Mechanical, Electrical and Thermal Properties of Polypropylene and Polycarbonate Blend Filled with Carbon Black

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ABSTRACT

In this work a composite materials were prepared containing matrix of polymer blend (polypropylene 80% + polycarbonate 20%) reinforced by (carbon black) with different of weight fraction %. The specimen sheet, were obtained by hot-compression from extruded material, using single extruder operated at a temperature between (190-200)C^{o}. The extrusion processes give homogeneous mixer through a regular selection of machine screw revolution per minute and temperature used in extrusion process. The weight fraction of the carbon blacks ranged from 0.0 up to 20 wt % with the polypropylene and polycarbonate blend. All samples related to, mechanical, thermal and electrical tests were prepared by single –extruder.

By discharging a high voltage through the composite it was found that the resistivity of the composite decreased from (1.00E+09)-(1.00E+028). Carbon black–polypropylene and polycarbonate composites show significant differences from the neat blends measured in the frequency range. The study of physical test show that the thermal conductivity decreases with the increase of weight fraction from (0.157-0.23).

Keywords: Thermal conductivity, Electrical conductivity, Carbone black, Polypropylène, Polycarbonate**,** Mechanical properties

دراسه الخواص الميكانيكية و الحراريه والكهربائيه للخلائط البولي البروبلين والبولي كاربونيت المدعم بمسحوق الكاربون

الخلاصة

في البحث الحالي تم تحضير مواد مركبة جديدة التي هي عبارة عن مخلوط بوليمري، يتكـــون من مزج بولي بروبلين مع بولي كاربونيت بنسبة وزنية ثابتة (80/20) مع اضافة نسب وزنيـــة مختلفة من مسحوق اسود الكاربون وذلك باستخدام جهاز الباثقة المنفرد حيث ركزت على أسلوب الخلط المتجانس بين المواد من خلال تحديد سرعة دوران اللولب الماكنة ودرجـــات الحـــرارة المستخدمة في عملية البثق. حيث تم تشغيلها عند درجات حرارة تتراوح بين (190-200) درجة مئوية.في هذا البحث تم دراسه الخواص الميكانيكيه و التوصيل الحراري والكهربائي للخلائـــط البولي البروبلين والبولي كاربونيت المدعم باسود الكاربون بنسب مئويه وزنيه تتراوح من 0 الى 20 % .وجد عند امرار فولتيه عاليه خلال النماذج المدعمة حدوث انخفاض واضح في المقاومه

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النوعيه مقارنه بنماذج البولي بروبلين مع بولي كاربونيت غير المدعمه باسود الكاربون.ووجـد زياده في خواص التوصيل الحراري لمتراكبات البولي بروبلين مع بولي كاربونيـت المـدعم باسـود الكاربون مقارنه بالخليط غير المدعم .

INTRODUCTION

Composites are made from different types of materials. They provide unique combinations of mechanical and physical properties that cannot be found in any single material. Polypropylene (pp) is a thermoplastic polymer with low specific gravity and good resistance to chemical. It can be readily colored, has good tensile strength and proven resistance to acid, alkalis and solvents.

Polycarbonate engineering thermoplastic is amorphous, clear polymers that exhibit superior dimensional stability, good electrical properties, good thermal stability, and outstanding impact strength [(1)].

Plastics and polymers are inherently low in thermal and electrical conductivity. For this reason applications that require conductive properties, which could also benefit from the use of polymer because of their light weight, high strength/weight ratio, easy mold ability, etc, cannot take advantage of this desirable material. Research is in progress on inherently conductive polymers, and some polymers with reasonable conductivity values are commercially available [(2)]. However, at the present time admixing inert, conductive fillers into non-conductive polymers remains very effective and economical way to produce an electrically or thermally conductive polymer component. the electrical conductivity of material is defined as

