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Experimental Evaluation of DC Conductivity of Rice Husk Reinforced Polypropylene Composites with Addition of Cenosphere

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Abstract

Insulating materials are used in electrical power circuits to prevent leakages of current. Main objective of this study is to evaluate the DC conductivity of rice husk filled polypropylene composites with and without cenosphere. The conductivity at room temperature was found to decreases from 2.64e-^{13} to 9.371e-^{14} Scm^{-1} with the addition of cenosphere. Dense packing of the material, collapse of pores and decreases in air gap between the rice husk and cenosphere particles could be the factors for the increase in conductivity. In case of DC conductivity of filled polymers interface interaction is the most important parameter which influences the DC conductivity of matrix and will depend on type of fillers, concentration of filler and the chemical bonding between filler and matrix. Rice Husk reinforced polypropylene composites having 20% rice husk with and without cenosphere is developed. Treated and untreated cenosphere with different concentration were loaded with chopped rice husk in polypropylene. The DC conductivity of rice husk-filled polypropylene was studied by adding cenosphere (2, 4, 6, 8 per h) respectively in concentrations. The loading of the polypropylene with the rice husk and cenosphere decreases the DC conductivity (σ_{dc}).

Keywords: *Composite, DC conductivity, fiber, polymer, cenosphere*

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INTRODUCTION

Insulation resistance and dielectric strength of lingo-cellulosic materials such as wood give an indication of their dielectric constant at different conditions under electric fields. Electrical properties of such materials indicate their suitability as insulating materials for special applications [1–2]. Among commodity thermoplastics, polypropylene (PP) possesses properties like low density, high vicat softening point, good flexlife, sterilizability, very good abrasion resistance and excellent electrical properties [3]. The uses of natural fiber composites are expanding day by day opening the new application windows. In recent years, low cost natural fiber composites proved of interest for dielectric applications, showing potential for future applications as dielectric materials and circuit boards.

These materials are employed as hollow cellular structure of plant fibers in providing insulation against heat and noise [4]. Cellulosic fillers have attracted considerable interest for the reinforcement of thermoplastics such as polypropylene and polyethylene, which melt or soften relatively at low temperatures. Among organic filler, wood and cellulose fibres offer a number of benefits as reinforcements for synthetic polymers because of their high specific strength and stiffness [5].

Organic fillers, such as rice husk obtained from milling process of rice, can be used as organic filler because of its availability. Rice husk roughly contains 35% cellulose, 35% hemi cellulose, 20% lignin and 10% ash (94% silica), by dry weight basis. From an environmental point of view, the ability to reuse rice husk-filled polypropylene specimen is of importance [6].

The effect of compatibilizing agents on the mechanical properties and morphology of thermoplastic polymer composites filled with rice husk flour have been studied by Yang *et al.* [7].

As the filler loading increases, the composites made without any compatibilizing agent show decreased tensile strength and more brittleness, but greatly improved mechanical properties by incorporation of the compatibilizing agent. Wheat straw has been used for making composites, panel boards and anion exchangers where the straw is used in powder form rather than in the fibrous form.

A limited number of studies have reported the use of wheat straw fibres for production of composites [8–9]. Panthapulakkal *et al.* have characterized wheat straw fibres to evaluate their potential as reinforcing material for thermoplastic composites [10].

MATERIALS AND METHODS

Materials

The rice husk used in the present study was collected from Betul, M.P., (India) in the form of agriculture residues [11]. Isotactic polypropylene (PP) with density 0.915 gm/cm³ was obtained IPCL Vadodra. Cenospheres of flyash used in this investigation were obtained from Cenosphere India Pvt Ltd. Kolkata of size 150 µm with density 0.6 gm/cm^3 [12].

Treatment of Fibers

Immersing the rice husk of length 5–7 mm in a solution of 340 ml Xylene, containing 18.5 gm of Maleic anhydride (MA) and 1.5 gm of benzoyl peroxide as catalyst; and then heating at temperature of 140^{o}C for 4 h. Finally, the immersed rice husk was dried at 70^{o}C in a vacuum oven until a constant weight is gained [11].

