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Investigation on Properties of Waste Acrylonitrile-Butadiene-Styrene (ABS) from Different Refrigerator Brands

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Abstract

This work investigated different brands of waste refrigerators properties in terms of the recycled acrylonitrile-butadiene-styrene (ABS) using solvent recycling technique at room temperature. The preliminary analysis showed that, tetrahydrofuran (THF) was the most suitable solvent among others, because it has solubility parameter of 9.79 cal/cm^3, which was closest to the solubility parameter of acrylonitrile-butadiene-styrene (ABS) of 9.4 cal/cm^3. The FTIR analysis indicated presence of ABS in recycled materials from all the refrigerator brands. However, the recycled ABS from Matsui fridge was found to have mechanical properties closest of the virgin acrylonitrile-butadiene-styrene whose tensile strength, modulus of elasticity and flexural strength were 31.66, 1021 and 60.18 MPa respectively, as compared to the virgin ABS with 48.3, 1312 and 65.75 MPa respectively. It is concluded based on the investigation that, the recycled ABS from Matsui fridge model has the best mechanical properties when compared to the others, as it values are closer to that of virgin ABS.

Keywords: *Acrylonitrile Butadiene Styrene, Solubility parameter, used refrigerators, Mechanical properties, Tetrahydrofuran*

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1.0 Introduction

The large waste emanating from electronics and electrical appliances has been attributed to rapid technological development [1]. Acrylonitrile-butadiene-styrene (ABS) is an engineering thermoplastic that is widely used in many practical aspects, such as in electronics and electrical appliances because of their good mechanical properties, low density and good thermal properties, thereby making increase in demand for the production annually [2, 3, 4]. ABS is used for refrigerators insulation because they are not readily attacked by fluorocarbon unlike high impact polystyrene, thereby making ABS one of the largest polymer components of refrigerators [1, 5]. However, this material is discarded into the environment after its service life which constitutes environmental menace. It has been established that, primary, secondary, tertiary (chemical) and quaternary recycling are the four major polymer recycling techniques that have been identified by many researchers [6]. These methods have been applied severally for the recovery of ABS and other polymer materials from different electrical and electronic appliances.

Recycling of ABS and high impact polystyrene from waste computer equipment was worked on by [1] using selective depressants for the separation of ABS and high impact polystyrene (HIPS). It was reported by [7] that, ABS/THF in the ratio of 1: 10 at a temperature of 40 ^{0}C over a period of 90min was investigated, and concluded that, THF is a suitable solvent for the study. It was also that acetone and tetrahydrofuran (THF) were used as solvent in the works of [8] and [9], but the effect of solubility parameter was not reported.

It was also reported by [3] that, an effective dissolution of polymer in a solvent is a function of proper solvent selection. One of the factors consider is the solubility parameter to inform the choice of polymer that will dissolve in a particular solvent, with the consideration of being soluble in a solvent. The solubility parameter of polymer (δ_2) and that of solvent (δ_1) are defined, where δ_1-δ_2 is less than 1.7-2.0.

In this work, the properties of waste acrylonitrile-butadiene-styrene (ABS) from different refrigerator brands was investigated using the theory of solubility parameter to determine the suitable solvent for the dissolution and the mechanical properties of the recovered ABS from these different sources were evaluated.

2.0 Experimental

2.1 ABS waste collection

Waste refrigerators which consist of metals and polymers were separated manually to remove the metals from the polymers. The inner lining which is rich in the ABS containing materials was stripped out. The sorted waste ABS containing material was washed thoroughly with detergent to remove all dirt and paper labels then rinsed with water and spread to dry. The dried materials were cut into flakes with a dimension of 3mm. This treatment was done to enhance the dissolution of the ABS materials.

2.2 Dissolution process

The dissolution process involved dissolving the waste into a suitable solvent and this was determined by evaluating the difference in solubility parameter of the solvent and the polymer. Three different solvents (Benzene, Toluene and Tetrahydrofuran) were tested and tetrahydrofuran (THF) was found to be the best. Therefore, the dissolution was carried out using THF in a fume cupboard. 75 g of the ABS material was weighed and poured into the beaker, 300 ml of THF was measured and poured into the beaker at room temperature and pressure condition for 1 hr, and the mixture was stirred intermittently for homogenization.

