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DIELECTRIC PROPERTIES OF OVEN DRY MALAYSIAN WOOD

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ABSTRACT

Four species of selected local hard wood had been studied for dielectric properties. Measurements were made at frequency 10^{-2} Hz to 10^{6} Hz from room temperature to 100°C. Dielectric behaviors show that the low frequency dispersion (LFD) proposed by Jonscher and the DC conductivity dominated the profile of the dielectric processes.
Dielectric analysis was made by shifting the data of relative dielectric permittivity and the loss factor to become a master curve. From the shift of the loss peak at various fixed temperatures the activation energy was determined by plotting of Arrhenius plot of ln ε" against 1000/T. The dielectric properties of wood were found to be dependent on temperature and density of wood species. Impedance, Z, and modulus, M, plots were also used to reveal the model of the dielectric behaviour in wood.

INTRODUCTION

One of the good insulators or high resistance are wood when it is in the dry condition. However significant variations in resistivity exist which is in grain orientation and temperature. In the longitudinal axes, the conductivity of wood is approximately twice rather than tangential or radial axes and electrical conductivity doubles for increasing of 10°C in temperature [1]. Electric and dielectric properties not only depend on the molecular structure but also on moisture. The dielectric constant of wood increased continuously as the moisture content increased, and decreased with increasing frequency of the applied field [1]. This work report on the result of dielectric property measurements carry out on the oven dry Malaysian wood.

METHODOLOGY

Wood samples were obtained from Forest Research Institute of Malaysia (FRIM), Kepong, Malaysia. The samples used are given in Table 1. The samples were cut into circular pieces of 35-40 mm in diameter and 3.0-3.5 mm in thickness and made smooth and parallel by gently using different grades of sand paper. All the sample were tested in oven-dry condition. The dielectric constant or relative permittivity and the dielectric loss factor measurements were carried out by holding a sample disk firmly between parallel-plate stainless-steel electrodes in a an evacuated cell. The dielectric constant and the lost factor were measured at temperatures of 21°C, 40°C, 60°C, 80°C, 100°C, by using dielectric spectrometer facilitate with temperature controller and controlled by computer at frequency from 10^{-2} to 10^{6} Hz. Prior to the measurement the samples were oven dried by heating the specimens in oven at 100^{o}C for 24 hour.

Table 1: Wood sample used in this work

Sample	**Scientific Name**	**Density (kg/m^3)**	**Dimension of the sample - A/d (cm)**
Balau	Shores spp.	975	0.105
Tualang	Koompassia Excelsa	835	0.108
Gerutu	Parashorea lucida P.densiflora P.Globasa	690	0.123
Macang	Magifera spp.	560	0.101

