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OF ADVANCED RESEARCH****RESEARCH ARTICLE****PROTECTION OF ELECTRICAL AND ELECTRONIC EQUIPMENT AND PART
AGAINST ELECTROSTATIC DISCHARGE****A. M. Abdel- Aziz¹, H. S. Seddeq², R. A. Refai¹, A. Y. Elmasry²****1. Professors in Al-Azher UNI.****2. Housing & Building Research Center****Manuscript Info****Manuscript History:**

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Key words:***Corresponding Author****A. Y. Elmasry****Abstract**

The technical requirement for ESD protection in clinical environment, equipment rooms, dispatch center and flammables, or explosives are stored or handled are very important for personnel and the electronic parts safety. Protection against electrostatic discharges (ESD) involves the technical requirements for floor that is very important to complete the protection program. Polymers usually used as antistatic control floor. Different polymer samples from nitrile butadiene rubber (NBR) have been prepared with different concentrations of carbon black (N660) to study the electrical properties for as antistatic floor application. The electrical properties have been measured for 8 samples through the effect of carbon black content (N660); (0,40,50,60,70,80,90,100) on the dc and ac electrical conductivity, Also the electrical resistance of conductive and dissipative samples was measured according to ASTM F150 and ANSI/ESD S7.1. The results show that dc electrical conductivity (σ_{dc}) increases by increasing the carbon black concentration up to the threshold value (~ 60 phr) and changed from 10^9 S/m to 10^6 S/m. The range of conductive resistance of samples N90 and N100 achieves the required limits in ANS/ESD S7.1-05 and ASTM F 150-98 when using conductive adhesive for floor. The range of dissipative resistance of all samples achieves the required limits in ANS/ESD S7.1-05 and ASTM F 150-98 with and without conductive adhesive for floor. Finally the carbon black concentration improves the conductive and dissipative resistance properties that required for antistatic polymer floor.

*Copy Right, IJAR, 2015., All rights reserved***INTRODUCTION**

Electrical static discharge (ESD) is the transfer of electricity between two objects that have different electrical potentials. The more common form of ESD in the electronic environment results from a discharge through an air gap; an example would be a user accumulating thousands of volts of potential by walking across certain floor surfaces and then reaching for a device. Electrostatic discharge can change the electrical characteristics of a semiconductor device, degrading or destroying it. Electrostatic discharge also may upset the normal operation of an electronic system, causing equipment malfunction or failure. Another problem caused by static electricity occurs in clean rooms when charging surfaces can attract and hold contaminants, making removal from the environment difficult. When attracted to the surface of a silicon wafer or a device's electrical circuitry, these particulates can cause random wafer defects and reduce product yields [1]. ESD can also causes fire because of trigger sparks and electro-static discharge. Typical areas requiring ESD protection are electronics manufacturing as (receiving, inspection, stores and warehouses, assembly, test and inspection, research and development, packaging, field service repair), Electronics laboratories, Electronics repair facilities, Medical facilities and Explosion hazard areas such as (

Munitions & fireworks factories and solvent handling areas) offices and laboratories. Protection program against ESD include technical requirements for number of items such as Wrist straps, foot wear, work surface, garment, seating, packing, ionization and floor. A common source of electrostatic charge in a work environment is the separation of foot or caster from the floor, resulting in the generation of electrostatic charge that can accumulate on personnel and equipment. The effect of this generation and accumulation of electrostatic charge can be minimized with appropriate selection or treatment of the floor material [2]. Therefore the main objective of this paper is to investigate and improve the electrical properties of polymer to use as antistatic floor. polymer flooring used as static control floor because they have many advantage as reduce component /part failure, reduce fire and explosions, prevent personal injury and reduce down time.