$$s = \frac{1}{R}$$

Electrical conductivity can be achieved by incorporation of highly conductive fillers, such as carbon-black (CB) particles, carbon fibers, metallic fillers, or intrinsically conducting polymers. Graphite and carbon black offer the benefit of low density and cost when compared to metallic substances used for the same function. Thermal conduction is affected by overlapping sigma bonds which are part of the same molecular bonding system. Regardless of whether or not the conduction is thermal or electrical, electrons provide the pathway for energy transfer [(3, 4)]. Published literature is rich with investigations of mechanical properties of composites. Many researchers like Carlos **Alberto Baldan** et al [(5)] prepared carbon black-filled epoxy composites using different carbon black ratios below and above the percolation limit and the samples were characterized during the cure process by dielectric impedance spectroscopy and by DC conductivity. The results present distinct behavior during the cure process because of the effect of the conducting filler on the matrix microstructure. Filled samples below the conductive percolation threshold should be monitored by dielectric spectroscopy analysis whereas samples above that limit displays conductive behavior during all the curing stages. The result of literature search even further identified the necessity and importance of carrying out the proposed research. **Hashmi**[(6)] studied rheological and mechanical properties of polymer composite (red mud filled PP/PC and PP/Nylon-6 blend systems), he showed that addition of RM particles to PP/ Nylon-6 blend increases the discontinuity and restricts the growth of crystal, and therefore crystalline peak intensity reduced in the field blend composites. A new type of cheaper blend is developed by melt mixing technique and incorporation of red mud modifies the PP/ Nylon-6 structure by interlocking the chains on the surface and composite. An increase in red mud content raises the tensile strength of the of PP/ PC blend. **Thomas**[7] and mather been investigated the relationship between the positive temperature coefficient (PTC) effect and the room temperature volume resistivity has been investigated. . **1n 1999, Al-Htimi** [8] studied the mechanism of effect of different types of pphr of carbon black on the performance of the tyre. **1n 1999, Prodder**[9] investigated the inter dependence of thermal conductivity with crucial properties of polymer. Selection of the filler and the resultant filler content in semiconductor molding compounds were discussed in view of the practical limitations of composite thermal conductivity. Particle semiconductor grade molding ompounds resulting from this work were extensively investigated. **Farshifar and mather**[10] been investigate electrical and mechanical properties of Conducive Carbon black/ polyolefin composites mixed with carbon fiber. Mechanical properties, including tensile strength, elongation at break, and impact strength of the conductive composites were evaluated. The results showed that incorporation of CB and CF in the composites will enhance tensile strength, but decrease elongation at break and impact strength of the composites. **Mather P.J and piggott**[11] have studies the structure and surface functionality of a high structure (H) carbon black by gasification with carbon dioxide, thereby allowing the properties of the corresponding composite to be modified systematically. The results are discussed in terms of a carbon black structure modification and its relation to mechanical and electrical properties.The aim of this paper is to study the conduction and mechanical of a composite consisting of a PP and PC as a matrix and carbon black as Conductive filler.

EXPERIMENTAL PART

Materials

Commercial polypropylene (Sabic, KSA) its melt flow index and density of the material are 11gm/10min and 0.908 (gm/cm^3) respectively, and **commercial polycarbonate.** The melt flow index and the density of the material are 2.1gm/10min and 1.20 (gm/cm^3) respectively,

Carbon black

The filler component was carbon black with apparent density (0.457 g/cm^3), 5.1 % moisture content, and ash content (8.9%)

Carbon black used in this work was produced by Iraqi Asala Company with particle size 66.21 μm.

Preparation Methods For Composites Materials

Polypropylene (PP), (PC), and (C.B) samples were kept in an air circulating oven at 70^{o}C for 4 hr to dry the materials. Weighted amounts of polymers were mechanically mixed and fed to 25 mm single screw extruder machine (Betol BM 1820 extruder) The barrel as well as die temperatures was monitored and controlled by a thermostat and was adjusted to yield uniform output of the polymer blend. Feed, compression and metering zone temperatures are shown in table (1). Polymer blend of PP and PC (80/20) were mixed with various compositions of filler (0, 5, 10, 15, and 20) %. and re-extruded again on the same machine (Table(1)). The extrudates produced in the form of monofilaments of about 2mm in diameter were cooled in water and cut in 3-4 mm in length.