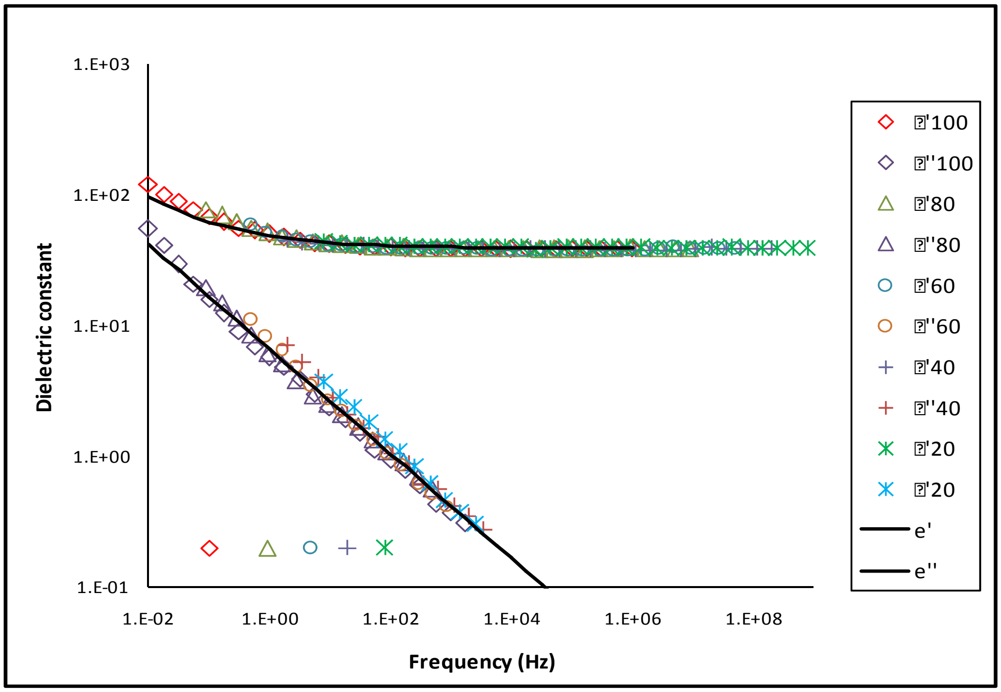
RESULT & DISCUSSION

Dielectric constants and dielectric loss factor for woods at 21^{o}C, 40^{o}C, 60^{o}C, 80^{o}C, and 100^{o}C as a function of frequencies are plotted in normalised form to produce a single master curve as outline [2] by lateral shifting of the data for the different temperature to characterize the different samples for Balau, Tualang, Gerutu and Macang as shown in Figure 1 (a), (b), (c) and (d) respectively.

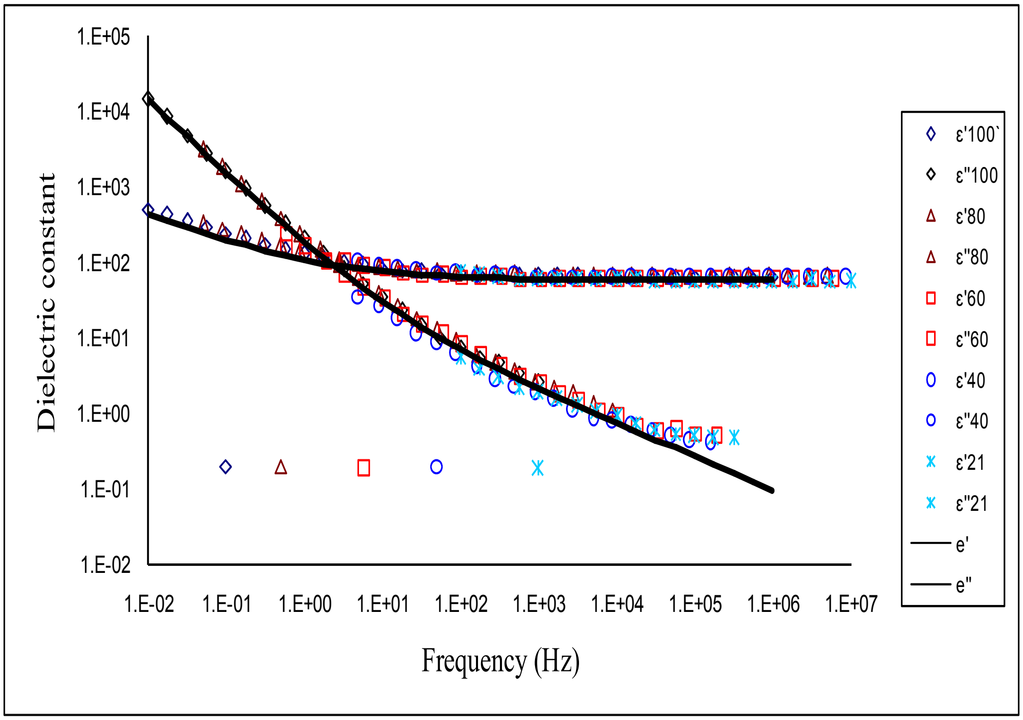
Dielectric loss factor increase sharply for all temperature as frequency decreased, in manner similar to Kabir [3,4]. The slope at low frequency is -1 indicating that the effect of dc conduction is strong. However, for the whole frequency range the dielectric behaviour obey the low frequency dispersion proposed by Jonscher [2] in the form of $A(i\omega)^{n-1}$ superimpose with dc conductivity and high frequency dielectric constant. The model for the dielectric behaviour can be written as the general equation in the form as

$$\varepsilon^{*}(\omega) = A(i\omega)^{n-1} + \varepsilon_{\infty} - i\sigma / \omega\varepsilon_{o} \qquad (1)$$

