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CONCLUSIONS:

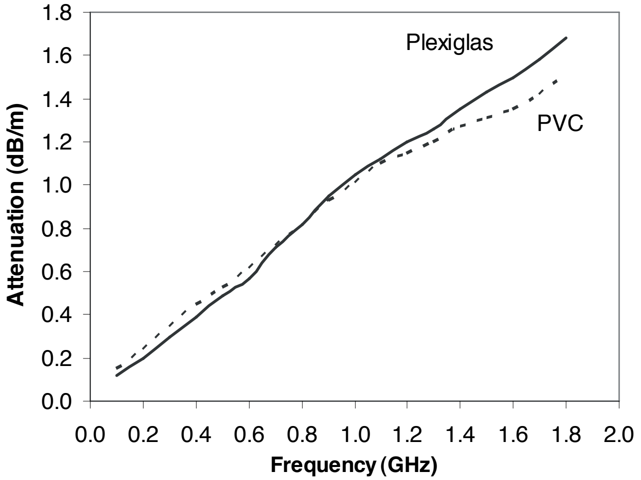
Coaxial cable is used as a sample holder to measure some electrical characterization of teflon, PVC, and plexiglas between 5 and 1800 MHz at room temperature. This is done by measuring parameters of reflected and transmitted waves.

It is concluded from fig.3 to fig.6 that dielectric constant and loss factor decrease with frequency, while conductivity and attenuation are direct proportional with frequency. The behavior of the sample holder is satisfactory due to its low attenuation, low reflection coefficient, and approximately constant characteristic impedance over the operating frequency range. The real part of permittivity of Teflon is constant and low compared with plexiglas and PVC whom permittivity decreases with frequency. PVC has larger permittivity due to its content of C1-atoms. The loss factor of PVC and plexiglas decreases with frequency and they have relatively low loss. Teflon has very low loss, and the available instruments are not suitable for measurement of its loss factor because of their relatively large uncertainty. Attenuation due to dielectric material is low because loss factor is low, too,(equation 2.4) and it increases with frequency. This is because the reduction in signal level is caused by the conductivity of the line material and dielectric material inside the line. The conductivity is very large compared with d.c. one, and it increases with frequency. For example dc conductivity of PVC at 20 oC is in the order of 10-14 mho/cm and for Plexiglas it is in the order of 10-12.

for PVC and plexiglas is shown in figure (5). The conductivity of teflon was not evaluated because its loss factor was not measured.

Equation (2.4) can be written in a form containing frequency and the real and imaginary parts of permittivity. This suggests that α is proportional to $f\,\varepsilon_r'' / \sqrt{\varepsilon_r'}$ .Both real and imaginary parts decrease with frequency, and therefore the variation of attenuation depends slightly on their ratio and it increases with frequency (fig. 6).

Fig. 6 :Frequency Dependance of Attenuation



Molecular polarization has limiting operating frequency due to the large mass of molecules compared with electrons. This is because at high frequency, the molecular dipole moments can't rotate fast enough to keep up with the electric field. As a result, its contribution to dielectric constant is neglected. [18].

Since the atom in the solid vibrates around the equilibrium position, there is a delay between changes in the field and changes in the polarization. This delay is expressed as a loss angle [18]. In polar polymers, the loss factor represents the sum of leakage and relaxation processes. Leakage loss is inversely proportional to frequency [16]. The variation of the loss factor of PVC and plexiglas with frequency is shown in figure (4). It decreases with increasing in frequency. Teflon has very low loss, and so evaluation of its loss factor by the used network and method is impossible due to uncertainty in the scattering parameters.

Fig. 4:Frequency Dependance of Loss Factor

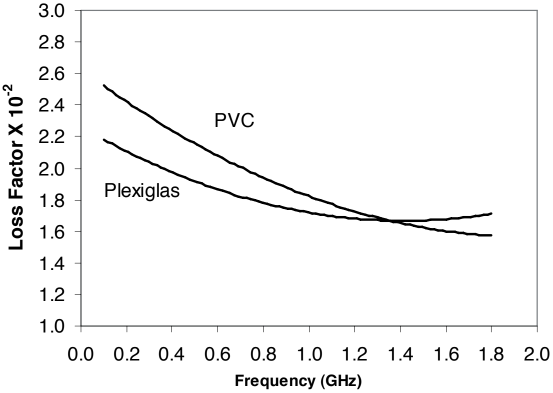
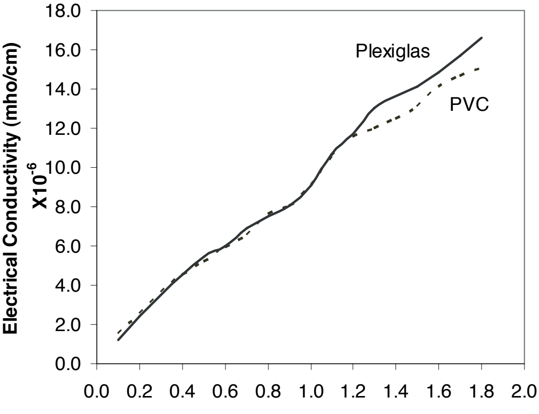


