INVESTIGATION OF ELECTRICAL PROPERTIES OF POLYANILINE/SILVER NANOCOMPOSITE FREE STANDING FILMS

By

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ABSTRACT

This work reports the synthesis and electrical characterization of polyaniline/silver (PA/Ag) nanocomposite free standing films. The DC conductivity measurements in the temperature range of 80-300K, Hall Effect studies at room temperature and dielectric measurements in the frequency range from 75 kHz to 5 MHz of the synthesized films, inferred semiconducting behavior of the samples. Significant improvement in the electrical properties of nanocomposites has been observed and discussed in this manuscript.

Keywords: Electrical Properties, Nanocomposites, Polyaniline, Silver Nanoparticles.

INTRODUCTION

The study of conducting polymer-metal nanocomposite materials has received much attention in the past few years. It is interesting to observe the improvements in the optical, mechanical and electrical properties of conducting polymers by the incorporation of the metal nanoparticles [1]. These organic-inorganic hybrid materials are found to have numerous applications in several fields such as sensors [2], catalysis [3], memory devices [4] etc. Among the various metal nanostructures, silver nanoparticles based composites have been chosen because of their unique optical, electronic, thermal, catalytic, and biocompatible properties [5, 6]. The aim of the proposed investigation is not only to characterize the new materials, but also to provide complete experimental study of the chosen materials to pave way for their applications in the required fields.

1. Experimental Details

In the present paper, chemical method has been used to prepare good quality free standing films of pure polyaniline (PA) as well as polyaniline/silver nanocomposite (PA/Ag) [6]. Pure PA and PA/Ag nanocomposite with different concentrations of silver nanoparticles such as 0.30 %, and 1.0 % by weight have been synthesized in the form of self standing films. The DC conductivity measurements of the films were performed by standard four probe method in the temperature range of 80-300K using Keithley 2612A System source meter and Lake Shore 340 temperature controller, after making the samples conducting by dipping them in 1M HCL solution. Hall measurements were taken using Ecopia Hall effect measurement system (HMS-3000 VER 3.51.5) at room temperature. Agilent 4285A Precession LCR meter was used for dielectric measurements of the synthesized films at room temperature in the frequency range from 75KHz to 5MHz. Silver paste was used on both sides of the samples for making contacts.

2. Results and Discussion

2.1 DC conductivity measurements

Figure 1 shows the variation of DC conductivity σ_{dc} with temperature. With increase in the concentration of silver nanoparticles within polymer matrix, the σ_{dc} significantly increases. It is found from the conductivity behaviour that, Mott's three dimensional variable range hopping (3D-VRH) model gives a better fit to the experimental results. The total observed conductivity of PA/Ag films may be correlated with the hopping of electrons along and between the molecular chains. The Mott's parameters, T_0 (energy difference between localized states), Rhop (hopping distance), W (average hopping energy), N (E_F) (density of states at Fermi energy level) are evaluated using α^{-1} = 1.1nm (the coefficient of exponential decay of the electronic wave function of the localized states) and are in good agreement with the values reported earlier [7]. The variation of concentration of silver nanoparticles within polyaniline is justifying the enhancement of conductivity of PA/Ag films. The results are consistent with the Mott's requirement ($\alpha R_{hop} >> 1$ and $W >> kT$ where k is the Boltzmann constant) for conductivity by hopping to distant sites. The improvement in electrical conductivity observed in composite material relative to pure PA is due to effective dispersion of Ag nanoparticles in the given polymer matrix. Properly dispersed metal nanoparticles lead to enhancement in the mobility of electrons due to increased tunnelling probability [8].

2.2 Hall Effect measurements

As a further test of the electrical conductivity of modified samples, the Hall resistivity ρ as a function of nanoparticle concentration was studied. The results are shown in table I. Parameters n (carrier concentration), μ (mobility), ρ (resistivity) and R_H (Hall coefficient) obtained from Hall measurements are of the same order as is calculated by DC measurements, indicating a very good corroboration of results.

2.3 AC conducting measurements

The AC conductivity σ_{ac} as a function of frequency at different concentrations of silver nanoparticles in polyaniline at room temperature has been studied. It is found that σ_{ac} of PA/Ag films increases with frequency as well as with concentration of nanoparticles in accordance with the Correlated Barrier Hopping (CBH) model.