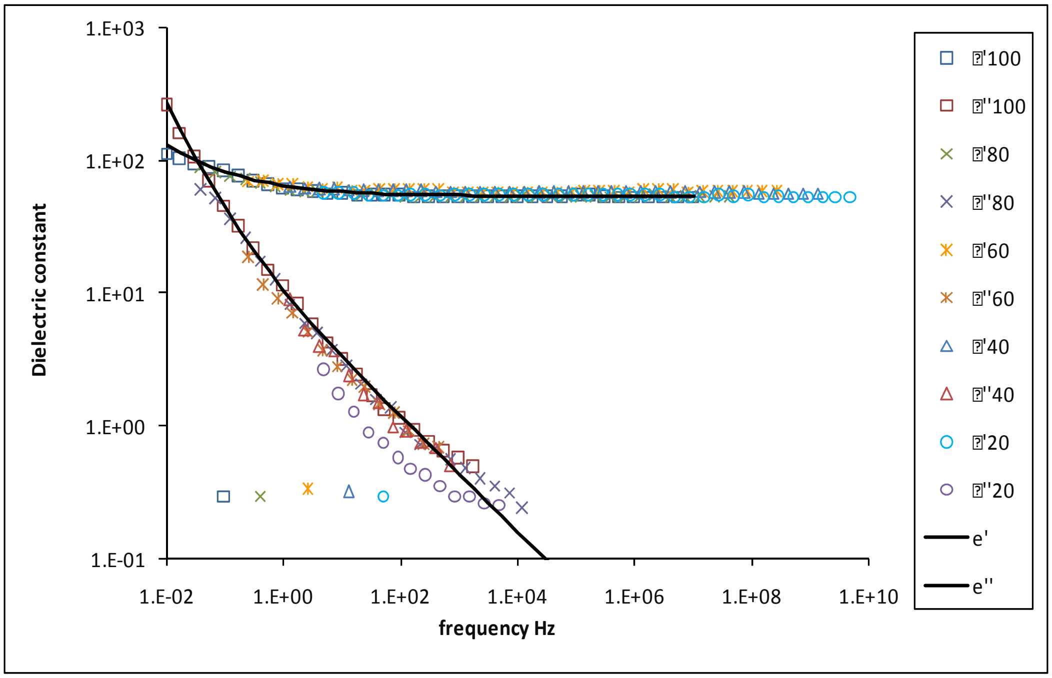
where ε_{∞} is high frequency dielectric constant, σ is and conductivity, ε_{o} is the free space dielectric permittivity = $8.854\text{x}10^{-14}$ farad/cm and ω is angular frequency is in radian. The first term in Equation 1 describes a power law in which the complex dielectric constant is $A\omega^{n-1}\sin n\pi/2 - iA\cos n\pi/2$ $(0<n<1)$, this expression can be related to models of ion-ion interaction [5]. Table 2 shows the values use to model the dielectric behaviour. The solid lines in Figure 1 are the curves drawn using the values indicate in Table 2.