Surface Treatment of Cenosphere

Cenospheres of size 150 µm were dried in an oven at 50^{o}C for approximately 20 min before treatment to make it moisture free. Cenospheres were treated with octadecyltrichloro (OTDC) silane with very low content of it.

In a solvent of methanol and water in 3:1 respectively, 0.4 wt% of silane is mixed. This solution was then hydrolyzed by 20% acetic acid and cenospheres are mixed in this solution with constant stirring. This slurry was stirred manually for 15 min gradually and kept at room temperature for 1 h.

These treated cenospheres were then washed with distilled water 2–3 times. The slurry was then dried for 24 h at room temperature and kept in vacuum oven at 120^{o}C for 20 min to make it moisture free [11].

Composite Preparation

Table 1 lists the composites used in the study. Varying the weight% of treated and un treated rice husk (10, 20, 30) were mechanically mixed with PP granules and compounded on a two roll mill by keeping the rollers at 200^{o}C, weighed amount of cenosphere (treated and un treated) were mixed gradually with rice husk [12].

Fourteen compositions (Table 1) of PP/rice husk/cenosphere (treated and un treated) were prepared respectively in identical conditions.

Table 1: *Ingredients Used in Making PP/Rice Husk/Cenosphere Composite.*

S.No.	Sample	Polypropylene (gm)	Rice Husk (gm)	Treated Rice Husk (gm)	Cenosphere (gm)	Treated Cenosphere (gm)
1	Pure PP	100	-	-	-	-
2	PP/Rice Husk (70/30)	70	30	-	-	-
3	PP/Rice Husk (80/20)	80	20	-	-	-
4	PP/Rice Husk (90/10)	90	10	-	-	-
5	PP/MATr. Rice Husk (70/30)	70	-	30	-	-
6	PP/MATr. Rice Husk (80/20)	80	-	20	-	-
7	PP/MATr. Rice Husk (90/10)	90	-	10	-	-
8	PP/Rice Husk/Ceno (80/20/8)	80	20	-	8	-
9	PP/Rice Husk/Ceno (80/20/6)	80	20	-	6	-
10	PP/Rice Husk/Ceno (80/20/4)	80	20	-	4	-
11	PP/Rice Husk/Ceno (80/20/2)	80	20	-	2	-
12	PP/MATr. Rice Husk/Silane Tr.Ceno (80/20/8)	80	-	20	-	8
13	PP/MATr. Rice Husk/Silane Tr.Ceno (80/20/6)	80	-	20	-	6
14	PP/MATr. Rice Husk/Silane Tr.Ceno (80/20/4)	80	-	20	-	4
15	PP/MATr. Rice Husk/Silane Tr.Ceno (80/20/2)	80	-	20	-	2

Methods

Resistance Measurement

Sliced PP/rice husk/cenosphere samples were coated by air-drying type conducting silver paint on both the sides. Resistance (R) values of these samples were measured by using a Kiethley Electrometer, model 610C at 30–120°C. Resistivity is calculated by following equation,

$\rho=R*A/L$

Where, R is the resistance of the sample. *A* (cm^2) is the area of the electrodes and *L* is the thickness.

DC Conductivity Calculation

DC conductivity was calculated by using the following formula:

$\sigma_{dc}=1/\rho=L/R*A$

Where, σ_{dc} is the DC conductivity of PP/rice husk/cenosphere, R is the resistance, *A* is the area and *L* is the thickness of the sample.

Density Measurements

Density of the PP/rice husk/cenosphere samples was determined by using a high precision Citizen machine, Model CX 265 as per ASTM D 792. Average of four values is reported here in Table 2.