2.2.1 Filtration

The stirred mixture of the acrylonitrile-butadiene-styrene (ABS) containing material was poured into the Buchner funnel of the filtration set up; it took 10 mins to separate the filtrate and the residue. The filtrate contained ABS and the residue was made up of the insoluble contaminants and the additives.

2.3 Sample preparation

A metallic mould of 21x16x4 mm was cleaned with a piece of cloth to remove all adhered particles and then coated with petroleum jelly as a releasing agent for easy removal of the sample from the mould after drying. The filtrate was poured into the mould and allowed to stand for 48 hrs. The dried sample was then removed from the mould and put in the oven to remove any trace of solvent in the sample at temperature of 80 ^{0}C. This method was adopted from the work of [10].

2.3.1 Compression

The dried material was cut into flakes and spread on a metal plate which was covered with aluminum foil that was folded to enclose the flakes between the two metal plates. The metal plates with the content were placed on hydraulic press with specified pressure 40 ton and temperature 170 ^{0}C for 5 mins. It was then removed after the 5mins of compression and left to cool for another 5 mins at ambient conditions according to ASTM D288 standard specifications. The sample was then removed from the mould and cut into test sizes. The same steps were used for all the fridge brands.

2 .3.2 Samples characterization

Three samples were used each for tensile test, flexural strength test, density and water absorption using ASTM D636M, D790M, D792-66 and D570-98 standard procedures respectively (ASTM, 1987).

2.3.3 Fourier Transmission Infrared Spectroscopy (FTIR)

FTIR analysis was carried out on the samples using spectrum Perkin Elmer FTIR machine to determine the functional groups present. This was done on the recycled and virgin ABS respectively. It was conducted by measuring 1 g of each sample and introduced into a cell of 10 cm length. These were transferred into potassium bromide disc, which then charged into FTIR spectrophotometer for spectral analysis of all the functional groups present in each sample charged into the machine.

3.0 Results and Discussion

The solubility parameter of ABS was evaluated to be 9.49 cal/cm^3. The solubility parameter of benzene, toluene and THF were also evaluated to be 8.9, 8.95 and 9.74 cal/cm^3 whose differences from that of ABS are 0.6, 0.5 and 0.3 respectively, which are all less than 1.7-2.0 cal/cm^3 as reported by [3]. This is because, solvent is suitable for the dissolution of a selected polymer if the difference between the solubility parameter of the solvent and the polymer values are less than 1.7-2.0 cal/cm^3. However, the lower the difference in solubility parameter the better. Therefore, THF was chosen as the best solvent and others discarded.

3.1 FTIR Analysis of ABS from Different Sources

Figure 1 presents the FTIR analysis of virgin ABS, recycled ABS from Fides fridge, recycled ABS from Tec fridge, recycled ABS from Mitsui fridge and recycled ABS from Bauchet fridge. The FTIR results were plotted and cascaded in one graph as shown in Figure 1.

As observed from the spectra of recycled ABS from Matsui fridge, the present of acrylonitrile (C=N) with absorbance peak value of 2305 cm^{-1} which is within the range of (2252 – 2350) cm^{-1}, the benzene ring which is associated with polystyrene fall within the peak value of 750.33-898.86 cm^{-1}, the =CH_2 bond was observed at a bend vibration of 975.05 cm^{-1}, CH_2 was observed at a bend rocking vibration with symmetric type and a range of 1265.35 cm^{-1}. However, there is other functional group such as C-C which was observed as a bond stretch vibration with the range of 975.05 and 1161.19 cm^{-1} (Figure 1).