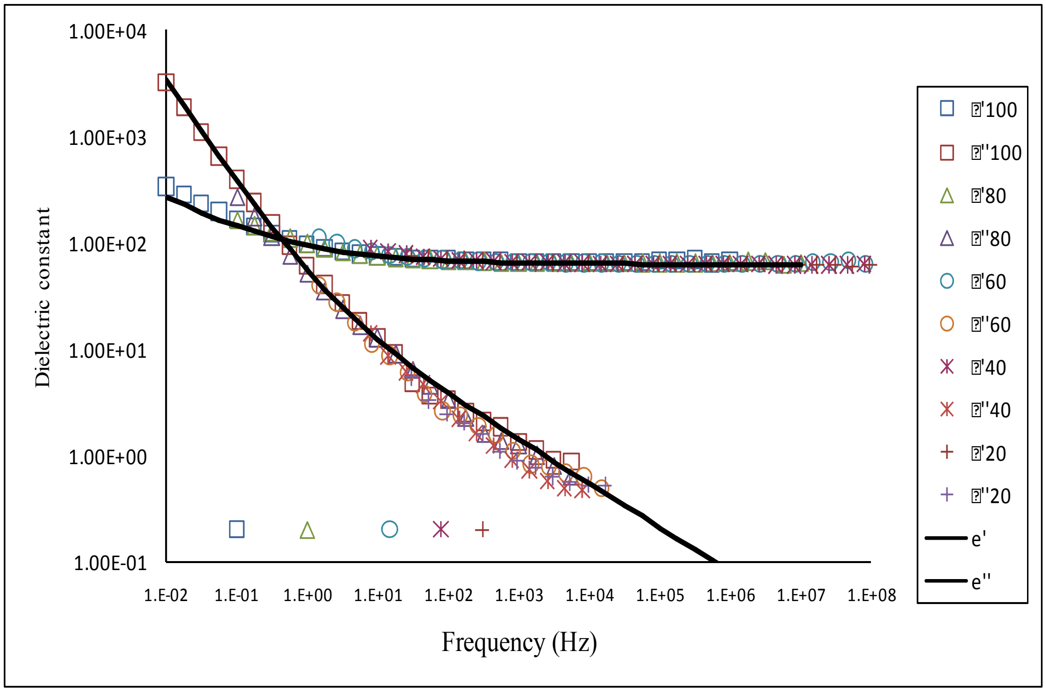
(a)Gerutu



(b)Balau



(c)Macang



(d)Tualang

Figure 1: The master plot of ε’ and ε” data for different temperatures for the hard wood.

Table 2: Parameters that are used in the theoretical dielectric spectroscopy plot and activation energy for each wood sample in this study.

Sample	**A (S cm^{-1} rad^{-n})**	**n**	ε_∞	**σ (S cm^{-1})**	**Activation Energy, E$_A$(eV)**
Balau	186.6	0.46	65.0	903.9	1.10±0.03
Tualang	116.9	0.41	63.3	203.3	0.96±0.11
Gerutu	40.8	0.40	39.0	-	0.78±0.07
Macang	38.7	0.43	54.2	13.6	0.75±0.04

From the Figure 1 it is clear that the ε” plot shown no peaks indicating that no dipolar process exits in the sample used. However the polarization process could be due to mobile charge species that move to and fro following the ac field. Types of process in the wood sample can be determined; other alternative formalism usually used to detect the electrode and bulk polarisations are dielectric modulus and impedance models. The dielectric modulus is defined as

$$M^* = \frac{1}{\varepsilon^*} = \frac{\varepsilon'}{\varepsilon'^2 + \varepsilon''^2} + i\frac{\varepsilon''}{\varepsilon'^2 + \varepsilon''^2} \qquad (2)$$