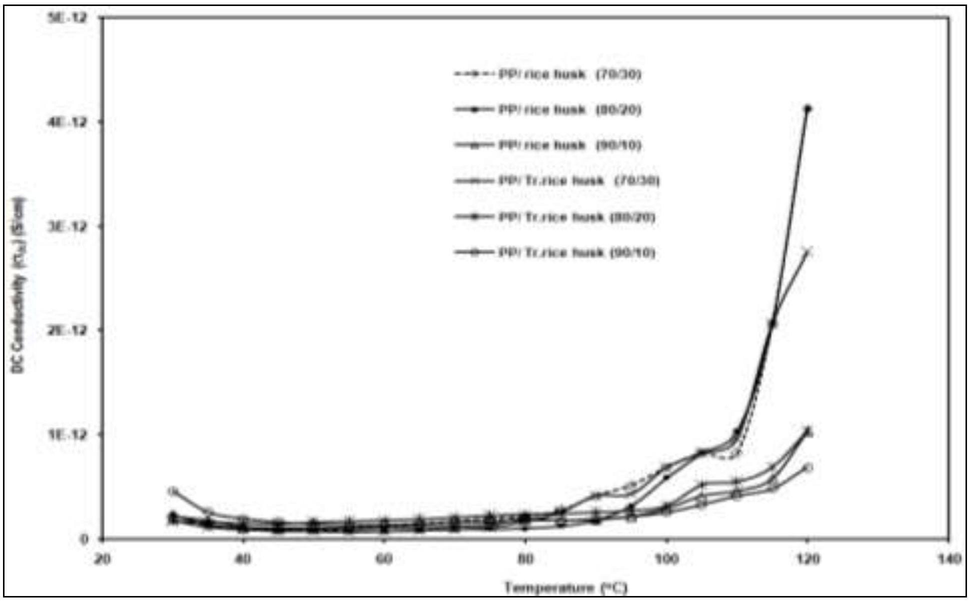
Table 2: *Density Values of PP/Rice Husk/Cenosphere Composite.*

S.No.	Sample	Density (g/cc)
1	Pure PP	0.915
2	PP/Rice Husk (70/30)	0.9274
3	PP/Rice Husk (80/20)	0.9245
4	PP/Rice Husk (90/10)	0.9194
5	PP/MATr. Rice Husk (70/30)	0.9254
6	PP/MATr. Rice Husk (80/20)	0.92107
7	PP/MATr. Rice Husk (90/10)	0.91018
8	PP/Rice Husk/Ceno (80/20/8)	0.9318
9	PP/Rice Husk/Ceno (80/20/6)	0.9311
10	PP/Rice Husk/Ceno (80/20/4)	0.9306
11	PP/Rice Husk/Ceno (80/20/2)	0.9291
12	PP/MATr. Rice Husk/Silane Tr.Ceno (80/20/8)	0.9305
13	PP/MATr. Rice Husk/Silane Tr.Ceno (80/20/6)	0.93
14	PP/MATr. Rice Husk/Silane Tr.Ceno (80/20/4)	0.9295
15	PP/MATr. Rice Husk/Silane Tr.Ceno (80/20/2)	0.9235

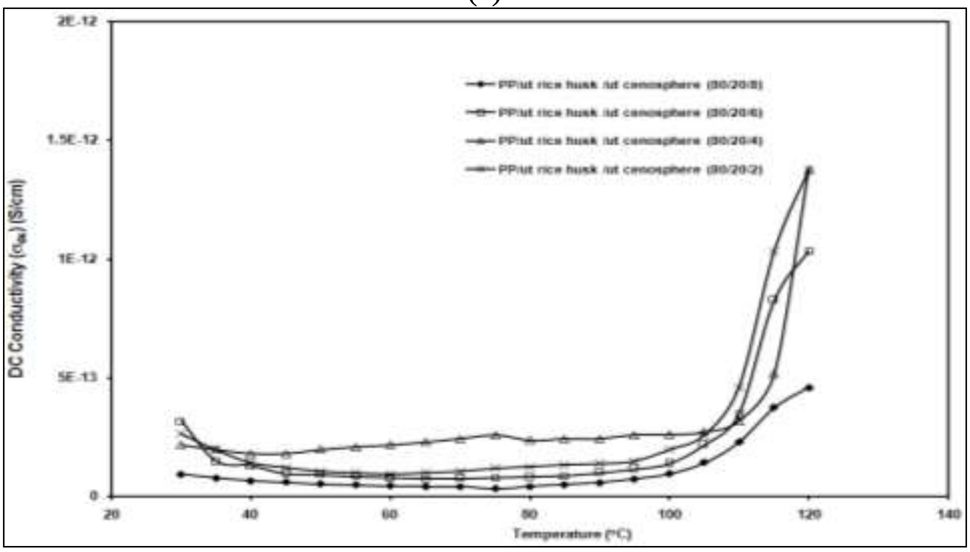
RESULT AND DISCUSSION

Table 1 shows the ingredients used for the preparation of the studied samples. It is clear from the table that the content of rice husk and cenosphere is changed for different samples. Table 2 shows the density of the composites studied, it is clear that the addition of rice husk and cenosphere increases the density whereas treatment of rice husk and cenosphere decrease the density to a little extent.

