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Full Length Research Paper

Analyses of dielectric properties of fertilizers (urea and diammonium phosphate) in aqueous solution at different temperatures in microwave frequency

Vivek Yadav*, Anil Kumar, Sudeep Sharan and A. K. Sinha

Gyrotron Laboratory, Central Electronics Engineering Research Institute (CEERI), Pilani-333031,
333031 Rajasthan, India.

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This paper reports experimental results which have been carried out for understanding the behavior of dielectrics in the form of mixer of fertilizers and water content at wide frequency range in different temperatures. A simple and rapid measurement (reflection method) was used in determining the dielectric response at microwave frequency. The dielectric constant and loss have been measured in frequency range from 1 to 40 GHz with different temperature according to environment. The measurement procedure has been performed by dielectric probe kit using 50 GHz Performance Network Analyzer (PNA). The samples were prepared by mixing different fertilizers in water according to the Department of Agriculture. The different fertilizers (urea and diammonium phosphate) were taken from the market. The experimental work shows the dielectric behavior of solution of fertilizers and water in temperatures. The amount of water and fertilizers content were taken according to the Department of Agriculture.

Keywords: Dielectric constant, dielectric loss, reflection, dielectric probe kit.

INTRODUCTION

The behavior of a dielectric material in the presence of an electromagnetic field is entirely different from that in presence of a direct current field. In order to understand the behavior of dielectric materials under the action of electromagnetic fields, one has to investigate its interaction in such electromagnetic field. In the presence of an alternative electric field, the dielectric materials get polarized along the field direction. The degree of polarization depends on the applied electromagnetic power and the nature of the material itself (Bottcher, 1952). The static dielectric constant and dipole moment values are a measure of the polarization of the material at low frequencies. However, in the presence of a high frequency field, there exist a time lag in the attainment of equilibrium in a system with changing field and hence an anomalous dispersion (dielectric constant decrease within increase in frequency) takes place. (Dakin, 1947 and Frohilch, 1949).

This in turn gives rise to the dielectric relaxation. Spatial and temporal variation of the water content in the fertilizers is considered important in agriculture. Its knowledge is important for the sowing, development, successful maturation of a crop along with rainfall runoff prediction agricultural yields forecasting and boundary layer heat exchange for meteorological and climate studies (Fedrick, 1993). The different percentage of water content in the fertilizers gives rise to a large variation in the dielectric constant. Thus, knowledge of the variation of the dielectric constant of the fertilizers at different water content is necessary for the efficient use in soil. Porosity of the soil greatly helps to judge the moisture movement within the soil. Macro pores allow readily movement of air and water. It does not hold water under normal condition. In contrast, macro pores can hold more water and restrict the movement of air and water in soil. Thus, in sandy soils, in spite of the low total porosity, the movement of air and water is surprisingly rapid because of the dominance of the macro pore spaces. The porosity of soil is easily changed. Any operations that reduce

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*Corresponding author. E-mail: vivek.ceeri@gmail.com. Tel : 91-1596-252229.

aggregation and decrease the amount of organic matter in the soil, decreases pore space (Wang, 1980).

Nature of dielectric properties variation

The dielectric properties of most materials vary with several different factors. In hygroscopic materials such as agricultural products, the amount of water in the materials is generally a dominant factor. The dielectric properties also depend on the frequency of the applied alternating electric field, the temperature of the materials, and on the density and structure of the materials. In granular or particulate materials, the bulk density of the air-particle mixture is another factor that influences their dielectric properties. The dielectric properties of materials are dependent on their chemical composition and particularly molecules in the materials (Benchimol, 1965).

Frequency dependence

With the exception of some extremely low-loss materials, that is, materials that absorb essentially no energy from RF and microwave fields, the dielectric properties vary considerably with the frequency of the applied electric fields. An important phenomenon contributing to the frequency dependence of the dielectric properties is the polarization arising from orientation with the imposed electric field of molecules which have permanent dipole moments. The mathematical formulation developed by Debye (Debye, 1929; Chaudgari, 2008) to describe this process for pure polar materials can be expressed as:

$$\epsilon = \epsilon_{\infty} + \frac{\epsilon_s - \epsilon_{\infty}}{1 + j\omega\tau}$$

where ε_{∞}, represents the dielectric constant at frequencies so high that molecular orientation does not have time to contribute to the polarization, ε_{δ} represents the static dielectric constant, that is, the value at zero frequency (dc value), and τ is the relaxation time, the period associated with the time for the dipoles to revert to random orientation when the electric field is removed.

