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DIFFUSIVITY AND ELECTRICAL PROPERTIES OF GUM ARABIC, CARBON BLACK/KBRO3 COMPOSITE MATERIAL

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ABSTRACT
Porous Gum Arabic (GA) doped with carbon black (Soot) was prepared using solid state chemical method. Potassium bromide (KBrO3) was used as raising reagent in different temperature (50, 70, 90 and 110 C). Impedance spectroscopy (IS), scanning electron microscope (SEM) and Energy-dispersive X-ray Spectroscopy (EDS) were used in order to investigate the electrical properties of Gum Arabic, the diffusion coefficient, dielectric constant and the existence of elements, respectively. The results of diffusion coefficient and dielectric showed direct proportionality with the logarithmic frequency. The porosity of the sample was found to be directly proportional to the dielectric constant. The effect of temperature was profound as diffusivity and conductivity were found to increase with temperature.

KEYWORDS: Diffusion, Porous, soot, impedance spectroscopy, scanning electron microscope

Introduction
Diffusion is defined as the transport of mass in gases, liquids and solids under the influence of a concentration gradient proceeds spontaneously due to microscopic movement of mass is an irreversible process which leads to an increase in entropy and is only reversible by supply of work [1]. Another definition of diffusion is defined as the process by which an innovation is adopted and gains acceptance by members of a certain community [2]. Impedance spectroscopy was said to be the most useful technique for measuring diffusion and various electrical parameters such as, conductivity, dielectrics etc; and physical parameters can be utilized for calculating different physical features including; diffusivity, permeability and overall microstructure properties of a given specimen [3]. Anja Buchwald determines the diffusion coefficients of salt ions in masonry materials such as brick, mortar and sandstone. Beside the usage of diffusion experiments the impedance spectroscopy has also be applied [3]. Binay K. Dutta et al fabricated a homogeneous silica film by dip coating, they annealed the film at elevated temperatures, and characterize the film by the measurement of particle size distribution, scanning electron microscopy, spectroscopy measurement of the refractive index and thermal conductivity. They found that the porosity of the films decreased whereas refractive index and dielectric constant of it increased with the increase in the annealing temperature [4]. General formulations for diffusion and mass transport are outlined in Fick's first law of diffusion, which expresses the steady state flux of diffusion per unit area [5]. Diffusion following the Fick's first and second laws is termed Fickian diffusion, generalized diffusion model containing terms for both stress (pressure) and thermal gradient. Therefore the diffusion coefficients were determined by impedance spectroscopy measurements [2, 6].

In this work, we aim to improve the properties of Gum Arabic (GA) by doping it with carbon black (soot) and potassium bromide. Sample of GA doped with Carbon black/KBrO3 was prepared. The effect of doped and effect of different temperature on the properties of GA was investigated using Impedance spectroscopy (IS), scanning electron

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microscope (SEM). The IS was used for exploring the electrical properties while the structure and existence of elements were studied using (SEM) and Energy-dispersive X-ray Spectroscopy (EDS), respectively.

MATERIALS AND METHODS

Sample Preparation

Powder of Gum Arabic (GA), amount of carbon black (soot), and Potassium bromide (KBrO3) was used as raising reagent, and these compounds were mixed together and the mixtures were then compressed into a suitable size to make a balk material (see Table 1), and then heated in a different temperature rising from (50 to 110□C).

Experimental

Impedance spectroscopy method were performed by LCR meter analyzer 1920 Precision (LCR Meter, has characteristic of 20 Measurement Parameters Basic Accuracy (0.1%)) [7].

Table 1 Composition of the samples by wt%

Sample No.	Amount of Gum Arabic (g)	Amount of Carbon black (g)	Amount of $KBrO_3$ (g)	Thickens (cm)	Diameter (cm)	Area (cm^2)
Sample1	1.0	0.01	0.002	0.0022	0.175	0.3644
Sample 2	1.0	0.03	0.002	0.00214	0.175	0.3713
Sample 3	1.0	0.05	0.002	0.00215	0.175	0.37414
Sample 4	1.0	0.07	0.002	0.00216	0.175	0.37612

The NeoScope benchtop (J6000 JOEL SEM) complements both optical microscopes and traditional SEMs in the lab, and can be configured for advanced analytical applications. This compact electron microscope is as simple to operate as a digital camera, but has the powerful electron optics of an SEM, with up to 60,000X magnification. The NeoScope makes it simple for any skill level of operator to obtain outstanding SEM images in less than three minutes from sample loading to imaging. The microscope has a sleek new design with up-to-date features. Operation is via a touch screen, and is simplified with auto focus, auto alignment, auto contrast and auto brightness controls. The NeoScope operates in both low and high vacuum modes with three settings for accelerating voltage [8].