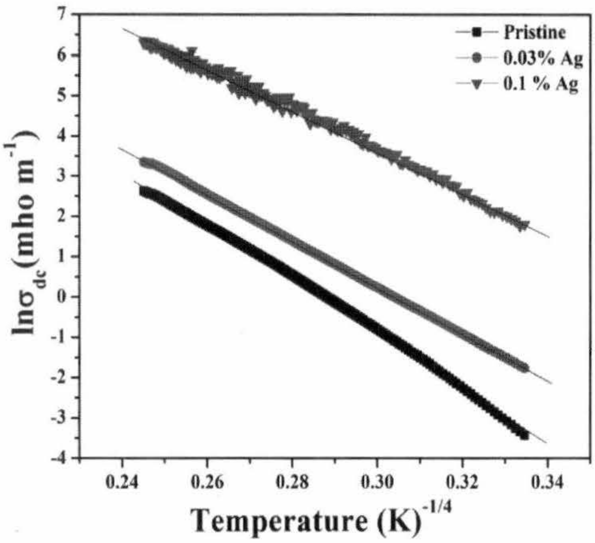

Figure 1. DC conductivity σ_{dc} plotted as a function of $T^{-1/4}$

Figure 2 shows the dependence of dielectric constant and capacitance respectively on the frequency of the applied field, at different concentration of silver nanoparticles. The dielectric constant remains almost constant for wide frequency range and increases with increase of metal concentration in PA. This behaviour may be due to volume fraction of the charges (electric dipoles) in the interfaces between polymer and metal particles. Charge carriers under electric field can hop readily out of sites with low free energy barriers but tend to 'pileup' at sites with high free energy barriers. This leads to a net polarization of the dipoles and large value of dielectric permittivity [9]. Thus, the dielectric constant of the composites is higher than pure polymer. As capacitance is directly proportional to

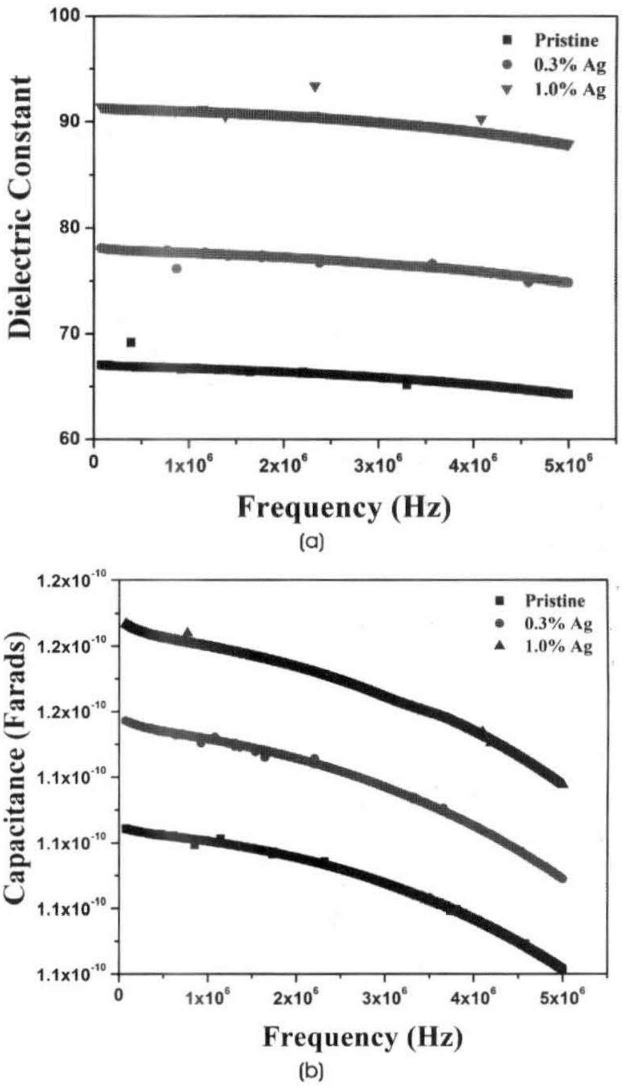

Figure 2. Plot of (a) dielectric constant & (b) Capacitance versus Frequency of PA/Ag films

Parameters	PA	PA/Ag (0.30%)	PA/Ag (1.0%)
T0 (K)	1.84x10	1.3x107	5.9x106
Rhop (nm) at 300K	6.45	5.97	4.88
W (meV)	102	94	77
N (EF) (cm-3eV-1)	8.76x10	1.2x1019	2.67x1019
αRhop	5.86	5.43	4.4
n (cm-3)	9.17x10	7.3x1018	2.07x1019
μ (cm2V-1sec-1)	2.55	7.9	5.1
ρ (Ω cm)	2.66	0.11	0.08
RH (m2C-1)	6.8	0.85	0.30

Table 1. Evaluation of various Mott's parameters, T_0 (energy difference between localized states), R_{hop} (hopping distance), W (average hopping energy), N (E_F) (density of states at Fermi energy level), α (the coefficient of exponential decay of the electronic wave function of the localized states) from DC conductivity measurements and n (carrier concentration), μ (mobility), ρ (resistivity) and R_H (Hall coefficient) from Hall effect measurements for PA and PA/Ag films.

dielectric constant, similar increasing trend of capacitance is observed with the increase of metal concentration.

Conclusions

Polyaniline doped with different concentration of Ag nanoparticles has been prepared by chemical polymerization process. The DC conductivity measurement obeys the 3-D variable range hopping among localized states for non-interacting carriers. The AC conductivity of PA/Ag films increases with frequency as well as with concentration. The parameters obtained directly from Hall measurement are in good agreement with that of DC measurements. Thus, the hybrid material has improved electrical conductivity, higher dielectric constant and capacitance, which may make it quite important from technology point of view.

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