Temperature dependence

The dielectric properties of materials are also temperature dependent, and the nature of that dependence is a function of the dielectric relaxation processes operating under the particular existing conditions and the frequency being used. As temperature increases, the relaxation time decreases, and the loss-factor peak will shift to higher frequencies. Thus, in a region of dispersion, the dielectric constant will increase with increasing temperature, whereas the loss factor may either increase or decrease, depending on whether the operating frequency is higher or lower than the relaxation frequency.

The temperature dependence of ε_{∞} is generally negligible (Bottcher, 1978), and while that of ε_{δ} is larger, its influence is minor in a region of dispersion. Below the region of dispersion, the dielectric constant decreases with increasing temperature. Distribution functions can be useful in expressing the temperature dependence of dielectric properties (Bottcher, 1978), but the frequency and temperature dependent behavior of the dielectric properties of most materials is complicated and can perhaps best be determined by measurement at the frequencies and under the other conditions of interest.

In this work, reports on the dielectric response of different fertilizers with water content were measured at different temperatures (as weather of India in summer, rainy season and winter season) in wide frequency 1 to 40 GHz in the laboratory condition. The temperature effect on dielectric response of fertilizers is important in judging the biological and chemical properties of soil.

MATERIALS AND METHODS

Dielectric properties of fertilizers with water content have been measured by performance dielectric probe kit as shown in Figure 1 (Agilent 85070E). This performance dielectric probe kit is based on reflection method. The power source for this method is Agilent PNA ranging from 200 MHz to 50 GHz (Agilent 85070E). The measurements are made by simply immersing the probe into the mixer of fertilizers and water. There is no requirement of special fixtures or connectors. The complete system is based on network analyzer, which measures the material's response to RF or microwave energy. The samples were prepared by mixing different concentrations of water in different fertilizers. The different fertilizers were taken as urea (IFFCO India, moisture 1%, nitrogen (N) 50%, biuret 1.5%) and D.A.P. (IFFCO India, moisture 1.5%, nitrogen (N) 18%, ammoniacal N 15.5%, N in the form of urea 2.5%, neutral ammonium citrate soluble phosphates 46%, water soluble phosphates 41%). First the fertilizers were weighed. Then measured quantity of water and fixed quantity (according to the Department of Agriculture) of different fertilizers (0.0381%) was added and allowed for four hours to facilitate internal drainage, subsequent homogenous mixing and settlement.

RESULTS AND DISSCUSSION

The results show the effect of temperature and frequency variation on dielectric properties of fertilizers and water mixture. The fertilizers give the efficient response with temperature and frequency. The values of dielectric constant, tangential loss of water and mixture of water and fertilizers are measured and plotted in Figures 2, 3, 4, 5, 6 and 7. By measurements, it is observed that there is a variation in the dielectric constant of mixture of water content with fertilizers. Another feature is that at high temperature, dielectric constant as well as dielectric loss becomes high as compared to low temperature. The value of the dielectric constant ε' decreases with respect

Figure 1. Dielectric property measurement set up for 1 to 50 GHz.

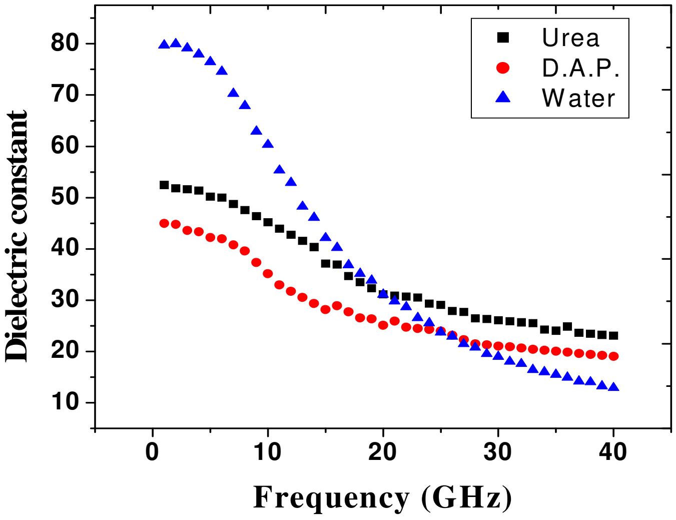

Figure 2. Variation of dielectric constant with frequency at 5℃ temperatures.

to frequency while tangent loss increases with respect to frequency.

