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# *Electrical study of reduced graphene oxide/epoxy polymer nanocomposites*


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## Abstract:

**Recently, graphene has attracted attention, presenting both academic and industrial interests as a nanofiller for polymer composites, due to its exceptional mechanical, thermal and electrical properties. In this work, we investigate the electrical transport properties in reduced graphene oxide (rGO) particles powder dispersed in an insulation epoxy resin matrix (diglycidyl ether of bisphenol A) at frequency range of $10^2$–$10^6$ Hz and over the temperature range of 300 – 400 K. For that purpose, the DGEBA samples with rGO additive were prepared with different percentages. The experimental results showed that the DC electrical conductivity of the composites displays an intense increase over 8 orders of magnitude with rGO concentrations. The AC conductivity of the composites has been also studied, as a function of frequency and temperature to understand the conduction mechanisms.**


## Materials:

**A commercially available diglycidyl ether of bisphenol A (DGEBA) type epoxy resin (D.E.R 321, Dow Chemicals Company) was used as a prepolymer with epoxy equivalent 180–188, the density of the epoxy resin is 1.14 g·cm-3 and viscosity 500–700 (mPa.s) at 25 ° C. The rGO particles powder obtained from Graphenea Company (Gipuzkoa, Spain). The average size of the primary rGO particles is about 260-295 nm, the density of rGO particles is 1.91 g·cm−3 [1-2].**

## Procedures:

**For the electrical measurements the opposite sides of the samples were painted with silver conducting paste. The dc conductivity (σdc) was measured with a Keithley electrometer, model 617, as a function of the temperature, from 300 to 400 K. The impedance spectroscopy measurements were performed in the frequency range from 100 to 1 MHz, using an Agilent 4294A, in the same temperature range and measuring in the Cp–Rp configuration.**