Molding Procedure

The CININATI hydraulic press was used with maximum load (15ton) and working area (0.4*0.3) m, for compression molding. The mold used for pressing the composite material has dimensions of (30*30*4) mm. It is made of steel. The sheet was prepared by hot pressing at 150^{o}C for PP/PC/C.B. A pressure of 20 kg/cm^2 was applied for 5min to allow the composite to melt and spread out between plates. Pressure was then increased to 100 kg /cm^2 for further 5min. The pressure was removed and the mold sheet was quenched in water at room temperature.

Compression measurements

Compressibility properties were measured by using the same hydraulic press. The test specimens with dimension of (4 x 4 x 8) mm were used in this work. The width of specimen had equal value to its thickness and the length to width had a ratio of (2:1). The test was carried out according to the test specification of ASTM (D695[(12)])

Electrical and thermal conductivity measurements

Electrical conductivity was measured by the standard four-probe method at ambient conditions [(13)]. In this method; four equally spaced probes are placed on the sample. A current source provides constantly increasing current I_0. When I_0 is passing though the two outer probes, the resulting voltage drop ΔV across the two inner probes is measured by the voltmeter. The electrical conductivity was obtained as the slope of voltage vs. current. The specimens had 10 mm diameter and 1 mm thickness.

The resistance of the sample can be obtained by the following equation

$$R = \frac{\Delta V}{I_o}$$

Thermal Conductivity

In order to determine the coefficient of thermal conductivity for all specimens before and after reinforced the Lee's disk instrument is used which was made by Griffin and George Company .The coefficient of thermal conductivity can be calculated by using eq.

$$K = \frac{ed(A_3(t_3 - t))}{A(t_2 - t_3)}$$

t_1, t_2 and t_3 are the temperatures of the three discs. t is the room temperature A_1, A_2 and A_3 are the emitting areas of the three discs (The amount of heat crossing the sample is the amount of heat emitted from disc 3. A across a sample of the material of uniform cross-section mm^2. K is the thermal conductivity in (W/ m.K).e is a constant which measures the heat loss per unit area of copper.d is the thickness of the sample. The sample was a cylinder with 40 mm diameter and 5 mm length. Figure (1) shows the arrangement of this apparatus.

RESULT AND DISCUSSION

Compression Test

This property is applied the tensile, but it is determined by compression rather than by stretching. It is the compression load at the breaking point divided by the cross – sectional area of the resisting surface [14]. The mechanical behavior of polymer can be characterized by its stress – strain properties. This involves observing the behavior of a polymer as on applied a compression stress to it in order to elongate (strain) it to the point where it ruptures. The stress – strain curves of the specimens are shown in figure (2).

From this curve, it can be seen that the strain increase linearly with the stress and with further increase in stress to the point of deviation from linearity. There is a slight increase in the strain with increasing the applied stress and this may be attributed to the reduction of free volume in polymer.

In general, it can be seen that the stress – strain curves are slightly concave to the stress axis and that there is no distinguishable yield point for all of the samples [15]. In principle, compression strength is the opposite of tensile strength. The material first goes through the elastic strain range and then enters the plastic deformation range. Compression stress-strain curves have the same types of critical or property points as described under tensile strength: elastic limit, proportional limit, and yield strength [14]. From the experimental work it was observed that no failure occurs, increasing the compression stress leads to flatten the specimens, therefore there is no certain compression strength at failure to be observed.

ELECTRICAL CONDUCTIVITY

Figure (3) represents the changes in (volume resistivity) and CBs content for PP/PS/C.B composites materials. The following results can be concluded:

1. The values of (volume resistive) decrease with increasing volume fraction.
2. Specimens that contain both (PP+PC) give (volume resistivity) higher than the Specimens that contain (PP+PC +C.B)

The resistivity lower is caused by enrichment of higher conductive material components.