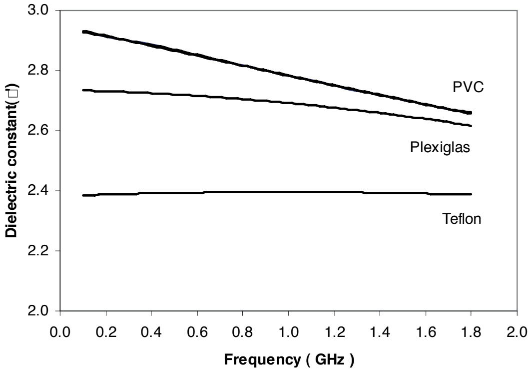
Fig. 5 :Frequency Dependance of Electrical Conductivity



Conductivity depends directly on frequency and the loss factor (equation 2.3). Conductivity increases with frequency because the variation of the loss factor is relatively small, and the change in frequency is dominant. The variation of conductivity with frequency

The real part of permittivity decreases with increasing the frequency; this can be attributed to the relaxation phenomena. At low frequency, there will be sufficient time for the polarizing charges to response to the electric field. Therefore, the contribution of these dipoles to permittivity will be large. As the frequency increases, the dipoles will not have the ability to rotate with sufficient speed to follow alternation of the field [7, 16].

Fig. 3:Frequency Dependance of Dielectric Constant



The variation of the real part of permittivity with frequency is shown in figure (3). Teflon has low dielectric constant; about 2.4; and independent of frequency. This provides the evidence that teflon is a non-polar polymer, and so it contributes only electronic polarization [17, 18].In the absence of applied field, teflon has zero electrical dipole due to its symmetrical structure. It is one of best materials for low - loss applications; particularly at high frequencies [12]. PVC and plexiglas have larger dielectric constant, because they have molecular polarization in addition to electronic polarization. The magnitude of the dipole moment per molecule for PVC is large because it has numerous polar sites along its chains; one with each chlorine atom. This will shift the dipole orientation with the application of electric field. Plexiglas has lower dielectric constant than PVC because the polar sites at C1-atoms in PVC are larger than those at O-atoms in plexiglas. This means that the dielectric constant depends on the molecular structure of the polymer [18].

(١) Vector analyzer with operating frequency range from 0.1 to 2000 MHz.
(٢) Sweep generator with frequency range from 0.4 to 2500 MHz.
(٣) S-parameter Test adapter with frequency range from 5 to 2000 MHz.

3.5 Measurement Procedure:

The desired quantities which can be measured directly and displayed on the vector analyzer are scattering parameters. The planes t_1 and t_2 are taken to be the reference planes of measurements. Evaluation of complex permittivity requires the measurement of scattering parameters at reference planes $T_{\varepsilon 1}$ and $T_{\varepsilon 2}$. The amplitudes of S_{11} and S_{12} at t_1 and t_2 are equal to those amplitudes of S_{11} and S_{12} at $T_{\varepsilon 1}$ and $T_{\varepsilon 2}$, respectively. The sample is fixed in the middle position inside the holder. Complex permittivity is calculated from equation (2.2) and then equation (2.3) is used to determine the conductivity and equation (2.4) to determine attenuation.

4. RESULTS AND DISCUSSION:

Results of measurements are given in the following table :

Sample	Dielectric Constant		Loss factor X 10^{-2}		Electric Conductivity (mho/cm)X10^{-6}		Attenuation (db/m)	
	From	To	From	To	From	To	From	To
Teflon	2.4	2.4						
PVC	2.66	2.93	1.50	2.77	1.52	15.08	0.15	1.51
Plexiglas	2.61	2.74	1.66	2.22	1.20	16.61	0.12	1.68

diameter. The holder consists of two pieces with total length of 34.4 cm, fixed together via flanges. The advantage of this type of the line is its ease of use and analysis.

The signal used for sample testing is transported via flexible coaxial cable before its entrance and after its departure from the holder. These lines are linked with the coaxial holder by HP connectors. The length of each connector is about 4.8 cm, and the medium between the inner and outer conductors is teflon with 5 mm in thickness. The characteristic impedance of the holder and the connectors is 50 Ω.

