properties are increasing tested by modern scientific methods for increasing the quality and product life associated with the food in use. Dielectric properties are primarily studied with respect to construction of various electrical instruments and use of different insulating strategies by use of various dielectric materials for it as components to such made designs. The research in material sciences and technology has given an insight into the invention of novel dielectric materials and their futuristic electronic and electrical applications form the Past era. In constant pursuit of higher range of frequencies suitable to characterize the properties of different newly found dielectric materials the techniques have gradually adapted and advanced to use of lower frequencies like radio frequencies to medium range frequencies like the Microwaves to the current stage use of higher Frequencies like the Millimeter waves.

Food needs to tested, protected and preserved with scientific principal of dielectric heating. This would calculate the exact extent of the moisture content in the given food product. Subsequently it will focus and analyze the material dielectric constraints associated with that material. Finally, we need to select suitable range of higher frequency or the Microwave frequency for suitable dielectric heating in terms of size and property of the selected material without creating any harm to the food under test.

Hence it can be stated that the Dielectric properties associated with the agricultural food materials have always been a subject of scientific investigation and research for academics and food industry from a long time (Nelson 2006). Recently Fresh apples are tested and characterized for their Dielectric material properties have been envisaged to articulate the strategy of dielectric Microwave food heating and sensing applications with reference to the desired outcome of storage of the food (Apple) for a long shelf life (Guo et al. 2007a). The intension of this article is to quantify and characterize dielectric material attributes of Agricultural food products which are dielectric in nature for resolve about the extent of Wetness percentage and such related qualities under preview for appropriate testing and application to optimize the agriculture product life.

DEFINITIONS AND PRINCIPLES: Introduction to the electrically fundamental ac properties of the dielectric materials has been already explained as the concepts with the principals of the Electromagnetic field principals by Nelson (Nelson, 1973a). The Concepts of parallel equivalence for a given electric or dielectric circuit is also discussed by Nelson (Nelson, 1965). In this paper we would use the terms like dielectric constant ε' (Real part), dielectric loss factor ε''(Imaginary part). The term relative complex permittivity is defined as $\varepsilon = \varepsilon - j\varepsilon'' = |\varepsilon| e^{-j\delta}$ where δ is the loss angle of the dielectric. Here Permittivity is a generalized term being symbolized as ε is nothing but the relative complex permittivity. The term relative complex permittivity is also called as the free space permittivity or in the other way also calculated as the proportion associated with the absolute permittivity with permittivity of free space, $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m.

tan δ = ε″/ε′ is also referred as loss tangent. It is also referred to be the dissipation factor. The descriptive dynamic factor also called as the power factor is [tan δ ⁄ (1+ tan2δ) ½].

The factor of ac conductivity can be calculated as below

$\sigma = \omega\varepsilon_0\varepsilon''$ [where ω = 2πf is known as angular frequency measured in Hz.]

ε″ is referred as loss of energy in the dielectric because of the pertinent mechanism of dielectric relaxation mechanisms. The dielectric losses also occur due to ionic conduction.

Largely the material properties and performance while it is subjected to the Radio frequency heating or Microwave heating is subject to its dielectric properties, Moisture constraint or the dryness associated with it.

The dissipated power in such a heating per unit volume would be measured in W/m3. The equation for the dissipation of the power is as subjected below

$$P = E^2\sigma = 55.63\, f\, E^2\varepsilon'' \times 10^{-12}$$

Here E is called as Electric field which is measured in rms values and measured in V/m. The Rate of increase in the temperature with respect to the time measured in °C/s, is given by

$$dT/dt = P/ (c\, \rho)$$

Here C is called as specific heat associated with that material kJ/(kg·°C). If we calculate the aspect of density material subjected to Dielectric property observation is given by kg/m3. While we dry the dielectric material, If we calculate the aspect latent heat of vaporization associated with that material in to consideration.

One must deliberate about power dissipation factor which is pertinent to the dielectric loss ε″. The power dissipation factor may also be a dependent factor related to ε′ (dielectric constant) for that material. It does correlate with intensity of the electric field which in turn is a function corelating to the dielectric constant ε′.

Consider that we are conducting the radio frequency heating of the material. Let ε_1 be permittivity of material as the when breach gap admits the parallel plates is taken to be d1. Let ε_2 be permittivity of material breach gap admits the parallel plates parallel plates is taken to be d_2. The value of rms intensity for the given electric field is given by

$$E_1 = \frac{V}{d_2 + d_2\left(\frac{\varepsilon_1}{\varepsilon_2}\right)}$$

In this case V is referred to be the rms potential difference amidst the electrodes. In case of the next example there is a inclusion of Spherical permittivity ε2. This permittivity is surrounded by the inestimable value of the permittivity ε1. Hence the value of E2 is given by

$$E_2 = E_1\left(\frac{3\varepsilon_1}{2\varepsilon_1 + \varepsilon_2}\right)$$

where E1 is referred to be intensity associated with the electric field pertaining to the inestimable medium. This does prove that dielectric constants associated with the materials do have significant impact to make on the intensity associated with the associated with the material with is dielectrically heated. It does also have effect which alters the dissipation of power in that material.