The Tec fridge had its own acrylonitrile peak (C=N) between the range of 2926.11-2305.01 cm^{-1}, the aromatic ring peak was found at 739.73 cm^{-1}, the CH_2 had a bend rocking at 1446.66 cm^{-1}, C=C was observed as a stretch at 1600.01 cm^{-1} and at 3056.31 cm^{-1}, $CH_2C(SP^2)$-H was seen as shown in Figure 1.

In the FTIR spectra of recycled ABS from Bauchnet fridge, benzene ring was observed between the peak range of 468.72 cm^{-1} and 738.76 cm^{-1} because the peak value is 542.02 cm^{-1}. Also, =CH_2 was obtained to be twist at 908.50cm^{-1} which fall between the peak value of 896.93 cm^{-1} and 972.16 cm^{-1} as presented in Figure 1. The CN peak was also observed at 2305.01 cm^{-1} while C-H bend peak value was identified at 1425.44 cm^{-1} as shown in the figure.

The acrylonitrile (CN) functional group absorbance peak of 1496.81 cm^{-1} as shown in Figure 1 of Fides fridge is associated with polystyrene has it stretch vibration. Also, the FTIR analysis peaks

which identified benzene ring stretch at vibration peak of 756.12 cm^{-1}, 1443.59 cm^{-1}, 1189.15cm^{-1} and 2924.18 cm^{-1} were identified for the functional groups of CH_2 bend, C-C stretch and CH_3 stretch respectively.

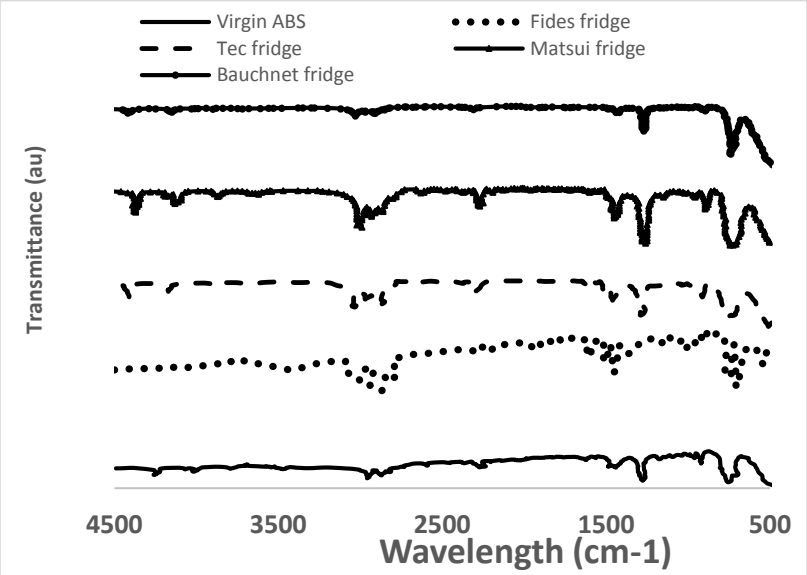

Fig. 1: FTIR analysis of virgin ABS and recycled ABS from four different fridges

All the peaks observed in the FTIR spectra of the recycled ABS were also observed in the FTIR spectra of the virgin ABS as shown in Figure 1, it is evident that there are presence of acrylonitrile, butadiene and styrene functional groups as revealed by the spectral. This confirms the presence of ABS in the samples.

3.2 Mechanical and Physical Properties of ABS from Different Sources

The mechanical properties of recycled and virgin ABS obtained are presented in Table 1. The results indicated that recycled ABS from Bauchnect fridge, Matsui fridge, recycled ABS from Fides and Tec fridge have tensile strength of 29.71, 31.66, 30.89 and 27.63 MPa respectively. The result showed that, recycled ABS from Matsui fridge has the highest tensile strength of 31.66 MPa which is slightly higher than that of Fides with 30.89 MPa, that were both closer to the value of 48.3 MPa obtained from virgin ABS when compared to the tensile strength of Bauchnet fridge and Tec fridge as shown in Table 1. The difference in tensile properties of the recycled ABS could be as a result of different grades of ABS that are available for different fridge manufacturing as reported by [11] and [12]. Also, the wide difference in tensile properties of recycled ABS as observed in, Matsui fridge compared to Tec and Bauchnect fridges be as a result of aging as also reported in the work of [11] and [12] which stated that, aging result into the degradation of poly butadiene components of the ABS and this could affect the overall properties. The tensile properties obtained for all the recycled ABS is less than the literature value of 48.3 MPa as reported by [13], which can be attributed to the effect of recycling because polymer generally can lose some additives or anti oxidant when in contact with solvent, thereby resulting to accelerated changes in properties during the recycling process according to [1].