The coaxial cable supports TEM-mode, which has no cutoff frequency. The frequency limit of the experiment is determined by the dimensions of the coaxial cable. However, an upper frequency limit could exist due to the appearance of higher-order modes, i.e., if the frequency exceeds this limit, the coaxial cable will not support TEM-mode [13]. The upper frequency limit depends on the coaxial dimensions, and it can be approximately given in terms of the wavelength as $\lambda > \pi (a + b)$, where a & b are inner and outer radii of the coaxial cable [14].

The upper frequency limit of the coaxial cable used in the present work is about 1.8 GHz. The higher-order modes are avoided because they destroy the desired incident field distribution, and make the interpretation of results difficult [13].

3.3 Fabrication of Samples:

The samples were prepared from sheets of different thickness. They were made in the form of annular discs with dimensions identical with the inner and outer conductors of the coaxial holder. The thickness of PVC and plexiglas samples is 20 mm, while the teflon thickness is taken to be 10 mm. The samples are smooth and their size fits exactly the coaxial cable.

3.4 Network Analyzer:

The network analyzer is a compact instrument which can be used to measure complex quantities such as impedance and scattering parameters. The use of this device is more convenient when rapid and direct measurements over a board frequency range are required [15]. The experimental set up includes the following equipments:

(2.2)

The scattering parameters in this equation are measured at reference planes $T\varepsilon_1$ and $T\varepsilon_2$, and they are normalized to the characteristic impedance of the coaxial line. Planes $T\varepsilon_1$ and $T\varepsilon_2$ are taken to be the surfaces of the sample as shown in fig.(2).

The conductivity of the medium can be determined from Maxwell's equations, and is given by [6, 7]

$$\sigma = 2\pi f\ \varepsilon_0 \varepsilon_r^{"} = (5.6\mathrm{X}10^{-4}) f\ \varepsilon_r^{"} \qquad \text{mhos/cm}$$

(2.3)

where f is frequency in GHz. Attenuation due to dielectric loss for non-magnetic and low loss materials (tan δ « 1) is given by [8,9] :

$$\alpha = \frac{27.3}{\lambda_0}\sqrt{\varepsilon_r^{'}}\tan\delta \qquad \text{dB/m}$$

(2.4)

where λ_0 is the free space wavelength.

3. EXPERIMENTAL WORK

3.1 Tested Samples:

Measurements were performed on three insulating polymers:

(١) Polytetrafluorethylene (PTFE): Its trade name is teflon and it has good electrical properties [10].

(٢) Polyvinylchlorride (PVC): It is the world's most widely used plastic and one of the cheapest materials [10].

(٣) Polymethylmethacrylate (PMM): It is known also as plexiglas, and it is excellent substitute for glass [11, 12].

3.2 Construction of the Sample Holder:

The sample holder used is the flanged coaxial cable shown in Figure (2). The inner conductor is made from brass with 3.2 cm in diameter, and the outer conductor is made from aluminum with 7.6 cm in

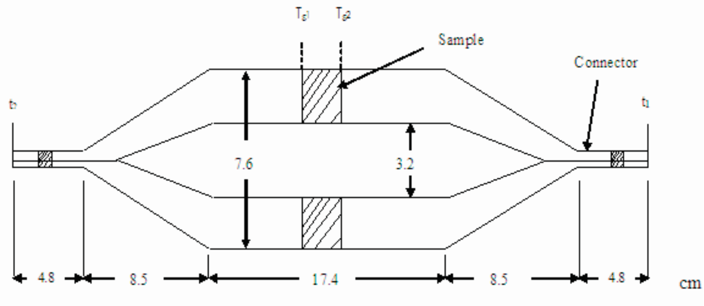


Fig. 2 : Coaxial Cable

2.2 Scattering Parameters:

The relationship between incident and scattered wave components of a junction is given by the scattering parameters. Two- port junction is shown in figure (1) with incident waves V^+_1, V^+_2 and scattered waves V^-_1, V^-_2.

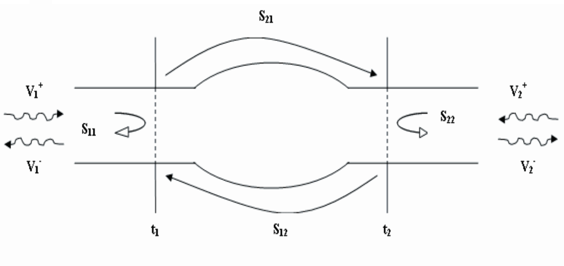


Fig. 1 : Two port junction

Quantities S_{11} and S_{22} represent the reflection coefficients at port 1 (plane t_1) and port 2 (plane t_2) respectively, while S_{21} and S_{12} represent the transmission coefficients from port 1 to 2 and from port 2 to 1 respectively. Shifting reference planes t_1 and t_2 will only affect the phases of the parameters [٥].