2. EXPERIMENTAL WORK

The electrical and mechanical properties of polymers with different concentration of carbon black have been investigated to improve the electrical performance as antistatic floor as given below

2.1. Materials

Eight polymer samples from nitrile butadiene rubber (NBR) have been prepared with different concentration of carbon black N660 (0, 40, 50, 60, 70, 80, 90 and 100). Polymer samples were pressed with different additive to improve their electrical properties and protect against accumulated electrostatic charge. The structure of these materials is as follows::

- Nitrile Butadiene Rubber (NBR), with specific gravity 0.90 g/cm³.
- Zinc oxide (ZnO) as activators with specific gravity at 15 oC is 5.55–5.61 g/cm³
- General Purpose Furnance Black (N660)
- Stearic acid: melting point 67–69 oC
- Benzothiazyl Disulfide. (MBTs) as accelerator with specific gravity 1.29–1.31 g/cm³
- Antioxidant N-isopropyl N'-phenyl-1,4 phenylenediamine (IPPD 4020): purple gray flakes have density 1.17 g/cm³.
- Elemental sulfur (S) with fine pale yellow powder and specific gravity 2.04–2.06 g/cm³.

2.2 Procedure of Measurements:

The electrical measurements of samples tested through the effect of carbon black content (N660) on the dc and ac electrical conductivity. The electrical resistance of conductive and dissipative samples was measured. The mechanical properties of the samples namely the compression and the abrasion resistance and the swelling characteristics were also measured.

2.2.1 Samples Description

The rubber composites were prepared by using a two roll mill of 300 mm length, 170mm diameter with speed of slow roll 18 rev /min and gear ratio 1.4. The prepared compounded rubber was left for 24 hours before vulcanization. The vulcanization process was conducted at 155±2 °C under pressure of 150 bar for 20 min. The test materials have the composites as shown in Tables (1.1) and (1.2). They were prepared from commercial ingredients according to standard techniques [3].

2.2.2.D.C. Electrical measurements:

Dc measurements were made using keithley type 485 auto ranging pico ammeter in room temperature. All samples were in the form of cylinders of 1cm height and cross section area of 1 cm². The dc conductivity calculated according to the following equation:

$$\sigma = \frac{Id}{AV} \quad (1.1)$$

Where:

I: the current flowing through rubber sample, V: potential difference, A: cross-section area , d: thickness

2.2.3. Alternating current conductivity measurements.

The measurement of as the dielectric properties of the investigated samples were carried out from room temperature as a function of frequency ranging from 100 kHz to 5 MHz using RLC Bridge (HIOKI model 3532 Z HiTester, “Japan”) [4, 5].

2.2.4. Measurements of electrical resistance for conductive and dissipative samples

The test method covers the determination of the electrical resistance of samples of size (65x20x0.35x1) according to ANS/ ESD S7.1 and ASTM F-150. Model 2003 Flooring/Work surface Resistance Audit Kit with $\pm 10\%$ accuracy was used for conductive and dissipative test as follows:

a. Surface to ground test (static dissipative test)

The positive electrode from the megohmmeter is attached to the ground connection and the negative is placed on the surface of the samples with and without adhesive where 50, 100, 250 and 500 voltages Figure (1.1).

b. Surface to surface test (static conductive test)

Place the electrodes in (25.4 mm) in from an edge of the sample with and without adhesive. The positive electrode from the megohmmeter is attached to the electrode and the negative is attached to the electrode and apply 50, 100, 250 and 500 voltages Figure (1.2).

2.2.5.Compression measurement

Determination of the Compression resistance are performed according to [ASTM D395-82]. The percentage of the compression employed shall be 25% of the original thickness [7]. The compression set % is defined as:

$$C\% = \frac{t_o - t_{24}}{t_o} \times 100 \dots \dots \dots (1.3)$$

Where t_o is the original thickness of the sample, t_{24} is the thickness of the sample after removing compression after 24 hrs.

2.2.6.Abrasion resistance measurements

Determination of the abrasion resistance for rubbers and elastomers are performed according to [ASTM D53516; 87(2010)] [8] using home made abrasion tester model (6102).To calculate the abrasion loss percent, the following formula was used:

$$A\% = \frac{m_o - m}{m_o} \times 100 \quad (1.4)$$

Where m_o , m are the weight of sample before and after abrasion, respectively.

2.2.7.Swelling measurements

Benzene was used to study its effects on the degree of swelling measurements were determined according to [7] Composite samples were weighted by using a digital balance (accuracy 0.1-mg) and inserted in a test tubes containing solvent and blotted with filter paper to remove excess solvent on the sample surface. They were weighted again at a given time and a fixed temperature. All these tests were performed at room temperature (25 °C) for 24 h. The degree of swelling was calculated by using the following relation

$$Q\% = \frac{m - m_o}{m_o} \times 100 \dots \dots \dots (1.2)$$

Where, m_o and m are the mass of the sample before and after swelling.