and the impedance is defined as

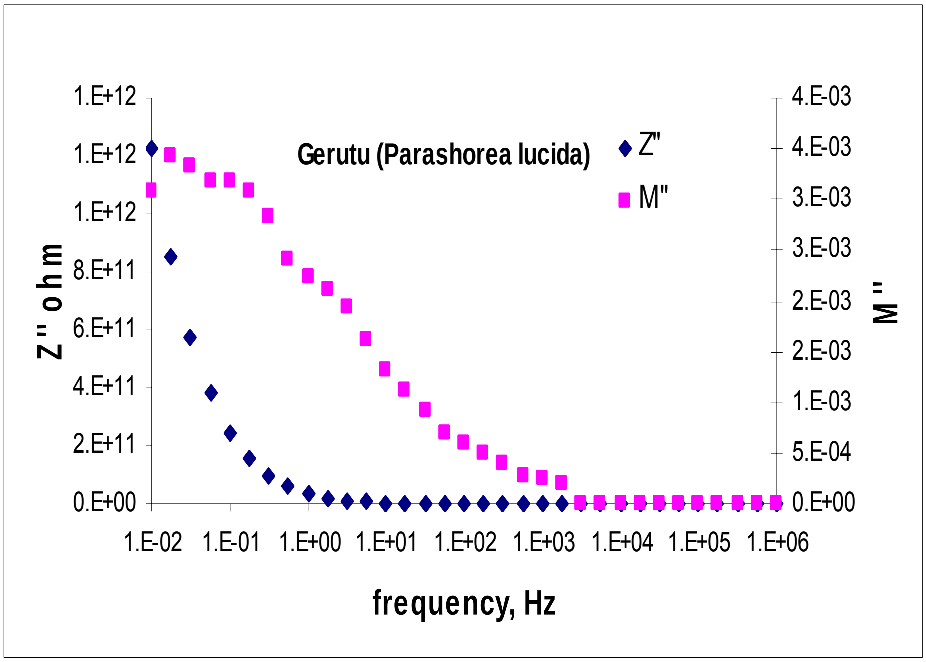
$$Z^* = \frac{1}{i\omega C_o \varepsilon^*} = \frac{\varepsilon''}{\omega C_o(\varepsilon'^2 + \varepsilon''^2)} - i\frac{\varepsilon'}{\omega C_o(\varepsilon'^2 + \varepsilon''^2)} \qquad (3)$$

where C_o is capacitance of the cell without sample. It is useful to plot Z” and M” in a same graph, it will help to distinguish whether a relaxation process in a material is due to the delocalised (long-range) or localised (short-range) movement of carrier or relaxation process. For bulk process with single relaxation, both localised and delocalised processes may occurred simultaneously [6]. If the process is delocalised, the peak in Z” against log f and M” against log f will coincide at the same frequency. If the process is localised then both peaks will occur at different frequencies [7]. Figure 2 shows the variation of parameters Z” and M” as a function of logarithmic frequency measured at 100°C for the studied wood sample. For the present wood studied the Z” and M” peaks do not overlap but are very close indicating the component from localised state. However there is dc conduction at low frequency, then we suggest that the different frequency for Z” and M” peaks are due to both long-range (delocalised) and localised relaxation.

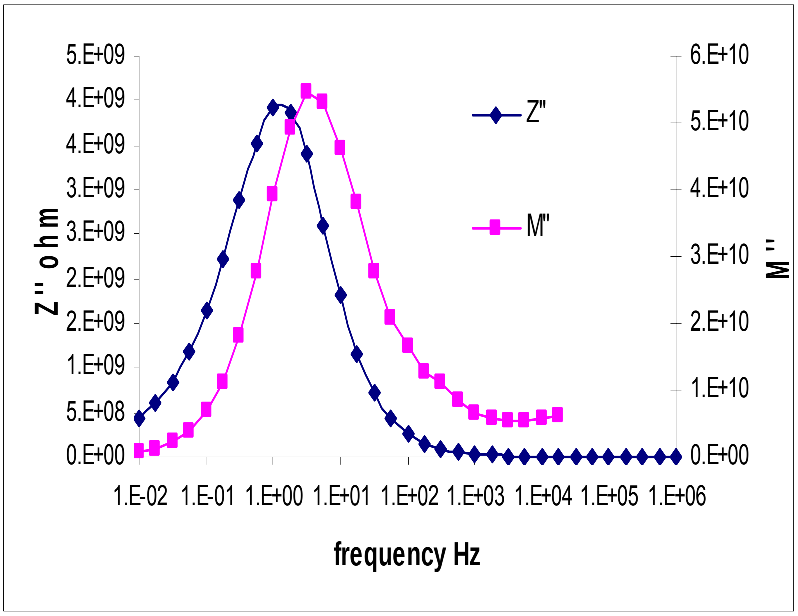
The activation energy values (E) are calculated from the frequency dependent Arrhenius equation.