The electrical properties are change when adding CBs particles to the blend. The composites behavior evolves from insulating material characteristics to those of conductive materials. The effective utilization of carbon black in composite applications depends strongly on the ability to homogeneously disperse them throughout the matrix without destroying their integrity [13].

THERMAL CONDUCTIVITY

Figure (4) represent the changes in (thermal conductivity) and CB content for PP/PS/C.B composites materials. The following results can be concluded:

1-The values of (thermal conductivity) increase with increasing volume fraction of C.B.

2 – Specimens that contain both (PP+PC) give thermal conductivity) lower than the Specimens that contain (PP+PC +C.B).

From this figure it is clear that there is a pronounced effect of addition of C.B at different weight percents ranging between (2-20) wt. % on the thermal conductivity of the material, increasing % C.B content leads to increase in the thermal conductivity, this may be due to fact that as the phonons represent the lattice vibration and will transfer the heat energy in the insulator solid materials.

The collision between two phonons represents very important phenomena at these temperatures leading to increasing the number of phonons during the collision. This means that the values of (K) depend on the mean free path (the distance that the phonons moved between two collisions)

The thermal conductivity of a composite depends on many parameters including:- Type of additives; Additives percentage; and) Resin type. The parameters of major influence on thermal conductivity are Additives percentage and conductivity properties of both resin and additives [16, 17, and 18].

Effect on X-Ray Measurement

X-ray phase analysis of the prepared samples was done on Phillips X-ray diffraction type (PW). Intensity values were recorded in the range between 10-60^o, 2θ angle value. Figures (5) and (6) illustrate the X-ray diffraction pattern of PP/PC (80/20) Wt % and PP/PC/carbon black (80/20/5) Wt%, The characteristic intensity peaks of PP are recorded at (13.8, 16.4, 18.3 and 21.4) 2θ values and the calculated d. spacing of (6.38, 5.38, 4.86 and 4.18) (Angstrom). The diffraction pattern of PP/PC filled with carbon black exhibit all reflections of PP/PC blend along with the addition of carbon black peaks at (4.4, 3.56, 2.88, 2.56 and 3.37) Angstrom figure (6). It can be observed that the addition of C.B modified the intensities of peaks of the crystalline PP polymer present in the matrix. The peak intensities for PP at for (5.38, 4.86 and 4.18) Angstrom reduced from (5000 to 4823, 3901 and 4450) respectively. This may be explained by the fact that addition of carbon black adversely the crystallization of PP/PC by increasing the discontinuity and therefore restricts the growth of crystals in the blend composites filled with the carbon black.

CONCLUSIONS

Mechanical, Electrical, and thermal properties of PP/PC/C.B composites were experimentally examined as the CBs loading was increased up to 20 wt.-%. Addition of carbon black significantly increases the thermal conductivity. The CBs yield much higher electrical and thermal conductivity than the neat PP/PC. The compression properties are reduced with increasing the C.B content in the polymeric matrix.

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Table (1) Extrusion parameter

POLYMER	Température ^oC Zone1	Zone2	Zone3	Zone4	Screw speed (RPM)
PP/PC	150	170	220	200	35
PP/PC/C.B	155	190	230	210	35