This all-new NeoScope now offers integrated, full-featured Energy-dispersive X-ray Spectroscopy (EDS) with SDD technology for advanced analytical applications. Whether used by trained electron microscopists as a simple screening instrument, or by lab technicians as a higher resolution alternative to the light microscope, the NeoScope accelerates the pace of research in the life sciences, forensics, and pharmaceutical fields as well as serves as a high throughput failure analysis tool [8].

HTF furnaces are ideal for testing and processing ceramic materials and other high melting point samples; Features; 1700 ºC , and 1800 ºC maximum operating temperature, 4, 5, 8, 10, 15, 25, and 27 liter capacity, outstanding performance from molybdenum disilicide heating elements for intermittent or continuous use, 8 segment programmable controller with separate over-temperature protection, up& away opening door keeps hot face away from user, advanced refractory interior, used in combination with energy efficient low thermal mass insulation, fan cooling for low external case temperature [9].

ELECTRICAL PROPERTIES

Measurement of the electrical properties of a material can be made in either the series or parallel mode. In the series mode, the complex impedance is measured as complex dielectric constant. So that the dielectric constant, or relative permittivity K*, of a material is the permittivity of the material normalized with respect to the permittivity of a vacuum, can be calculated by using the complex conductivity, [10].

$$\sigma^* = Y^* \frac{t}{A} \qquad (1)$$

$$K^* = \frac{\sigma^*}{i\omega\varepsilon_\circ} \qquad (2)$$

Where ω is angular frequency and $\varepsilon_\circ$ is the permittivity of a vacuum, $\varepsilon_\circ = 8.85 \times 10^{-12}$ F/m.
The conductivity σ_{eff} of the material can then be determined using R and the geometry h (thickness of cylinder) and A (area of cylinder) [10] figure (2):

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$$\sigma_{eff} = \frac{h}{R\,A} \qquad (3)$$

Using Nernst-Einstein-relation, the diffusion coefficient D_{eff} can be calculated from σ_{eff} and the carbon concentration in the sample [3]:

$$D_{eff} = \sigma_{eff} \frac{K\,T}{Z^2 F\,e\,c} \qquad (4)$$

k: Boltzmann constant, T: Temperature, z: charge number, F: Faraday constant, and e: electron charge.

RESULTS AND DISCUSSION

The measurements of dielectric impedance, diffusion and scanning electron microscope are done for the pure gum Arabic sample and that doped with carbon black (soot)/ Potassium Bromide Oxide (KBrO3). Figure (1) shows the Nyquist plot of a sample with Xs (Imaginary part of impedance Z") is plotted as function of Rs (Real part of impedance Z'). The frequency range is chosen between (20- 1MHz).The effect of temperature is investigated and the Xs was found to be inversely proportional to the temperature.

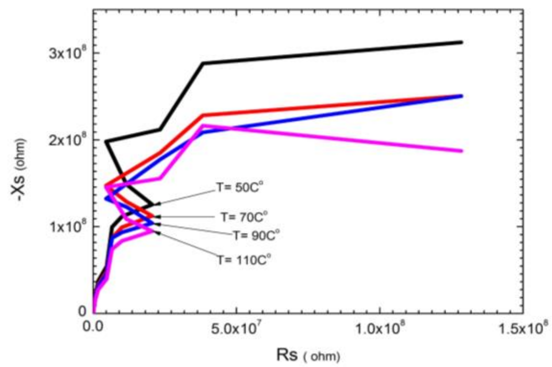

Figure 1 Nyquist plot of a sample (Rs: Real part of impedance Z', and Xs: Imaginary part of impedanceZ'') at frequency ranging between (20-1MHz).