3. RESULTS AND DISCUSSION

Table (1.1) and (1.2) show the composition of NBR sample N0 and NBR samples with different concentrations of N660 black respectively.

Table (1.1): Composition of NBR sample (N0)

Ingredients, phr ^(a)	Sample
NBR	100
Stearic acid	2

Zinc oxide	5
Glycerine	13.5
DOP ^(b)	10
N660	0
TiO ₂	10
MBTS ^(c)	2
SiO ₂	10
IPPD 4020 ^(d)	1
Sulfur	2

(a) Part per hundred parts of rubber by weight

(b) Dioctyle phthalate

(c) 2 – dibenzothiazyl sulphide

(d) N- (1,3- dimethyl butyl) - N- phenylenediamine

Table (1.2): Composition of NBR samples with different concentrations of N660 black

Ingredients, phr	Sample						
	N40	N50	N60	N70	N80	N90	N100
NBR	100	100	100	100	100	100	100
Stearic acid	2	2	2	2	2	2	2
Zinc oxide	5	5	5	5	5	5	5
DOP	10	10	10	10	10	10	10
N660	40	50	60	70	80	90	100
MBTS	2	2	2	2	2	2	2
IPPD 4020	1	1	1	1	1	1	1
Sulfur	2	2	2	2	2	2	2



Figure (1.1) Typical RTG megaohm meter[6]



Figure (1.2) Surface resistance meter

3.1.Effect of carbon black content on the dc electrical conductivity

Figure (1.3) shows the dependence of dc electrical conductivity (σ_{dc}) on the carbon black content. It is noticed that σ_{dc} increases by increasing the carbon black concentration. This behavior could be understood on the basis of the variation of the interspacing distances between the carbon black particles and /or aggregates.

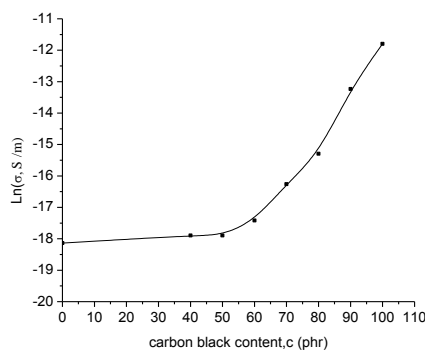


Figure (1.3) Electrical conductivity of all samples at room temperature (25°C)

3.2. Temperature dependence of dc electrical conductivity

Figure (1.4) shows the relation between $\ln(\sigma)$ and $1000/T(K)$ for all samples of rubber loaded with different ratios of carbon black (N660). From the figure it is clear that, the conductivity increases with increasing of temperature for all samples. The interspacing distances between the carbon black particles or aggregates are small enough to enhance hopping or tunneling conduction through the rubber matrix. The dc conductivity increases by increasing the temperature due to the expected increase of the mobility of charge carriers [9].

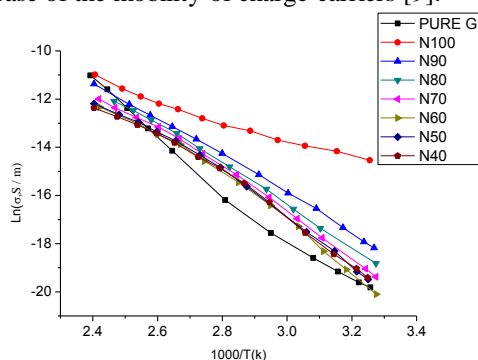


Figure (1.4) $\ln \sigma$ versus $1000/T$ for NBR loaded with different ratios of N660 black filler.

The values of activation energy E (eV) for all samples are presented in Table (1.1). It is noted that, the values of E increases with increasing of carbon black content up to 60 phr then decreases again. This could be explained as above 60 phr the carbon aggregate are close to each other and are mostly interconnected such that the hopping of electrons is greatly enhanced due to the decreased potential barrier of hopping [10].

Table (1.1): The calculated values of the activation energy.

Sample	Activation Energy E(eV)
N0	0.69
N40	0.74
N50	0.76
N60	0.79
N70	0.76
N80	0.71
N90	0.67
N100	0.35

3.3.Ac conductivity

The dependence of ac conductivity on frequency of carbon black filled NBR composites measured at 25°C is shown in Figure (1.5). σ_{ac} that increases as the concentration of the filler increases and also as the frequency increases.