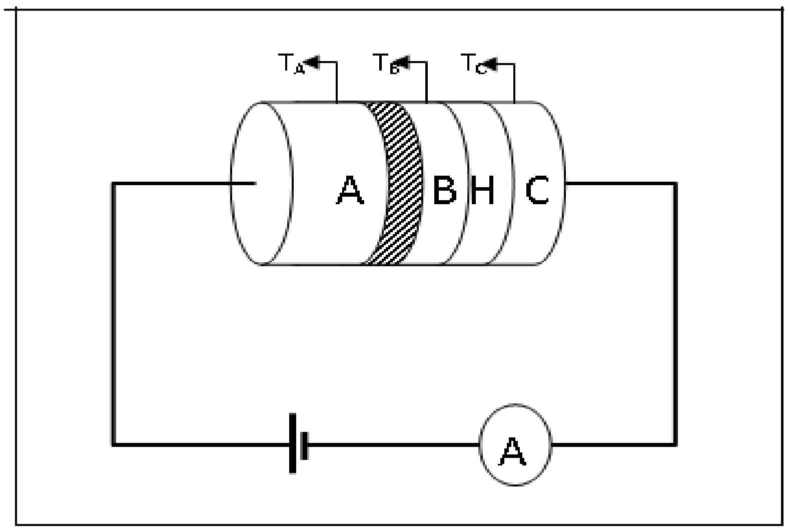

Figure (1) lee's disk for calculating thermal conductivity

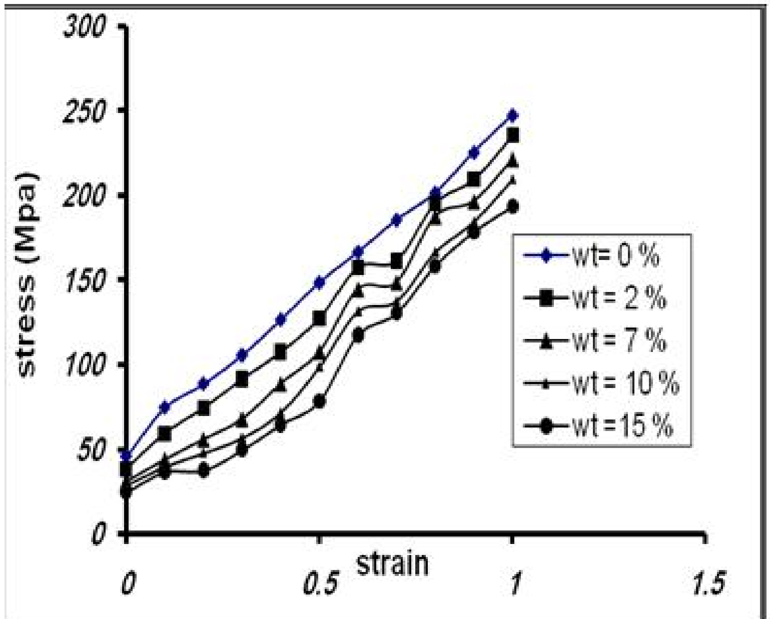

Figure (2) Stress-strain curve of PP/PC at different weight fraction of carbon black