## *Results and Discussion*

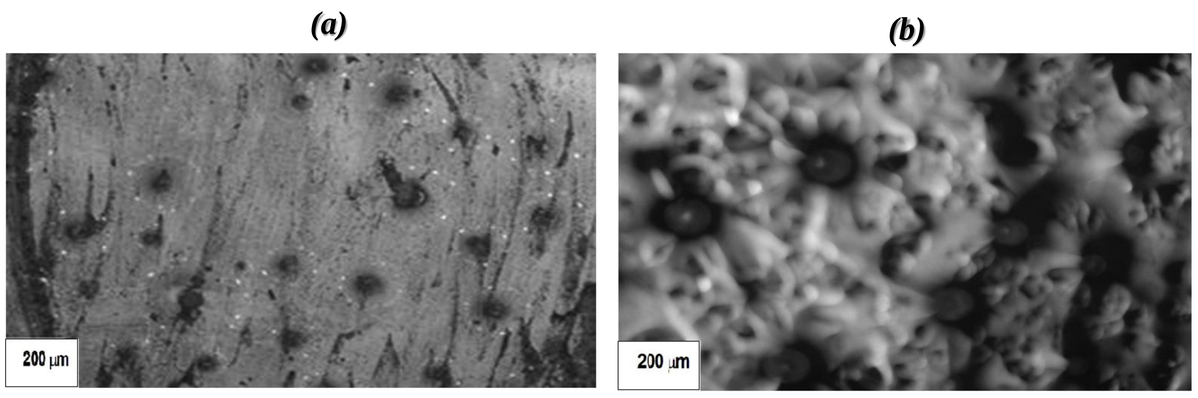


**Figure 1: Micro-photograph of the specimens with (a) 1.2 vol % and (b) 3.66 vol% of composites, magnification 200X.**

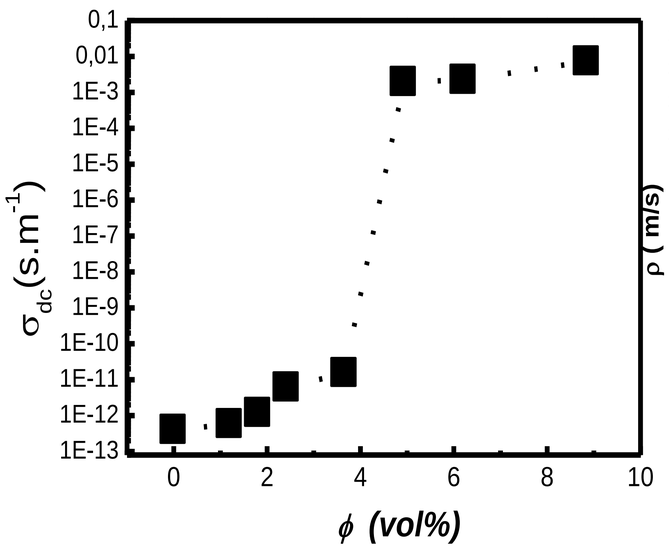


**Figure 2: Variation of DC electrical conductivity with rGO vol% concentration for (DGEBA/rGO) composite.**

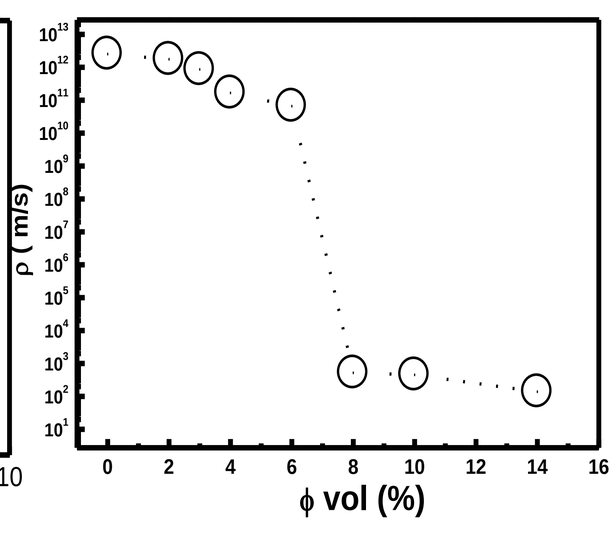


**Figure 3: Variation of DC electrical resistivity with rGO vol% concentration for (DGEBA/rGO) composite.**

The Alternating Current (AC) conductivity of all samples has been calculated from the dielectric losses according to the Equation :

$$\sigma_{ac} = \varepsilon_0 . \omega . \varepsilon''$$

Where ε0 = 8.854·10–12 F/m is the permittivity of free space.

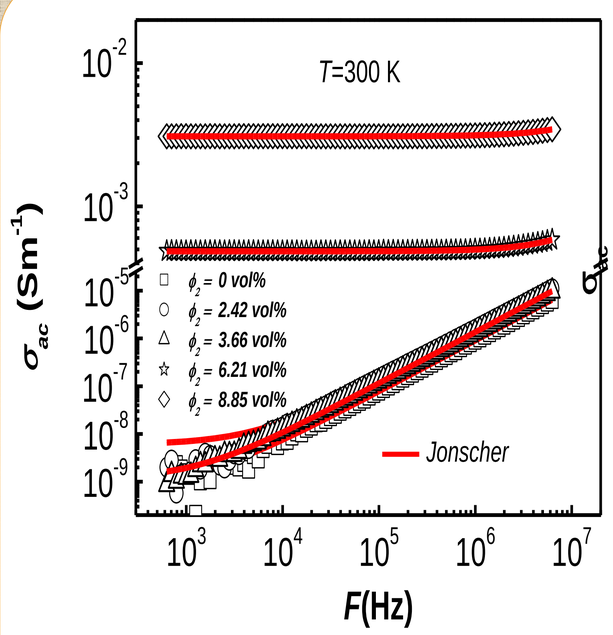


**Figure 4: The Electrical conductivity versus frequency at room temperatures for different concentration**

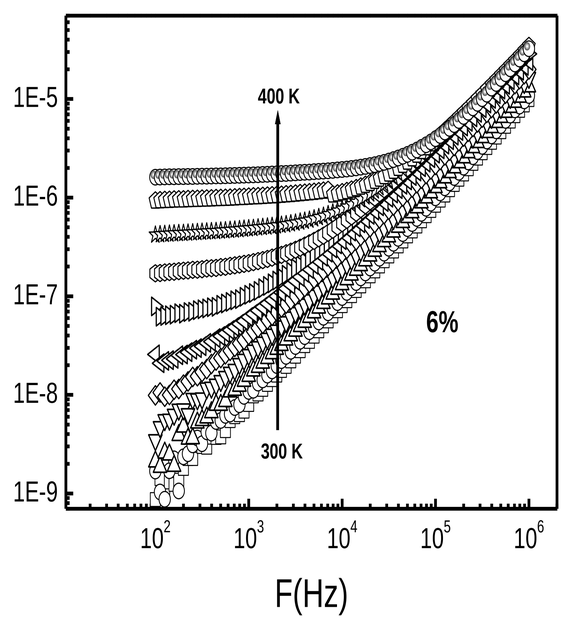


**Figure 5: The Electrical conductivity versus frequency at elevated temperatures for composite with 3.66 vol%.**

The variation of conductivity can be interpreted by using the Jonscher's UPL [3].

$$\sigma_{ac}(\omega) = \sigma_0 + A.\omega^n$$

Where **A** and **n** are constants depending on the temperature and material property.

| ϕ (vol%) | σdc (Ω-1m-1) | n | A |
|---|---|---|---|
| 0 | 9.18 ×10−10 | 1.05 0.05 | 5.01×10 − 13 |
| 2.42 | 5.97×10−9 | 1.01 0.02 | 1.25×10 − 12 |
| 3.66 | 1.14×10−9 | 1.00 0.02 | 1.30×10 − 12 |
| 4.22 | 4.8×10-4 | 0.12 0.03 | 9.80×10 − 5 |
| 6.21 | 7.6×10 -4 | 0.03 0.01 | 4.80×10 − 4 |
| 8.85 | 0.30×10-2 | 0.06 0.03 | 1.07×10 − 3 |

**Table 1**: Experimental values of n and A extracted from sac using Jonscher's UPL. T=300 K. [4]

## References:


[1] Park, S. and Ruoff, R. S., "Chemical methods for the production of graphene," Nat Nano, 4(4), 217-224 (2009).

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## Conclusion:

* The distribution of rGO particles appears to be an homogeneous in this composite, while some agglomerates are present even at low concentration of the rGO filler. Though the sizes of the agglomerates remain the same in all the composite.

* The sudden jump in DC conductivity is observed when the rGO content greater than the percolation threshold (4.2 vol%), can be attributed to the formation of an infinite agglomerate pathway.

* The best fit of the ac conductivity in the dispersive region is obtained using the Jonscher's UPL dependence on frequencies. The values of n is about 0 – 1.05 for the different concentration at room temperature.