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DIELECTRIC PROPERTIES OF HEVEA RUBBER LATEX

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DIELECTRIC PROPERTIES OF HEVEA RUBBER LATEX

By

JUMIAH HASSAN

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LIST OF SYMBOLS AND ABBREVIATIONS

C	capacitance
Q	charge
V	voltage
ε^*	relative complex permittivity
$\varepsilon^*(\omega)$	frequency dependent relative complex permittivity
$\varepsilon^*{}_w$	relative complex permittivity of water
$\varepsilon^*{}_r$	relative complex permittivity of solid continuum
$d\varepsilon^*$	increment of the relative complex permittivity
ε_o	permittivity of free space (ε_o = 8.85 x 10^{-12} F/m)
$\varepsilon(0)$	permittivity at low frequency
$\varepsilon(\infty)$, ε_∞	permittivity at high frequency
ε_s	static permittivity
ε_{lp}	loss peak response
ε_{qd}	quasi-dc response
ε'	permittivity or dielectric constant
$\varepsilon'(\omega)$	frequency dependent permittivity
ε''	dielectric loss factor
$\varepsilon''(\omega)$	frequency dependent dielectric loss factor
$\varepsilon''_{\max}$	maximum dielectric loss factor

$\varepsilon''_{\min}$	minimum dielectric loss factor
ε''_c	dielectric losses due to ionic conductivity
ε''_d	dielectric losses due to dipolar orientation or polarisation
ε''_e	dielectric losses due to electronic polarisation
ε''_a	dielectric losses due to atomic polarisation
ε''_i	dielectric losses due to interfacial polarisation
ε''_t	total dielectric losses
A	area of the plates of the capacitor
d	distance between the plates of the capacitor
P	polarisation
$P(t)$	time dependent polarisation activation energy
$\overline{E}_{av}$	average electric field
$\overline{E}_w$	average electric displacement in water
$\overline{E}_r$	average electric displacement in solid continuum
$E(u)$	time dependent electric field
$f(t-u)$, $f(t)$	current decay function
e	natural logarithmic base
t	time
τ	relaxation time
α_e	electronic polarisation
α_i	ionic or atomic polarisation

α_d	distortion or orientation polarisation
α_s	space charge polarisation
j	$\sqrt{-1}$
J	current density
σ	conductivity
∇	del operator
H	magnetic intensity
$\nabla \times H$	curl of H
D	electric displacement
$\overline{D}_{av}$	average electric displacement
$\overline{D}_w$	average electric displacement in water
$\overline{D}_r$	average electric displacement in solid continuum
$D(t)$	time dependent electric displacement
$\frac{\partial}{\partial t}$	partial derivative with respect to time
ω	angular frequency
ω_p, ω_c	characteristic angular frequency
f	frequency
f_{rel}	relaxation frequency
f_p, f_c	peak or characteristic frequency
f_i	field ratio

$\propto$	proportional
α	empirical constant
π	pi ($\pi = 3.14$)
F_o	normalizing parameter
${}_2F_1(.:;)$	gaussian hypergeometric function
$\Gamma(\,)$	gamma function
n	correlation coefficient for intra-cluster relaxation mechanisms (low-frequency region)
m	correlation coefficient for inter-cluster relaxation mechanisms
p	fractional correlation index
δ_w	volume fraction of water
δ_r	volume fraction of solid continuum
M_w	weight of wet sample
M_d	weight of dry sample
γ_r	relative density of the solid continuum
γ_w	relative density of water
A_l	depolarisation factor
$a,b,c.$	semi-axes of the ellipsoid
λ	ellipsoidal coordinate
U	magnitude of the average electric field
η	mixing condition (microwave region)

G	conductance
k	Boltzmann constant (k = 8.63 x 10^{-5} eV/molecule.K)
W	activation energy
T	temperature
eV	electron volts
MC	moisture content
tsc	total solid content
drc	dry rubber content