The conductivity as a function of frequency for sample for different temperature is shown in Figure (2). The conductivity is found to decrease with increase in temperature, (sample have more pores), but when we increase the amount of carbon black in sample and temperature less than 50 C (room temperature), so that the sample is said to be conducting, (carbon black properties), at low frequency [11].

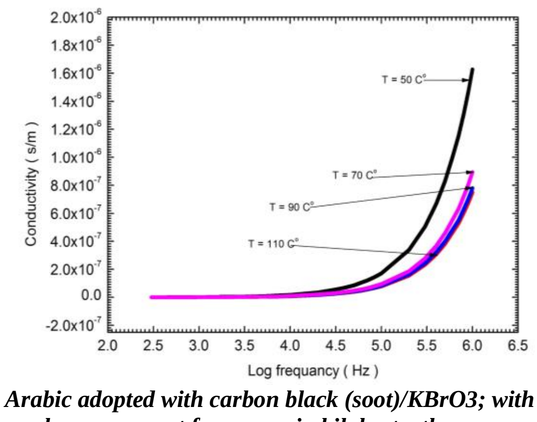

Figure 1 The conductivity of Gum Arabic adopted with carbon black (soot)/KBrO3; with constant weight; heated in different temperatures (T). The numbers represent frequency in kilohertz; the axes are in arbitrary scale units.

Dielectric constant as a function of frequency was performed for different temperature as shown in Figure 3. It can be observed that the dielectric is decreased when temperature was further increased. This behavior is expected as an opposite of that observed in case of conductivity.

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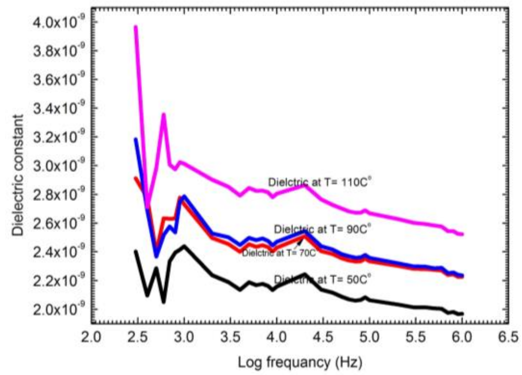

Figure 2 Dielectric constant of Gum Arabic adopted with carbon black (soot)/KBrO3; with constant weight; heated in different temperatures (T). The numbers represent frequency in kilohertz; the axes are in arbitrary scale units.

The diffusivity was calculated using equation (4). The effect of different temperature on diffusivity was investigated and plotted as shown in Figure 4. At low frequency the diffusivity was found to be identical for sample with different temperature. The diffusivity was found to increase with temperature. Furthermore, the relation between diffusion coefficient and heating treatment was shown in Figure (5). Linear relationship is observed for sample with different temperature. It can be observed that diffusivity and conductivity is increased as temperature is further increased.

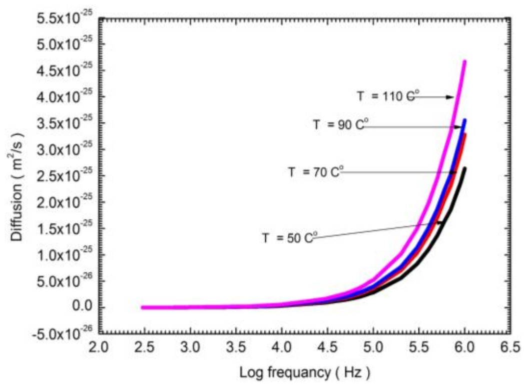

Figure 3 Diffusion coefficient of Gum Arabic adopted with carbon black (soot)/KBrO3; with constant weight; heated in different temperatures (T). The numbers represent frequency in kilohertz; the axes are in arbitrary scale units.

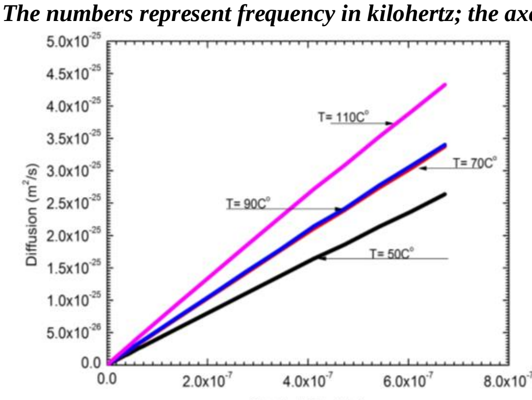

Figure 5 The relation between Diffusion coefficient and conductivity of the sample heated in different temperatures (T) is linearity; the axes are in arbitrary scale units.