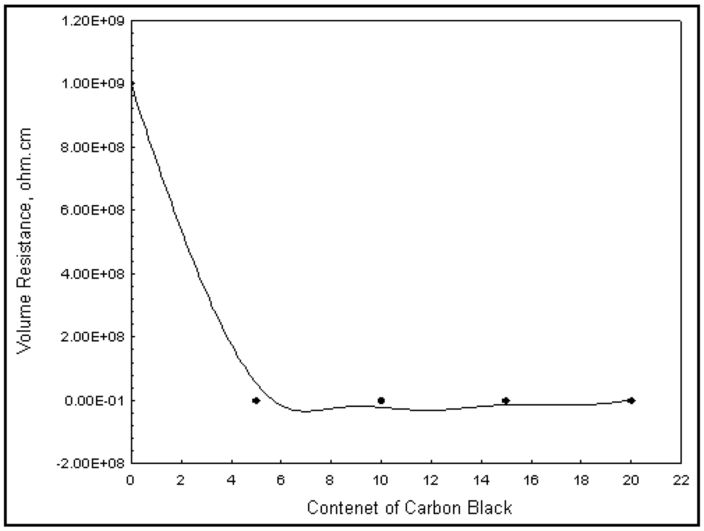

Figure (3) Effect of carbon black content on volume resistivity

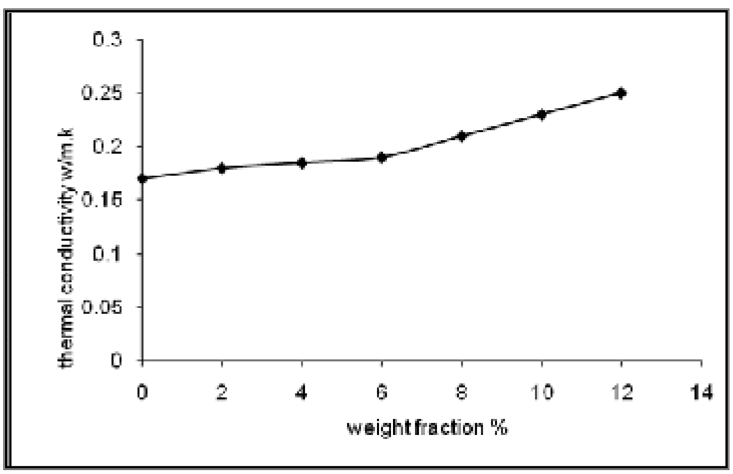

Figure (4) Effect of carbon black content on thermal conductivity

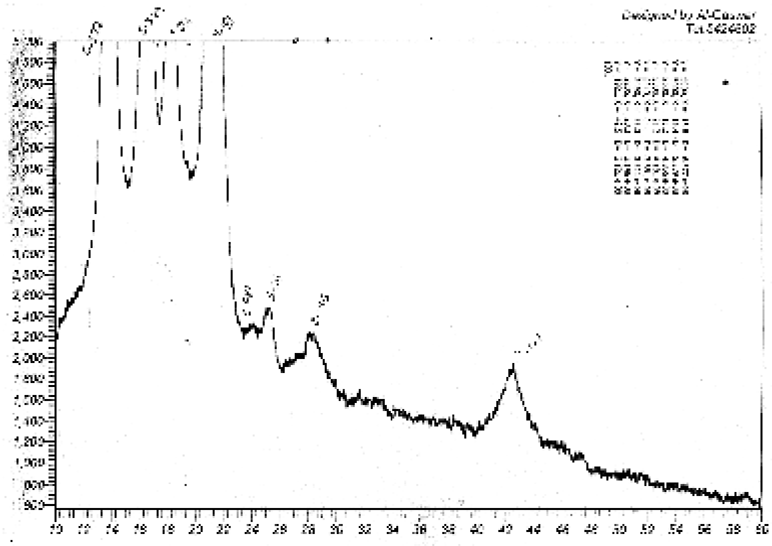

Figure (5) X-ray diffraction pattern of PP/PC (80/20).

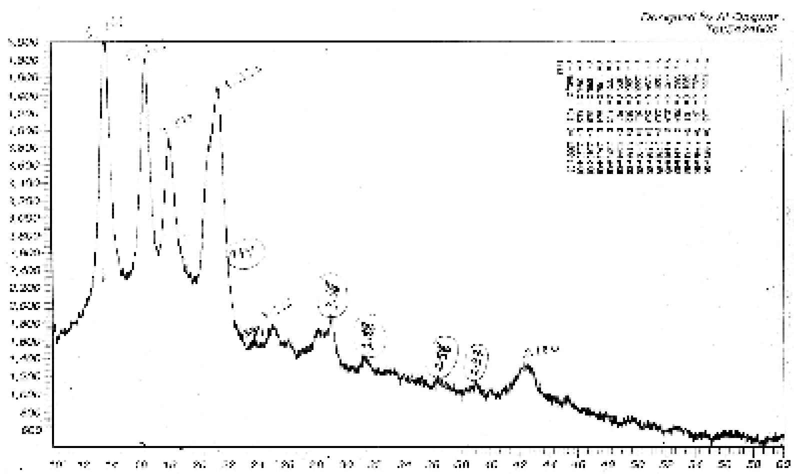

Figure (6) X-ray diffraction pattern of PP/PC/carbon black (80/20/5) %.