As shown in Table 1, the modulus of elasticity (MOE) Matsui fridge had the highest value, while Bauchnect and Tec fridge have very close values, the fides fridge has the least values. The reason for this trend can not be readily explained, but on a general note the reasons advanced for the tensile strength may hold in this case.

Table 1: Mechanical properties of recycled and virgin ABS

Materials	Tensile strength (MPa)	Modulus of elasticity (MPa)	Flexural strength (MPa)	Elongation (%)
Fides Fridge	30.89	820	57.5	4.11
Tec fridge	27.63	925	51.2	3.71
Matsui fridge	31.66	1021	60.18	4.8
Bauchnet fridge	29.71	935	55.25	4.4
Virgin ABS	48.3	1312	65.75	13.37

However, for the flexural strength also known as modulus of rupture (MOR) the values for all the sample are very close but still lower than the experimentally determined value of virgin ABS but they all fall within the literature values [3]. For the elongation at break Matsui fridge has the highest value very close to the experimentally determined values of ABS which fall within the literature value while the values obtained for Tec and Bauchnect fridge are lower than the literature value. Some variation between samples was noticed but it was not generally great as the standard deviation of the test were mostly less than 10 %.

Water absorption and density of the recycled and virgin ABS are presented in Table 2. The virgin ABS has water absorption of 1.6 % higher than the 0.3 % as reported in the work of [14]. The recycled ABS from Bauchnet fridge and Tec Fridge as shown in Table 2 have water absorption higher than the virgin ABS and the value reported by [14]. This could be as a result of presence of impurities that could not be removed completely. The Fides fridge and Matsui fridge has low water absorption relative to the virgin ABS, which may be due to the type of impurities presents in this recycled from the fridges that are not susceptible to water absorption.

The density of Bauchnet fridge as determined was 1.03 g/cm^3 which is very close to the density value of virgin ABS determined to be 1.04 g/cm^3. These two values fell within the related reported literature ranges of 1.02-1.04 g/cm^3 by [3] and [14]. However, the density values of Fides and Tec fridges were determined to be 1.06 g/cm^3 and 1.07 g/cm^3 respectively, which are higher than the virgin ABS density value and the range of values reported by [3] and [14]. More so, it was observed that, the value for matsui Fridge obtained to be 1.01 g/cm^3 was lower, which could be attributed to either the absorption of solvent by the samples, change in crystallinity nature of the sample or loss of plasticizer as reported by [1, 15, 16].

Table 2: Physical properties of recycled and virgin ABS

Materials	Density (g/cm^3)	Water absorption (%)
Fides fridge	1.06	0.2569
Tec fridge	1.07	0.3934
Matsui fridge	1.01	0.2625
Bauchnet fridge	1.03	0.3211
Virgin ABS	1.04	0.3048

4. Conclusions

Based on the investigation on the properties of waste ABS from different refrigerators, it was concluded that, recycled ABS from Matsui fridge has the highest tensile strength of 31.60 MPa compared to from Bauchnect, Fide and Tech fridges with tensile strength of 29.71, 30.89 and 27.63 MPa respectively. However, it was observed that, Matsui fridge has a density value of 1.01 g/cm^3 which fell below the standard specification ranges of 1.02-1.04 g/cm^3, it was therefore concluded that, recycled ABS from Bauchnect fridge performed better in terms of density as its value 1.03 g/cm^3 is within the range of specifications while Matsui fridge ABS waste has superior tensile strength property when compared to other type of refrigerators investigated.

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