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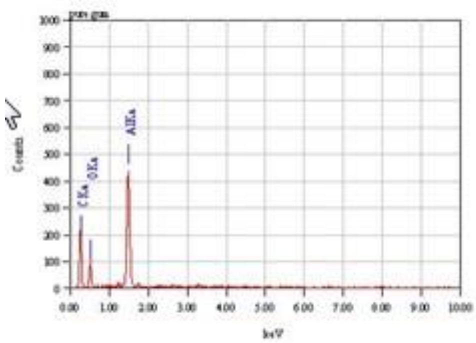
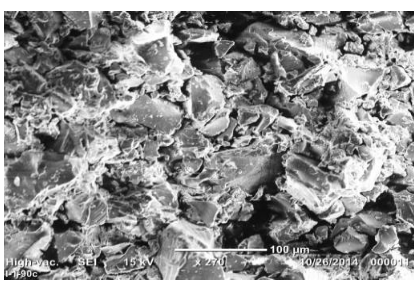


Figure 6 EDX spectrum of pure Gum Arabic; which indicates the presence of carbon, aluminum and potassium (Gum is composed of mainly Polysaccharides, Arabinose and Rhamnose).

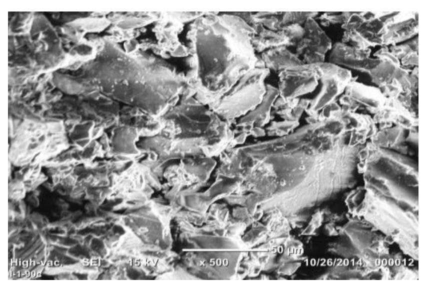
NeoScope offers integrated, full-featured Energy-dispersive X-ray Spectroscopy (EDS) with SDD technology for advanced analytical applications. As it can be seen in Figure 6, the spectrum of the Gum Arabic sample, so the spectrum is indicated the existence of Carbon, Aluminum and Potassium. Table (2) shows the analysis of EDX of GA doped with carbon black/$KBrO_3$ composite.

Table 2 The analysis of the EDX results for Gum Arabic composite (carbon black (soot)/KBrO3

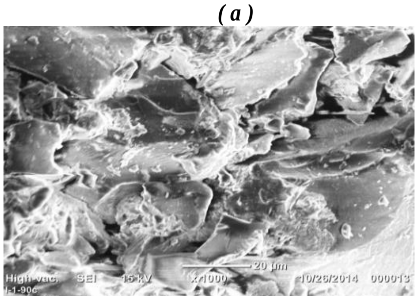
Element	(keV)	Mass %	Sigma	Atom%	K
C K	0.277	54.39	0.57	64.28	35.8260
O K	0.525	32.47	0.96	28.81	28.6761
Al K	1.486	13.14	0.24	06.91	35.4979
Total	-	100.00	-	100.00	-



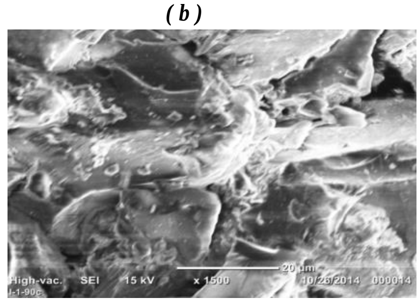
(a)



(b)



(c)



(d)