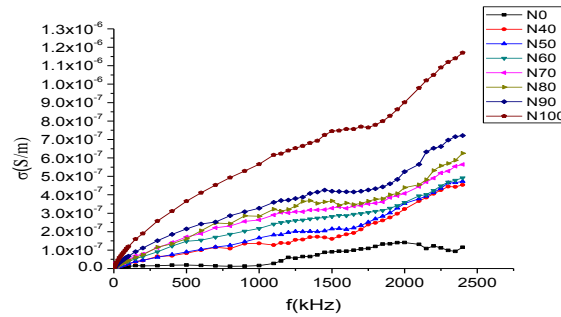


Figure (1.5) Frequency dependence of conductivity for NBR composites containing carbon black N660

3.4. Electrical resistance of conductive and static dissipative flooring.

Figure (1.6) to (1.8) show the resistance relationship with the carbon black filler content. It is obvious from the curves that at the concentration 40 phr the resistance decreased from 10^9 to $10^8 \Omega$. The obtained results can be explained in light of the basic statistical percolation theory proposed by Mamunya and coworkers [11] demonstrating the relationship between filler content and electrical conductivity. The range of surface conductivity of the different carbon black composite is by far much higher than the unfilled NBR. The highest range of surface conductivity of samples 90 and 100 was found to be suitable for electrostatic dissipation applications as the range of conductivity for such application should be $10^4 \sim 10^9 \Omega[12]$.

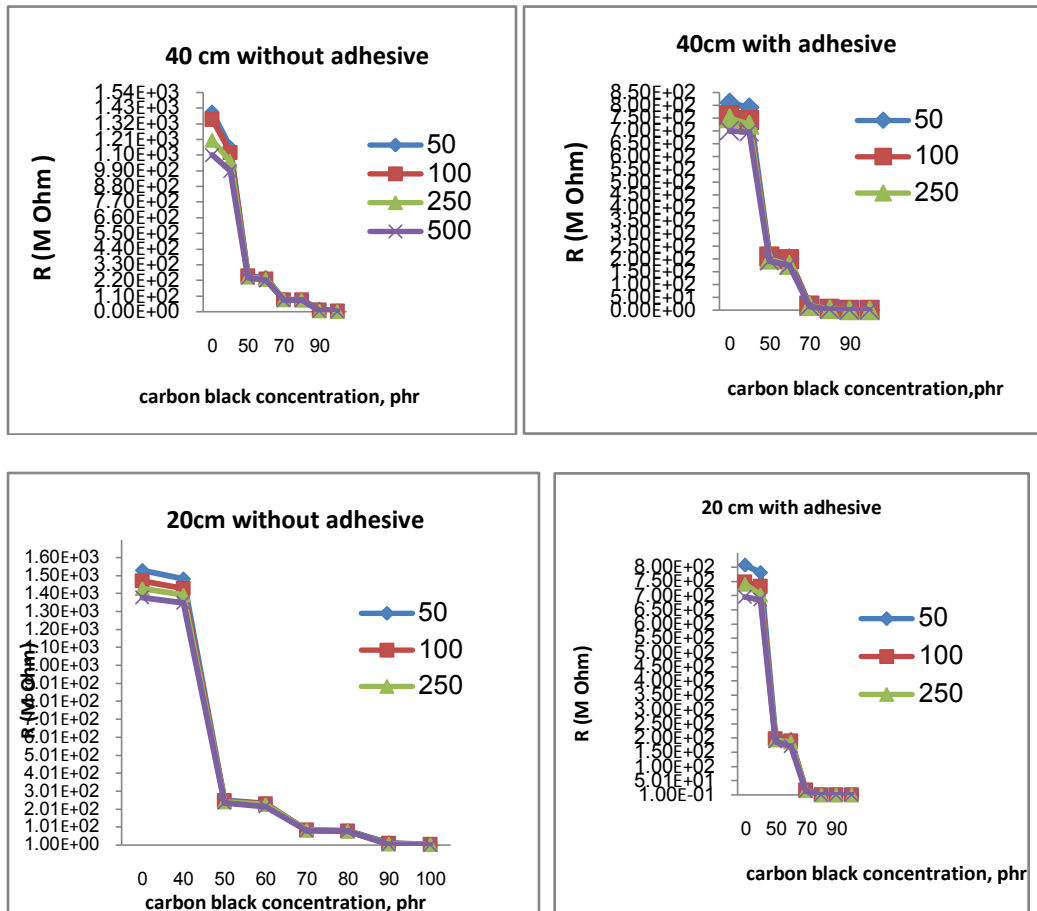


Figure (1.6): Dependence of surface resistance on carbon black concentration measured with and without adhesive with distance 40 cm and 20 cm between two the electrode