At temperature of 5℃, the dielectric constant of urea sample decreases from 52 to 23 with the frequency while the dielectric constant of D.A.P. sample decreases from 45 to 18 with the frequency as shown in Figure 2. The dielectric loss of urea sample increases from 0.1 to 0.35 and for D.A.P. sample it increases from 0.02 to 0.25 as shown in Figure 3. The dielectric constant of water varies from 80 to 15 with frequency while tangent loss varies from 0.2 to 1.8 with frequency.

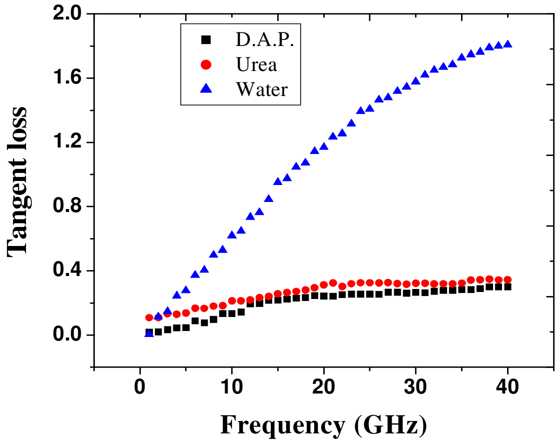

Figure 3. Variation of tangent loss with frequency at 5℃ temperatures.

The dielectric properties of samples at temperature 25℃ are as shown in Figures 4 and 5. At 25℃ temperature, the dielectric constant of urea sample is seen decreasing from 62 to 37 with the frequency and the dielectric constant of D.A.P. sample decreasing from 52 to 25 with the frequency. The dielectric loss of urea sample increases from 0.1 to 0.4 and for D.A.P. sample it increases from 0.03 to 0.30. As temperature increases, the dielectric constant of water decreases as shown in Figure 4.

The dielectric properties of samples at temperature 50℃ are shown in Figures 6 and 7. At 50℃ temperature, the dielectric constant of urea sample is seen decreasing from 73 to 45 with the frequency and dielectric constant of D.A.P. sample decreasing from 62 to 30 with the frequency. The dielectric loss of urea sample increases from 0.15 to 0.45 and for D.A.P. sample it increases from 0.04 to 0.37.

The dielectric constant is higher for urea (CH_4N_2O) than for the diammonium phosphate [$(NH_4)_2HPO_4$] due to other factors, such as: ligand field strength compared to the $NH_3 < CO$. The parameter of the ligand field splitting varies with the nature of the ligand. It was found that some ligands caused greater deployment of field than others, that is, increases the energy of light absorbed and the transition will have a shorter wavelength, resulting in different colors for the respective complexes. Experimental data showed that regardless of the identity of the metal ion, the same order is followed. Ryutaro Tsuchida proposed to organize the ligands in order of increasing energy of the transitions which he called spectrochemical series (Thomsoann, 1973):

$I^- < Br^- < S^{-2} < SCN^- < Cl^- < NO_2^- < N_3^- < F^- < OH^- < C_2O_4^{-2}$
$< H_2O < NCS^- < CH_3CN < py < NH_3 < en < bipy < phen <$
$NO^{-2} < PPh_3 < CN^- < CO$

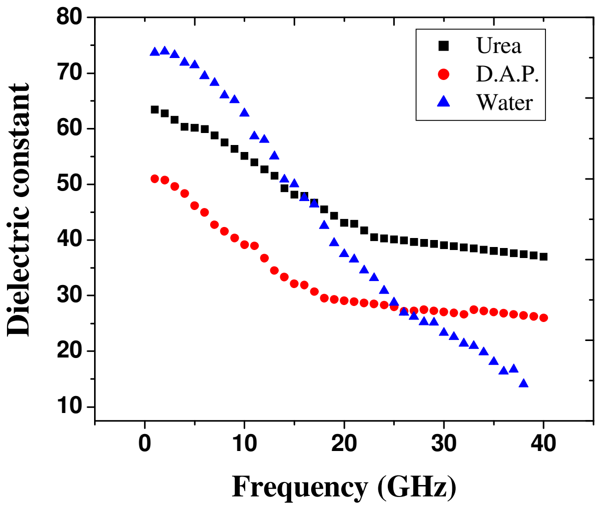

Figure 4. Variation of dielectric constant with frequency at 25℃ temperatures.