Figure 1 the effect of cenospheres content on the dc conductivity of rice husk/PP composites. It is clear that as the weight% of cenosphere in RH/PP composites increases the DC conductivity decreases. This increase is due to displacement of electrical charges being displaced inside the polymer due to their lower concentration. The decreases in DC conductivity by increase in wt% of cenospheres may be due to particle blockage conduction path by cenospheres in RH/PP composites. As the cenospheres content increases the interchain distance also increases due to which hopping between chains becomes more difficult, this decreases the DC conductivity.



(a)



(b)

***Fig. 1: (a, b and c)**: DC Conductivity of PP/Rice Husk/Cenosphere Composites.*

Figure 1a shows the DC conductivity of rice husk/PP composites (treated and untreated). It is clear from the graph that the DC conductivity increases with temperature but decreases with weight% of rice husk. Treatment of rice husk decreases the dc conductivity of the composites by a little amount. This is because the treatment of rice husk removes the waxes from the surface. Figure 1b shows the DC conductivity of the cenosphere filled PP/rice husk (80/20) composites. It is clear from the graph that the addition of cenosphere in the PP/rice husk fiber composites decreases the DC conductivity of the composites whereas as with increase in temperature of the composites DC conductivity increases. Addition of cenosphere increases the porosity of the composites which tends to decrease the DC conductivity. It is clear from Figure 1b is that for the same rice husk content, the greater cenosphere proportion in the composite shows the smaller is the DC conductivity of the composites. The other way to evaluate the fillers effect on the composite DC conductivity is investigation of the effect of increasing cenosphere while rice husk concentration is kept constant. Figure 1c shows the DC conductivity of the treated cenosphere filled PP/rice husk (80/20) composites. It is clear from the graph that the addition of treated cenosphere in the PP/rice husk fiber composites decreases the DC conductivity of the composites whereas as with increase in temperature of the composites DC conductivity increases. The resistivity of rice husk reinforced composites depend on the moisture content, crystalline and amorphous component present, presence of impurities, chemical composition, cellular structure, microfibrillar angle etc. The hydroxyl groups in the hydrophilic fiber can absorb moisture and hence the presence of the natural fiber increases the conductivity of the resin. With increasing of the content of the rice husk or the cenospheres particles, conductive paths among the fibers or the cenosphere particles increases, and the average distance between the fibers or the cenosphere particles becomes smaller; thus, the DC conductivity of the composites decreases.

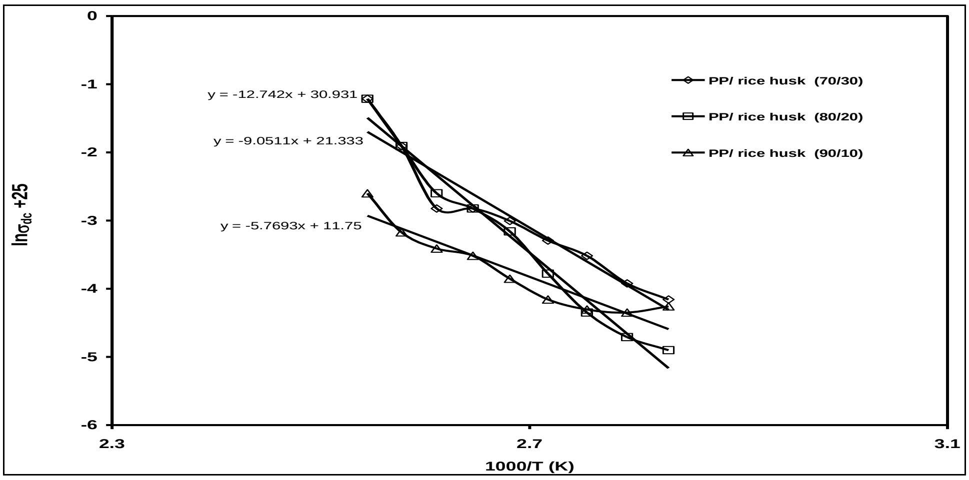
It is marked from the figure that conductivity increases with volume fraction of RH. It is well known that in any semi-crystalline polymeric material, there are crystalline and amorphous regions. The current mainly flows through the crystalline regions. The amorphous regions allow the current to pass through due to the presence of moisture. The presence of moisture and filler content increases the conduction. In addition, rice husk incorporated in a thermoplastic melt act as a nucleating agent for the growth of spherulites which is the main cause of electronic conduction.