2.3 Dielectric Material:

An important quantity related to dielectric material is its dielectric constant. Relative permittivity (complex dielectric constant) can be written as:

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0} = \varepsilon'_r - i\,\varepsilon''_r = \varepsilon'_r(1 - i\tan\delta)$$

(2.1)

The imaginary part ε''_r is called the loss factor of the material, and δ is called the loss angle which is proportional to the ratio of the power lost as heat to the stored energy in the dielectric material [1, 5]. When the measurement of scattering parameters is performed in coaxial cable (TEM mode) filled with dielectric material, and then the relative permittivity is given by [5]:

$$\varepsilon_r = \frac{(1-S_{11})^2 - S_{12}^2}{(1+S_{11})^2 - S_{12}^2}$$

1. INTRODUCTION:

The electrical and mechanical characteristics of materials are very important for different electrical and electronic applications. Knowledge of their electrical properties such as permittivity (ε), permeability (μ) and conductivity (σ) is very essential for different applications including; microwave heating and biological effects [1]. Measurements of ε and μ are; nowadays; of increasing importance in telecommunication and in the design and specification of circuit components. Determination of dielectric loss is important for the construction of microwave ovens, diathermy applicators and industrial dielectric heating [2]. In the intermediate frequency range; i.e; 1 MHz < f < 3 GHz, an appropriate mean to perform measurements is by using coaxial cable. This cable is capable to support all frequencies from low frequency (≈ dc) up to microwave frequencies without any side effects. Tapered coaxial cable is used as sample holder to perform required measurements on different materials to evaluate some of their characteristics for the required applications [3].

The aim of this work is to construct a special coaxial cable, which will be used as a sample holder in order to measure the electrical characteristics of some insulating materials in the frequency range 5-1800 MHz at room temperature.

2. THEORY:

2.1 Structure of Coaxial Cable:

Coaxial cable consists of a round inner conductor and concentric outer conductor separated by a dielectric medium. The insulating materials used to separate the conductors must have low loss at high frequencies. Teflon and polyethylene are commonly used for these frequencies [3] . The electric field **E** and magnetic field **H** of the propagating electromagnetic wave are confined entirely inside the cable. This is because the thickness of the outer conductor is; in general; many times greater than its penetration depth [3,4].

ملخص

في هذا البحث صمم كابل محوري يحمل العينة المراد اختبارها، وذلك لقياس الخواص الكهربائية لبعض المبلمرات. وقد قيس ثابت العزل الكهربائي (السماحية)، والايصالية الكهربائية والتوهين الكهربائي. أما العينات التي تم اختبارها فهي: التيفلون، PVC وزجاج البلكسي. جميع القياسات تمت في مجال التردد من ٥ إلى ١٨٠٠ ميجاهيرتز عند درجة حرارة الغرفة. وقد قيست معاملات التشتت باستخدام جهاز المحلل الشبكي والذي يقيس مقدار التشتت وزاوية الطور، ومن هذه القياسات حساب ثابت العزل الكهربائي بجزئه الحقيقي الذي يمثل سماحية الوسط والجزء الخيالي الذي يمثل معامل الفقدان. أما الايصالية الكهربائية ومعامل التوهين فقد تم قياسهما من معرفة معامل الفقدان خلال الوسط أو العينة. ولقد أظهر الكابل المحوري كأسلوب للقياس كفاءة في ايجاد الخواص الكهربائية مقارنة مع الطرق الأخرى.

Abstract

In this work a coaxial cable is constructed to be used as a sample holder to measure some electrical properties of polymer samples. Complex dielectric constant, electrical conductivity and attenuation for Teflon, PVC and Plexiglas are measured at certain frequencies. All measurements are carried out at room temperature between 5 and 1800 MHz. Measurements of scattering parameters are carried out using network analyzer device which measures the magnitude and phase angle. From these measurements dielectric constant, which involves permittivity (real part) and loss factor (imaginary part), is determined as a function of frequency. Electrical conductivity and attenuation are measured from their relation with loss factor through the sample or media. The coaxial cable provided us with a satisfactory method for measuring electrical properties.

Electrical Properties of Dielectric Materials at Intermediate Frequencies

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