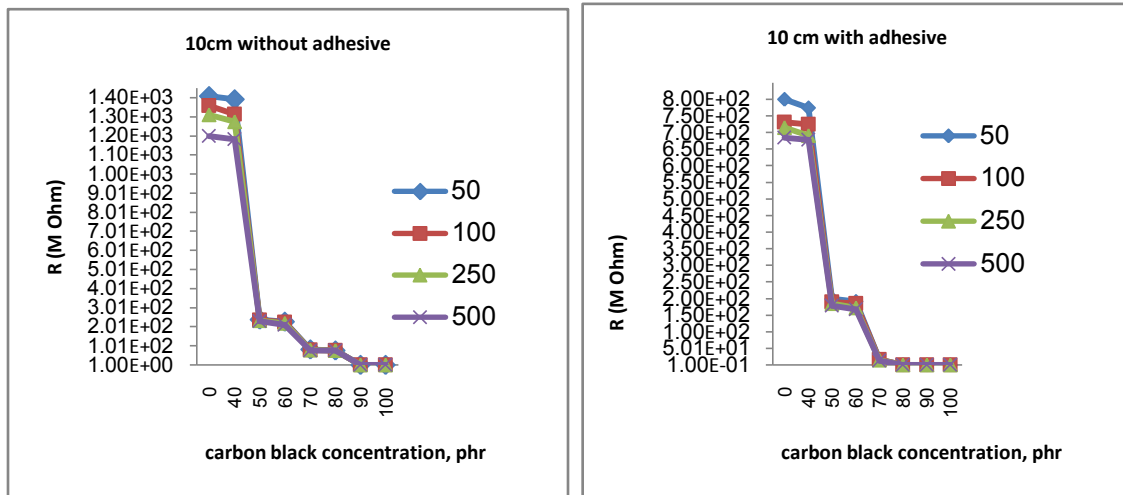


Figure (1.7): Dependence of surface resistance on carbon black concentration measured with and without adhesive with distance 10 cm between two the electrode

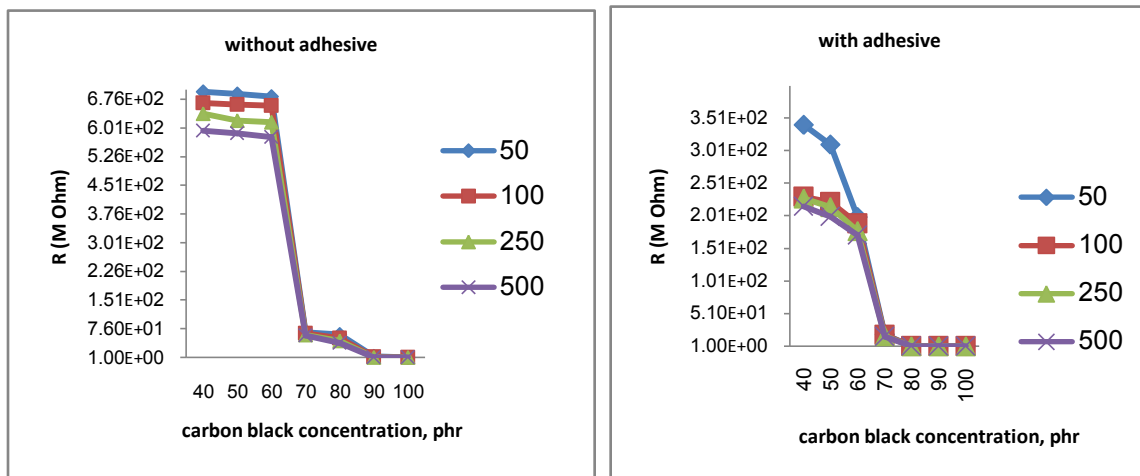


Figure (1.8): Dependence of resistance on carbon black concentration measured with and without adhesive from sample to the ground

The success of samples 90 and 100 to act as material that can enhance the electrostatic dissipation is also clear especially regarding their ability to dissipate charges accumulated on the surface shown in Figure (1.9). As the carbon black content increases the ability of the sample to dissipate the charge from its surface increases. This effect becomes more noticeable when the floor samples are fixed on the ground using a conductive adhesive material.