The propagation and microwave energy being absorbed while traversing across the dielectric material does depend on the equation describing E1. These properties hence certainly very critical while describing he characteristics of that material. The related and selected frequency of the Microwave passing through the material dielectrics is very significant factor. The term power absorption in a dielectric material is proportionate with the value of the intensity of the Electric field square value. Intensity associated with the applied electric field is hence defined to be

$$E_z = E_0 e^{j\omega t - \gamma z} w$$

In this case E_0 is termed to be the electric field intensity at the point of desired reference. t is the time factor, γ is the constant of propagation for the travelling wave. Z defines the actual remoteness navigated across desired direction of traversing. The constant of propagation being a complex quantity is actuated as

The propagation constant is a complex quantity,

$$\gamma = \alpha + j\beta = j\frac{2\pi}{\lambda_0}\sqrt{\varepsilon}$$

α is termed to be attenuation constant, β is termed to be phase constant λ0 is termed to be the free-space wavelength. The values of the attenuation constant α and the constant phase value β are corelated with the dielectric properties associated with the material medium.

$$\alpha = \frac{2\pi}{\lambda_0}\sqrt{\frac{\varepsilon'}{2}}\left(\sqrt{1+\tan 2\,\delta}\right) - 1\,)$$

$$\beta = \frac{2\pi}{\lambda_0}\sqrt{\frac{\varepsilon'}{2}}\left(\sqrt{1+\tan 2\,\delta}\right) + 1\,)$$

.Whenever a wave traverses into a material medium it does suffer significant attenuation in its energy due to loses which are also referred as dielectric losses. The combination of above two equations of α &β results in cumulative dielectric loss which can be stated as below.

$$E(Z) = E_0\ E^{-\alpha z e^{j(\omega t-\beta z)}}$$

In this equation the exponential part of the equation defines the magnitude of intensity associated with the electric field. This intensity decreases with continuous propagation of the wave into the material medium.

Power dissipation through the material medium actuated as square proportional to Energy (E2).

The exact equation of this proportionality is $P \propto e^{-\alpha Z}$. The distance where this dielectric power is dropping down to the level e^{-1} = 1/2.7183 with respect to the value that it has at the surface is referred as Dp

$$D_P = \frac{1}{2\alpha}$$

This attenuation fo the energy is measured in terms of decibels per meter (dB/m). If this attenuation is high, then such a dielectric heating would be given out rapidly as the wave traverses deep inside the dielectric medium which is calculated by following equation.

$$10\ log_{10}\left(\frac{p_0}{p(z)}\right) = 20\ log_{10}\left(\frac{E_0}{E(z)}\right) = 8.686\ \alpha z$$

when we have (ε″)2 << (ε′)2 then

$$\alpha \cong \frac{8.868\pi\varepsilon''}{\lambda_0\sqrt{\varepsilon'}}$$

When a material wave incident onto a dielectric material, some part of he energy /dielectric power does get reflected Po and some of the dielectric power does get penetrated into the material. The relationship Pt.

$$p_t = p_0\ (1-|\,\Gamma|2)$$

Here Γ is known to be the reflection coefficient for the dielectric material. The reflection coefficient derived as relative complex permittivity is given by

$$\Gamma = \frac{1-\sqrt{\varepsilon}}{1+\sqrt{\varepsilon}}$$

The dialectic power slowly attenuates as exponential loss of power as stated below

$$P = P_t\ e^{-\alpha z}$$

α is measured in terms of nepers/m. 1 neper= 8.686 dB, and dB/cm = 0.08686 x nepers/m.

PRINCIPALS AND TECHNIQUES OF MEASUREMENT: The technique adopted for actuating the dielectric parameters is dependent of the parameters like 1. The type of material, 2. Electrical as well as physical attributes of that dielectric material 3. Extent of accuracy required in the dielectric parameter measurement. Many paramedic analysis methods are evolved, and consequently relevant instrumentation has also been evolved depending upon the range of frequency in consideration.

In case of the RF frequency range measurement, the given material must electrically have modulated as a series circuit or a parallel circuit of equivalence. By measurement of RF parameters like the admittance or the impedance concurrently we can derive inference about the prevalent dielectric parameters associated with that material. Those dielectric parameters are in turn related to the aspect of permittivity associated with that material. The entire aspect of actuating the dialectic attributes and its accuracy of measurement depends upon the reliability of the series or the parallel circuit modelled as well of measurement technique adopted by actuating the values of permittivity by use of these circuits.