The increase in temperature exponentially increases the portion of space charge in the conduction band. Defect conduction in the case of polypropylene is reported that the thermal agitation gives rise to defects in the material and conduction takes place by movement of ions from an occupied position to an unoccupied position. $\ln\sigma_{dc}$ vs 1000/T plot has been analysed by using the following Arrhenius equation for high temperature zone [13].

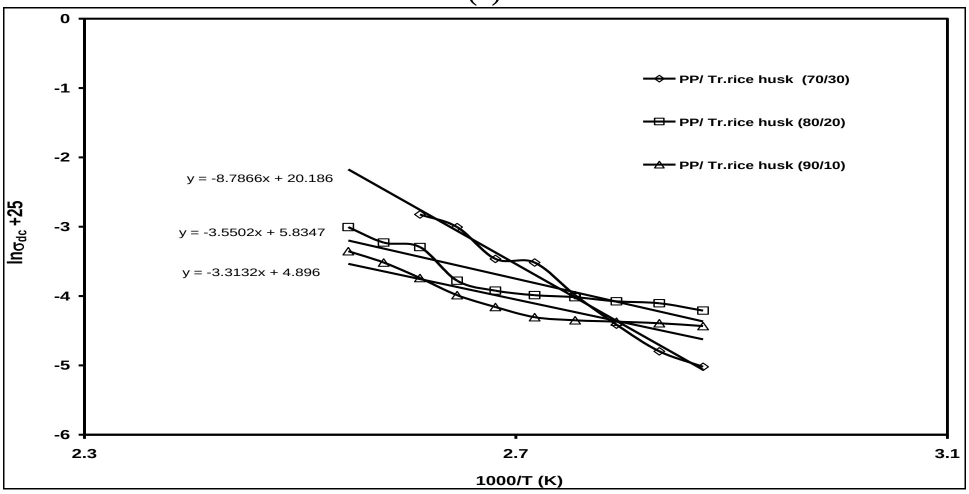
$\sigma_{dc}=A\exp^{-WE/kT,}$

Where, W_E is the activation energy, k is the Boltzmann's constant and A is a constant. T is the temperature in K.

Activation energy (W_E) of PP/rice husk/cenosphere composites is listed in Table 3 and is always >1 which shows that there is the predominance of ionic conduction. This decrease of activation energy with increase of cenosphere content is similar to the activation energy calculated for composites which has been explained by the formation of border layer at the interface of the rice husk filled polymer composites. Figure 2 shows the activation energy analyzed at high temperature zone. The activation energies of the composites are given in Table 3. It is clear from the table that the composite with low activation energy conducts better than those with relatively high activation energy. The lower the activation energy, the greater is the number of electrons that would have the necessary energy to move and conduct electricity.



(a)



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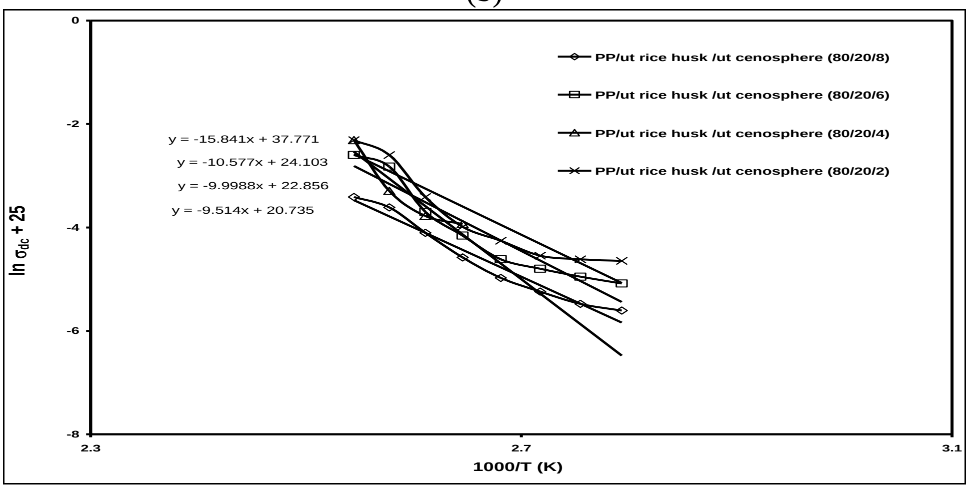

