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Introducing deinked old newsprint as a new resource of electrical purposes paper

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ABSTRACT

Finding new uses for recycled paper (a cellulose rich raw material), and increasing the rate of recycling is beneficial to the environmental efficiency of the whole paper industry. The present work introduces, for the first time, deinked recycled old newsprint as a new resource of electrical purposes paper. Impregnation of recycled deinked old newsprint paper, by linseed oil, enhances the breaking length of paper and remarkably improves its electrical properties i.e., the dielectric constant increases greatly and the a.c. conductivity decreases significantly due to impregnation. It was found that the electrical properties of deinked recycled old newsprint paper and its linseed oil impregnated counterpart, are close to the electrical properties of paper made from the more expensive virgin wood pulps and their linseed oil impregnated counterparts. In a series of research articles, the authors and others threw light for the first time on the electrical properties of paper made from agricultural residues pulps, and their linseed oil impregnated counterparts. Some, of the investigated agricultural residues papers, showed electrical properties close to wood papers, or even superior to it. This motivated the authors to expand the studies, on electrical properties of paper, to other cheap and abundant raw materials. Recycled old newsprint is an abundant raw material that is cheaper than virgin wood pulps. Therefore, recycled deinked old newsprint paper was chosen as a new raw material to study its electrical properties in this work. The effect of elevated temperatures on the electrical properties of paper is, also, studied. It is shown that improvement in electrical properties, due to impregnation, is sustained at elevated temperatures. Impregnated deinked recycled old newsprint paper produced in this work finds its use as specialty electrical purposes paper.

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1. Introduction and object

Cellulose possesses an exceptionally high dielectric constant. However, the dielectric constant of paper is much lower. This is due to the high percentage of air voids and pores in paper. Air has a comparatively low dielectric constant. Therefore, to raise the dielectric constant of paper sheets it is a common technique to replace -to some extent- the air in paper voids by oils, resins..etc. The impregnating material should possess greater dielectric constant than air (greater specific inductive capacity than air). The dielectric constant of impregnated paper is a complex function of the electrical properties of individual cellulose fibers, paper, and the impregnating material.

The dielectric constant of cellulose ranges from 6 to 8.1, while that of paper ranges from slightly greater than 1–2.5. The dielectric constant of typical insulating paper ranges from about 1.2 to 4.

There is a wide range of new and conventional uses for paper in electrical purposes. Examples of these applications include: insulations for integrated circuits in electronic devices, insulations for radio wires, insulations for electricity cables and transformers, or as dielectric paper for various types of capacitors (Willis & Raju, 2003; Mobarak, Mounir, & Mohsen, 1999a; Mobarak, Mounir, & Mohsen, 1999b; Mohsen & Mobarak, 1996; Mobarak, Mounir, & Ali, 1996a; Mobarak, Mounir, & Ali, 1996b; Casey, 1962).

In a series of research articles, the authors and others threw light for the first time on the electrical properties of paper made from agricultural residues pulps, and their linseed oil impregnated counterparts. (e.g., rice straw paper, cotton stalks paper and bagasse paper). Commercial wood papers were, also, investigated for the sake of comparison. Some, of the investigated agricultural residues papers, showed electrical properties close to wood papers, or even superior to it (Mobarak et al., 1999a; Mobarak et al., 1999b; Mohsen & Mobarak, 1996; Mobarak et al., 1996a; Mobarak et al., 1996b). This motivated the authors to expand the studies, on electrical properties of paper, to other cheap and abundant raw materials (Fahmy, Mobarak, & El-Meligy, 2008). Recycled old newsprint is an abundant raw material that is cheaper than virgin wood pulps. In addition, finding new uses for recycled paper and increasing the rate of recycling is beneficial to the environmental efficiency of the whole paper industry (Bobu & Ciolacu, 2007). Therefore, recycled deinked old newsprint paper was chosen as a new raw material to study its electrical properties in this work. The effect of linseed oil impregnation, on the electrical properties

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of recycled old news print paper, will be investigated. The effect of elevated temperatures, on the electrical properties of the impregnated and unimpregnated paper sheets, will be also studied in this work.