$$f = f_o \exp(-E/kT) \qquad (4)$$

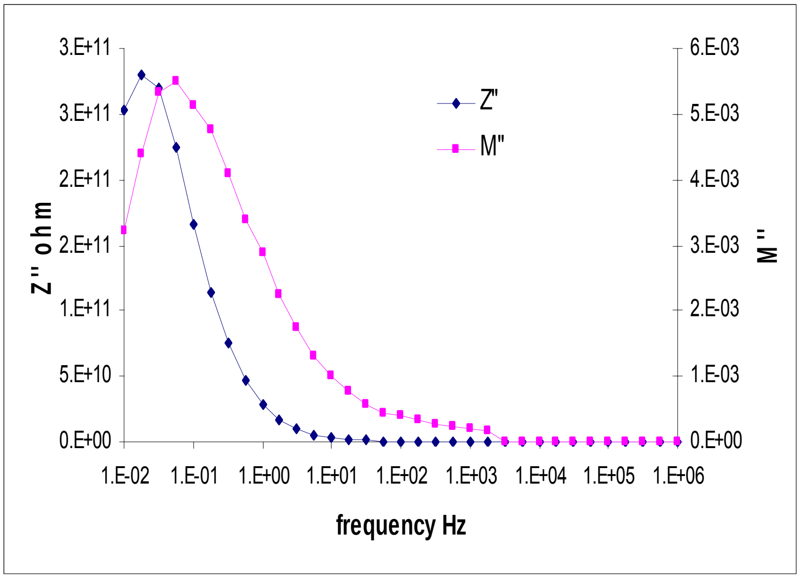
where k is the Boltzman constant, E is the activation energy, and T is the absolute temperature and f_o is pre-exponential factor. The Arrhenius plot is shown in Figure 3 is done by plotting the corresponding frequency shift (from Figure 1) against reciprocal temperature for the balau wood only. Others wood were done in the same procedure. The Activation Energy for Balau, Tualang, Gerutu and Macang woods are listed in Table 2. The lowest density exhibits lowest activation energy, whereas largest density has the highest activation energy. Figure 4 shows the variation of activation energy values with density. The activation energy value obtained is higher (double) than the wood studied by Norimoto and Yamada [8]. This may be due to Malaysian wood (tropical area) is not the same with wood from seasonal area country.