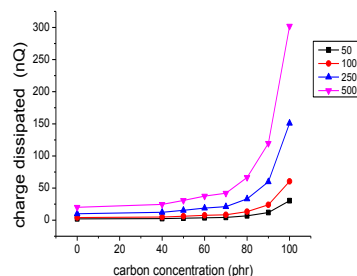


Figure (1.9) Charge dissipation as a function of carbon black concentration

3.5.Compression test according to [ASTM D395-82]

Figure (1.10) shows the variation of the compression percentage for NBR samples loaded with difference concentration of carbon black (N660). The compression test being nearly constant after the 40 phr of carbon black content (about 2.7 %) while the sample without carbon content exhibit about double compression ratio (~ 6%).

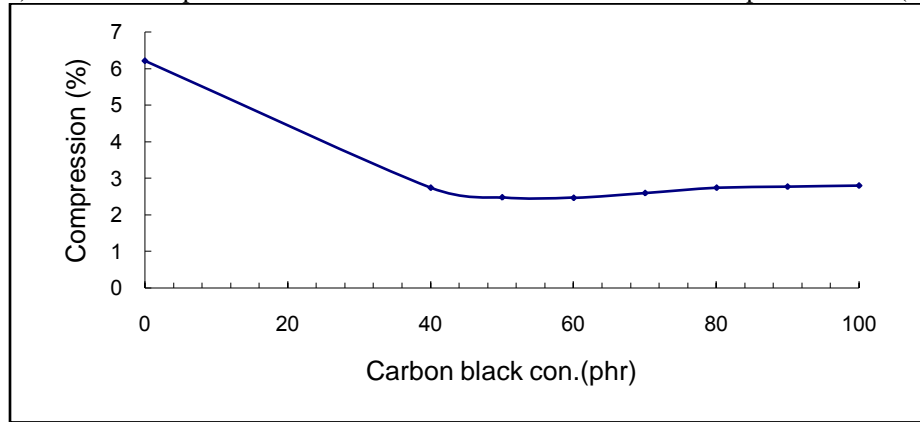


Figure (1.10) Effect of carbon black content (N660) on the compression percentage

3.6.Abrasion test

Figure (1.11) shows the abrasion test decreases approximately linearly by increasing the carbon black concentration. It is also noticed that, the abrasion ratio drops to about one tenth of its original value indicating that the carbon content resists the abrasion of the samples from 6.1 % to 1.6% .

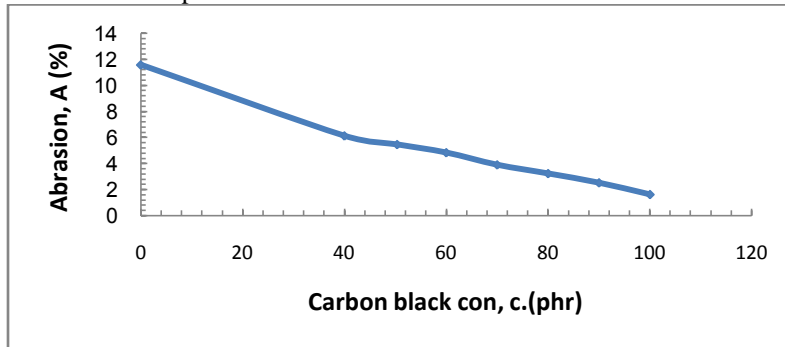


Figure (1.11) Effect of carbon black on the abrasion percentage

3.7.Swelling behavior

Figure (1.12) shows the variation of the degree of swelling Q (%) in benzene with time for all samples. the swelling characteristics were also measured. The percentage of solvent was increased rapidly in the initial stage because of its great affinity to uptake solvent and show a rise of the curve and then it slowly increased until ultimate value of swelling Q_m was reached [13].