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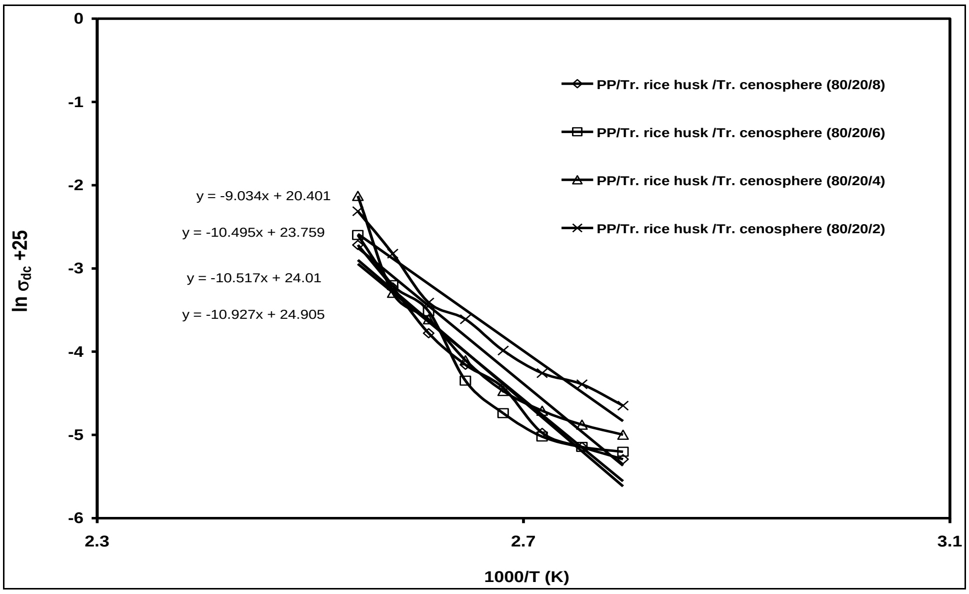

Fig. 2: (a, b, c and d): *Activation Energy for PP/Rice Husk/Cenosphere Composites Calculated at High Temperature Zone.*

Table 3: *Activation Energy of PP/Rice Husk/Cenosphere Composite.*

S.N.	Samples	Activation Energy (eV)
1	PP/Rice Husk (80/20)	7.792997
2	PP/MA.Tr.Rice Husk (80/20	3.056722
3	PP/ut Rice Husk/ut Ceno (80/20/8)	8.191554
4	PP/ut Rice Husk/ut Ceno (80/20/6)	8.608278
5	PP/ut Rice Husk/ut Ceno (80/20/4)	9.106797
6	PP/ut Rice Husk/ut Ceno (80/20/2)	13.6391
7	PP/Tr.Rice Husk/Tr.Ceno (80/20/8)	7.778274
8	PP/Tr.Rice Husk/Tr.Ceno (80/20/6)	9.036195
9	PP/Tr.Rice Husk/Tr.Ceno (80/20/4)	9.055137
10	PP/Tr.Rice Husk/Tr.Ceno (80/20/2)	9.408147

CONCLUSIONS

1. In this paper, experimental study about the effects of rice husk/cenosphere content on the DC conductivity of composites of polypropylene has been described.
2. Composites with higher concentration (8 gm) of cenosphere shows low values of DC conductivity compared to less concentration (2 gm) of cenosphere composites.
3. Activation energy decreases with increase of cenosphere content.

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