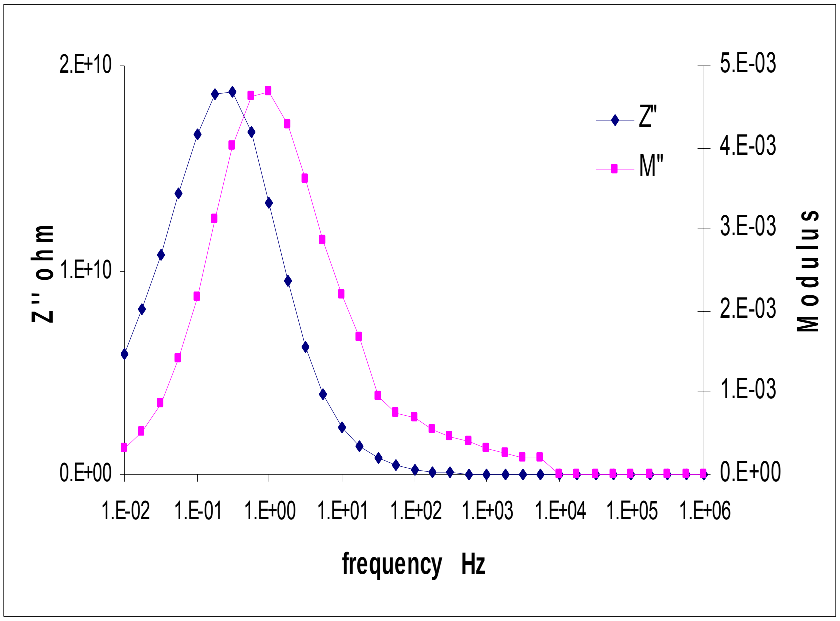
(a)Gerutu



(b)Balau



(c)Macang



(d)Tualang

Figure 2: Z" plot and M" plot for local hard wood at temperature 100^{o}C

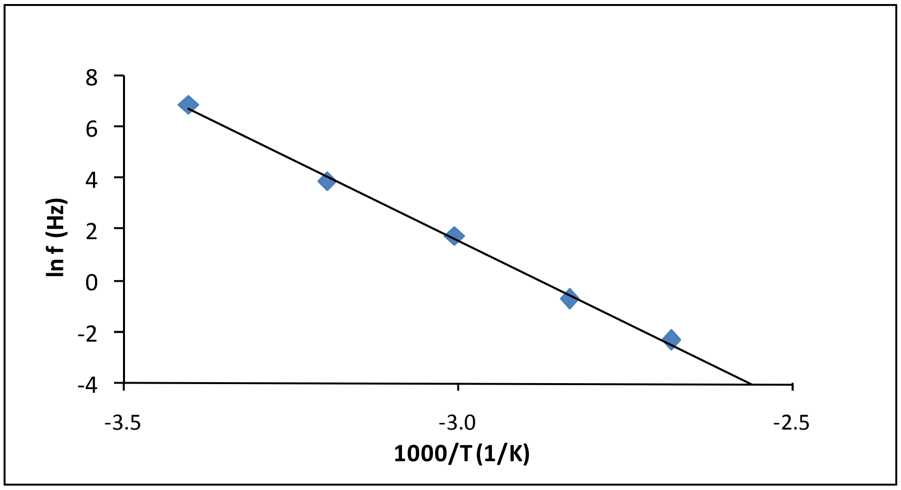


Figure 3: ln *f* against 1/T for Balau wood

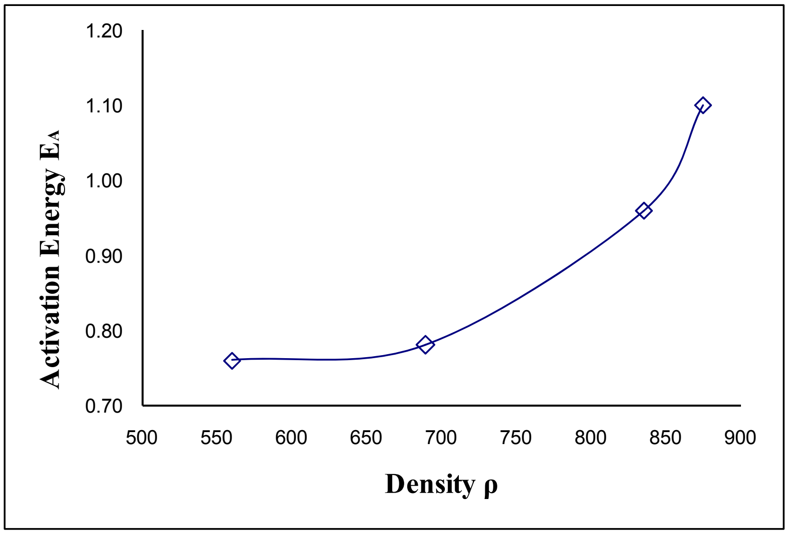


Figure 4: Graph of the activation energy for different Density

CONCLUSION

The high frequency dielectric constant and the activation energy of oven dried wood in this studies increases with density. The relaxation processes are due to both long-range and localised migration of carrier. No dipolar relaxation is found but the relaxation is due to the quasi dc (low-frequency dispersion) process as proposed by Jonscher [2].

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