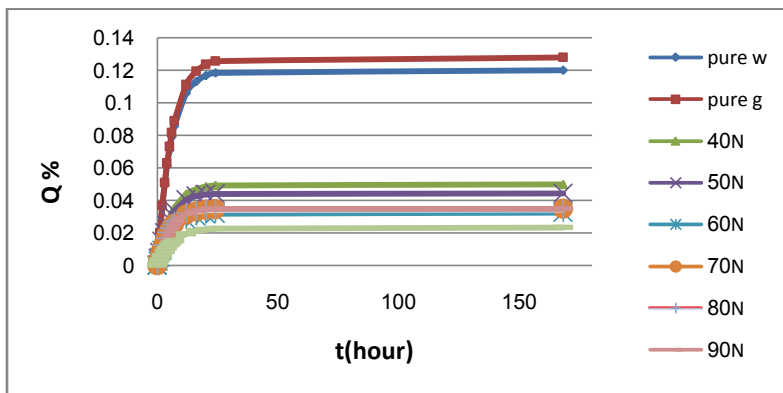


Figure (1.12) Degree of swelling with time in benzene at room temperature

3.8. Effect of carbon black on the maximum degree of swelling

Figure (1.13) shows the dependence of the maximum degree of swelling in benzene on the particle size of carbon black for all samples. The swelling percentage of carbon black decreased with increasing carbon black loading.

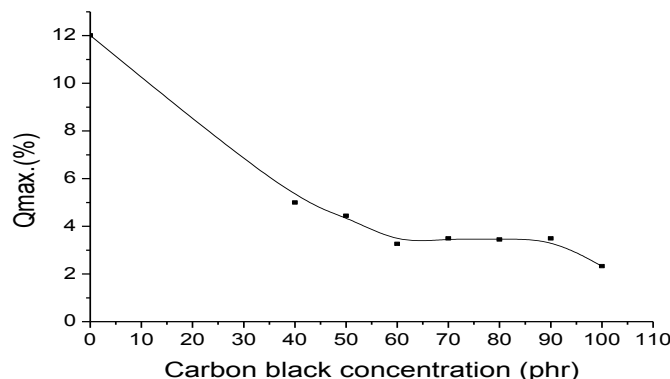


Figure (1.13) variation of maximum degree of swelling with different concentration of carbon black

CONCLUSION

The electrical and mechanical properties of polymers with different concentration of carbon black were investigated to improve the electrical and mechanical performance. The measurements carried out for 8 polymer samples through the effect of carbon black content (N660); (0,40,50,60,70,80,90,100) on the dc and ac electrical conductivity, Also the electrical conductive and dissipative resistance of samples were carried out for antistatic floor application. The mechanical properties of the samples namely the compression and the abrasion resistance and the swelling characteristics were also measured. The results show that:

- The electrical resistance of conductive and dissipative samples was measured for antistatic floor application. The conductive and dissipative electrical resistance does not decrease continuously with increasing the conductive filler content, i.e., the relationship is nonlinear. There is a critical composition (N40) at which resistance decreases by about one order of magnitude from 10^9 to $10^8 \Omega$.
- The range of conductive test resistance of samples N90 and N100 are $0.2 \times 10^6 \Omega$ to $1 \times 10^6 \Omega$ with conductive adhesive that comply with ANS/ESD S7.1-05 and ASTM F 150-98 as antistatic floor.
- The range of dissipative test resistance of all samples are $1.01 \times 10^6 \Omega$ to $6.7 \times 10^8 \Omega$ without conductive adhesive and $1.01 \times 10^6 \Omega$ to $3.40 \times 10^8 \Omega$ with conductive adhesive that comply with ANS/ESD S7.1-05 and ASTM F 150 -98 as antistatic floor .
- The obtained data of resistance vs. carbon black content are satisfying the percolation theory.
- The charge dissipation as a function of carbon black concentration was studied. As the carbon black content increases the ability of the sample to dissipate the charge from its surface increases. This effect becomes more noticeable when the floor samples are fixed on the ground using a conductive adhesive material.
- The mechanical properties of the samples improve with increase the carbon black content.
- Finally the carbon black concentration from improve the conductive and dissipative resistance properties that required for antistatic floor.

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