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DIELECTRIC PROPERTIES OF HEVEA RUBBER LATEX

By

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FEBRUARY 1999

Chairman: **Associate Professor Hj. Kaida bin Khalid, Ph.D.**

Faculty: **Science and Environmental Studies**

The dielectric properties of Hevea Rubber Latex have not been thoroughly investigated and are, therefore, not well understood. It is a biological product with a complex composition. A typical composition of freshly tapped natural rubber is made up of 50-80% water, 18-45% rubber hydrocarbon and 2-5% non-rubber constituents. The basic components of non-rubber constituent are proteins, lipids, quebrachitol and inorganic salts. Measurements of the dielectric properties at various moisture contents and temperatures -20 to -60°C in the low-frequency region of 10^{-2} to 10^{6} Hz were done using the Dielectric Spectrometer. The results of the measurement in the low-frequency region are expressed using the dielectric response model. For Hevea rubber latex, three distinct responses have been indicated. These are the real relative permittivity at high frequency $\varepsilon(\infty)$, the loss peak response ε_{lp} and the conductance G. The total losses are

conductive losses which arise due to the conducting phases found in latex, and dipolar losses which appear as loss peak responses due to the relaxation of the water molecules.

The relaxation peak is shifted to a higher frequency as water content in the latex decreases and as temperature increases. This phenomenon could be due to the difference in the mechanism of polarisation relating to ion and the polarisation relating to ice.

The activation energy for latex concentrate is 1.66 eV while for fresh latex 2.34 eV. Ice has a non-constant activation process. This is due to the existence of two activation processes. The first activation process gives an activation energy of 0.51 eV whilst the second activation process results in a much lower activation energy. The high activation energy for fresh latex as compared to ice could be due to latex particles being bonded by the water molecules which needs more energy to dissociate.

In the microwave region of 0.2 to 20 GHz, dielectric measurements were done using an open-ended coaxial sensor and an automated network analyser at various moisture contents and temperatures from -30 to 50°C. Experimental results in the microwave region show that in the liquid state a conductive loss due water molecules. However, at 10 GHz there is a good relationship between the dielectric properties of hevea latex and moisture content and is almost unaffected by the non-rubber constituents, presevatives and temperature Therefore, 10 GHz is the most suitable frequency for the analysis and design of the microwave moisture meter or latexometer There is a steep increase in the real relative permittivity of about one order of magnitude and dielectric loss factor of about two orders as the phase of latex changes from solid to liquid

The effect of temperature on the conductive losses and dipole orientation can be clearly seen in the studies These results are compared with the values predicted by the biphase dielectric mixture model recommended by Weiner, Bruggeman and Krazewski All the measured values lie within the Weiner's boundaries and they are well below and close to the upper limit of the Weiner's model The study suggests that the dielectric properties of Hevea latex are mainly due to the orientation of loosely bound water molecules and the shape of the molecules is assumed to be ellipsoidal

The dielectric properties of Hevea latex will also be useful in estimating microwave absorption during microwave heating, drying and curing operations and to study the degree of binding of the water molecules.

Abstrak dissertasi yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SIFAT DIELETRIK SUSU GETAH

Oleh

JUMIAH HASSAN

February 1999

Pengerusi: **Profesor Madya Hj. Kaida bin Khalid, Ph.D.**

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Sifat-sifat dieletrik susu getah belum dikaji dengan begitu mendalam, maka pemahaman megenainya amatlah kurang. Susu getah adalah hasil biologi yang mempunyai komposisi kompleks. Kebiasaannya, komposisi bagi susu getah yang baru ditoreh mengandungi 50-80% air, 18-45% hidrokarbon dan 2-5% bahan bukan getah Komponen asas bahan bukan getah adalah protein, lipid, quebrachitol dan garam inorganik. Pengukuran sifat dielektrik pada kelengasan yang berbeza dan suhu -20 ke -60°C pada rantau frekuensi-rendah 10^{-2} hingga 10^{6} Hz dibuat dengan menggunakan Spektrometer Dielektrik Keputusan pengukuran dalam rantau frekuensi-rendah diungkapkan dengan menggunakan model sambutan dielektrik. Bagi susu getah, tiga proses yang berbeza telah dikenalpasti Ini adalah pemalar dielektrik pada frekuensi tinggi $\varepsilon(\infty)$, sambutan kehilangan puncak ε_{lp} dan konduktans G. Jumlah kehilangan adalah kehilangan konduktiviti yang di sebabkan wujudnya fasa kekonduksian di dalam susu getah