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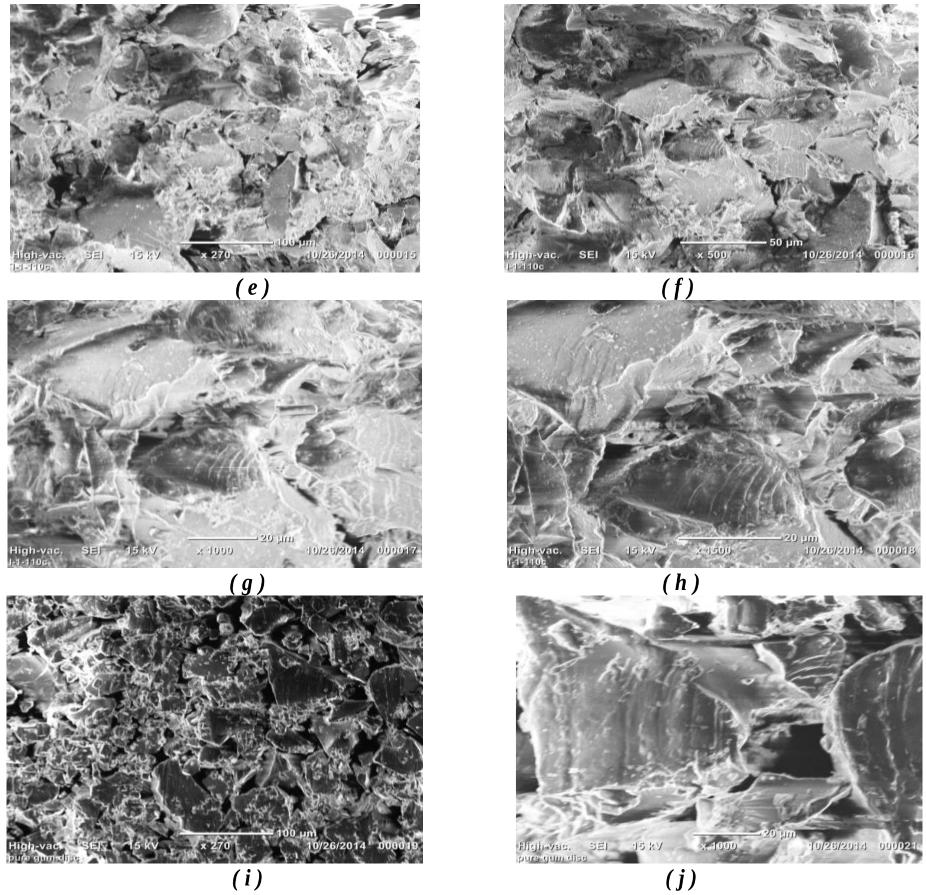

Figure (7) a, b, c, d, e, f, g, h, i and j show the Scanning Electron Microscope (SEM) images, pores structure and micrograph of Gum Arabic composite (carbon black (soot)/KBrO$_3$ with constant weight; heated in different temperatures (T).

Scanning electron microscope is performed for sample with different temperature. Figure 7 a-j shows the images of SEM for GA doped with carbon black/KBrO3 composite for different temperature. From the results it can be noticed that, there is a clear difference in the doped samples when heated, and the difference is obvious for the all samples.

The conductivity of the samples that doped by carbon black (soot) and KBrO3 is found to be decrease when frequency and temperature is increased, as shown in Figure (2), while a dielectric constant and diffusion coefficient (K') increase, Figure (3, 4) respectively. These results is found to be in agreement with, porosity of the material (sample) is increase when temperature increase and diffusion decreasing, Figure (7-j) represents the image of pure Gum Arabic without carbon (soot) at room temperature, and there is no pore (grain). On the other hand, Figure (7-i) represents the image of pure Gum Arabic with carbon (soot) at room temperature, and there is few pores (grain). But in Figures (7 a-h) there are more of pores which can be observed and this may lead to that the sample porosity increase with temperature. At low frequency there will be more vacancy, hence increase in dielectric constant (K') was expected and at the same time such vacancy may represent the highest diffusion sites leading to interstitial diffusion for carbon black atoms [11].

CONCLUSION

Sample of Gum Arabic doped with carbon black (Soot) and Potassium bromide (KBrO3) was successfully prepared using solid state chemical method. The results of diffusion coefficient and dielectric showed direct proportionality with the logarithmic frequency. The porosity of the sample was found to be directly proportional to the dielectric constant. The effect of temperature was profound as diffusivity and conductivity were found to increase with temperature. Such results might be attributed to the increase in grains surface to volume ratio obtained in our sample and being the good evident for porosity formation. The rate of diffusion is proportional to the concentration gradient

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of the diffusion. General formulations for diffusion and mass transport are outlined in Fick's first law of diffusion, expresses the steady state flux of diffusion per unit area.

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