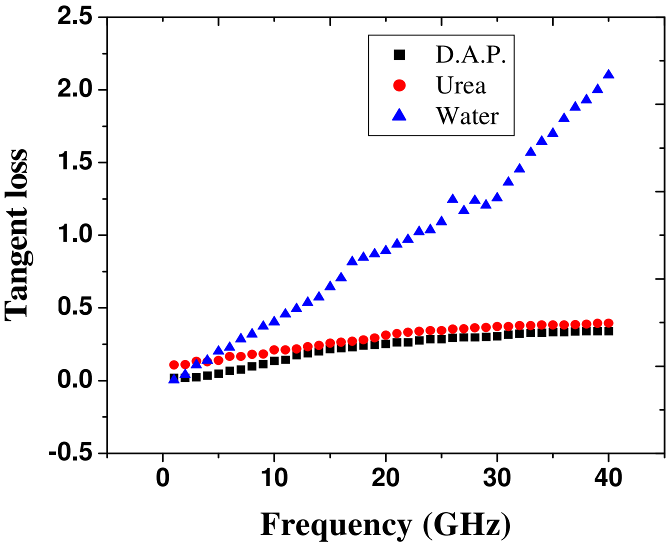

Figure 5. Variation of tangent loss with frequency at 25℃ temperatures.

Urea (CH_4N_2O), amine ($-NH_2$) and carbonyl (CO) group and $(NH_4)_2HPO_4 \rightarrow (NH_4)_2HPO_4 \leftrightarrow NH_3 + NH_4H_2PO_4$

These experimental results show the temperature dependent behavior of fertilizer and water composition. According to these results the solution of fertilizers and water gives effective dielectric properties in summer season (50℃) as compared to other seasons. The fertilizers increase the pore space of the soil. Because the dielectric constant is directly proportional to pore space of soil (Wang, 1980) and due to more pore space the grains of the crops get the sufficient space for growth, so fertility of soil is also increased (Vivek, 2009).

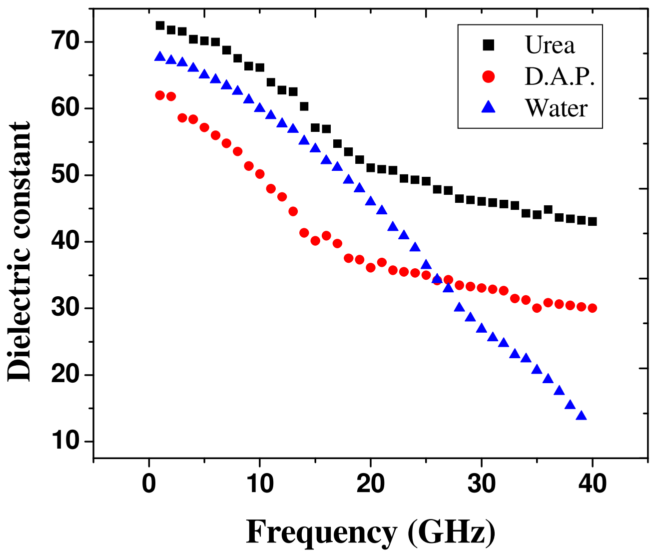

Figure 6. Variation of dielectric constant with frequency at 50℃ temperature.

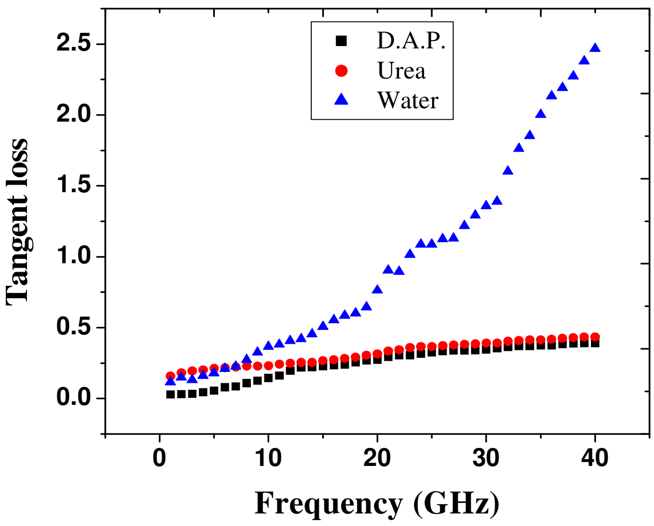

Figure 7. Variation of tangent loss with frequency at 50℃ temperatures.

Conclusion

Study of the dielectric properties of fertilized microwave frequencies in the laboratory is useful in Agriculture. Good results are obtained for the dielectric constant and tangent loss of different samples at wide frequency range. The dielectric properties of the liquid dielectrics in the form of water and fertilizers mixture are useful in understanding the effect of fertilizers on soil. The results of such studies are important for an understanding of the fundamental nature of the response of the particulate soil to the high frequency electromagnetic fields.

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