The methods of actuating the values of dielectric properties for agricultural products specifically in the domain of low frequency and high frequency are reviewed by Stuart O. Nelson (2005) by use of various resonant circuits and precision bridge circuits. Audio frequencies ranging 250 Hz to 20 kHz associated to confined samples were tried by (Corcoran et al.) using a coaxial holder. Kuang and Nelson, 1998, proved the fact that in case of low frequency measurement keen attention must also be given to polarization of the electrodes which finally may overturn the measured data.

Significant extent of dielectric properties data was generated using 1- to 50-MHz range of Microwave frequency by Nelson (1979). Techniques suing higher frequency ranges which involved use of RX-meter ranging 50- to 250-MHz and Admittance meter ranging 200- to 500-MHz. (Jorgensen et al., 1970 & Stetson and Nelson, 1970)

A novel technique involving a microwave range of 100 kHz to 1 GHz with the use of calibrated impedance analyzers and the technique of Cross ratio was used by (Lawrence et al., 1989).

Lawrence et al., 1998 used a coaxial sample holder in order to compensate the flowing grain and further use of the two-port scattering analysis of parameters by use of numerous alcohols with known values of permittivities studied dielectric properties in the Microwave range of 25 to 350 MHz Methods have been devised using microwave measurement techniques in the range more than 1GHZ are also used which used resonant cavity and transmission lines.

Use of network analyzers (Kraszewski et al., 1983; Lawrence et al., 1989, Brodwin and Waters) and impedance analyzers using Computer control (Lawrence et al., 1989) has instinctive calibration of the dielectric aspects a very low to a very high Microwave range. Now we know several types of techniques of dielectric properties calibration techniques using coaxial line systems with elimination of errors.

DIELECTRIC PROPERTIES AND THEIR APPLICATIONS:

- In studies have given a scope to study the moisture content, the behavior of foods during microwave heating, dependence of these properties on temperature, the attributes of the dielectrics food materials and their constituents is critical information (Mudget, 1995; Datta et al., 1995).
- The attributes of the dielectrics material tried for ranging to a wide frequency range in this information is really useful in describing the dielectric relaxation phenomena in materials (Kuang and Nelson, 1997).
- The dependence of dielectric attributes associated with the agricultural properties on the characterizing properties like Moister percentage and mass density has created a new insight into the agricultural products and their use in longevity.
- The extension analysis of the dielectric characteristics right form the sensing to maintaining the moisture content in moving grain (Trabelsi and Nelson, 1998) has created new possibilities of improving the farm yield fortitude which gives the harvesters scope of precision in their farming activities.
- To conclude the application of wide-frequency-range associated with the dielectric attributes associated with the Agricultural crops has created a promise for entirely novel applications which does involve Application of dielectric spectroscopy and its associated techniques to provide a much needed to for product characterization through dielectric property measurements.
- Current day measurement techniques involve computerized statistical and computational procedures based on the principles of dielectric properties. Such innovations in the processes of measurement are providing new inroads the scope of this subject.

REFERENCES:

1. Guo W., Nelson S.O., Trabelsi S., Kays S.J. (2007a): 10–1800-MHz *Journal of Food Engineering*, 83: 562–569
2. Guo W., Trabelsi S., Nelson S.O., Jones D.R. (2007b): Journal of Food Science, 72: E335–E340.
3. Nelson S.O., Trabelsi S. (2006): Measurement Science and Technology, 17: 2294–2298.
4. Nelson S.O., (2005): Journal of Non-Crystalline Solids 351 (2005) 2940–2944
5. Corcoran, P. T., S. O. Nelson, L. E. Stetson, and C. W. Schlaphoff. 1970. Transactions of the ASAE 13(3): 348-351.
6. Kuang, W., and S. O. Nelson. 1997. Microwave Power Electromagnet. Energy 32(2): 114-122.
7. Nelson, S. O., and P. G. Bartley Jr. 1997. IEEE IMTC Proc. 1: 653-657.
8. Jorgensen, J. L., A. R. Edison, S. O. Nelson, and L. E. Stetson. 1970. Transactions of the ASAE 13(1): 18-20, 24.
9. Corcoran, P. T., S. O. Nelson, L. E. Stetson, and C. W. Schlaphoff. 1970. Transactions of the ASAE 13(3): 348-351.
10. Lawrence, K. C., S. O. Nelson, and P. G. Bartley Jr. 1998. *Coaxial dielectric sensor for cereal grains.* IEEE IMTC Proc. 1: 541546.
11. Lawrence, K. C., S. O. Nelson, and A. W. Kraszewski. 1989. Transactions of the ASAE 32(1): 304-308.
12. Mudgett, R. E. 1995. M. A. Rao, and S. S. H. Rizvi, 389-455. New York, N.Y.: Marcel Dekker, Inc.
13. Trabelsi, S., A. W. Kraszewski, and S. O. Nelson. 1998. Meas. Sci. Technol. 9: 1548-1556.