2. Experimental

- *Waste paper used:* The waste paper used in this work was composed of uncolored and colored newsprints in equal ratios.
- *Deinking, recycling of the old newsprint, and paper sheet making:* An efficient deinking and recycling method for old colored newsprint was implemented. This method was previously established by the authors and others (El-Meligy & Ibrahim, 2001).The paper sheets were prepared according to the SCA standard, using the SCA – model sheet former (AB Lorenzen and Wetter).
- *Analyses of the deinked recycled newsprint:* We have carried out analyses for the deinked recycled newsprint. The results of the analyses are reported in Table 1.
- *Scanning Electron microscopy:* The scanning electron micrograph of the deinked recycled newsprint is shown in Fig. 1. The scanning electron microscopy was conducted by Jeol JXA-840 A Electron Probe Micro analyzer.
- *Electrical properties of the prepared paper sheets:* The dielectric constant (É), and the alternating current conductivity (σ a.c.) were calculated using the following formulas respectively: $É = (C/E_o) \times (d/A)$, σ a.c. $= (d/A) \times (1/R)$, where C is the capacitance of the sample in Farads, E_o is the capacity of vacuum (8.85E-12 F/m), d is the sample thickness in m, A is the area of the used gold electrode in m^2, R is the sample resistance in ohms. C and R were measured using computerized Hioki 3532-50 LCR Hi Tester.

3. Results and discussion

The old newsprint was deinked, recycled, and paper sheets were prepared from it as mentioned in the experimental part.

Some of the paper samples were impregnated with linseed oil using dipping technique then hanging the impregnated paper sheets to dry in air at room temperature. Electrical properties of the unimpregnated and impregnated paper sheets were investigated at room temperature (30 °C), 70 and 110 °C, for alternating current frequencies up to 20,000 Hz.

Tables 2–4 show the comparisons between the electrical properties of the unimpregnated and impregnated paper sheets at a.c. frequencies of 200, 2000, and 20,000 Hz respectively.

Table 2 shows the electrical properties of both the unimpregnated and impregnated deinked recycled paper sheets at a.c. frequency of 200 Hz (at room temperature 30, 70, and 110 °C). It is evident from Table 2 that the dielectric constant increased due to impregnation. This was true at all investigated temperatures. At room temperature (30 °C), the dielectric constant for unimpregnated sheets was 3.03, while that of the impregnated sheets increased to 4.31. Thus the percentage increase in dielectric constant, due to impregnation, was 42.24%. The a.c. conductivity decreased due to impregnation. This was true at all investigated temperatures. At room temperature (30 °C), the a.c. conductivity of unimpregnated

Table 1
Analysis of the deinked recycled newsprint

Alphacellulose %	61.31
Hemicellulose %	17.80
Lignin %	20.60
Ash %	0.83

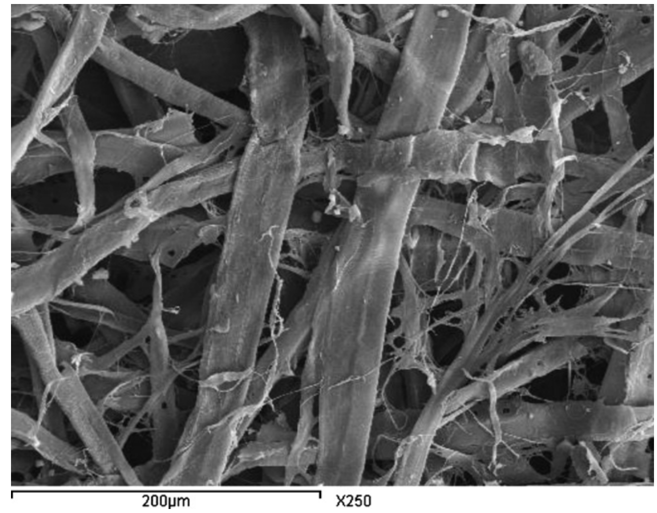

Fig. 1. The scanning electron micrograph of the deinked recycled newsprint (at 250×).

paper sheets was 1.09 E-10 (1/ohm cm), while that of the impregnated paper sheets decreased to 0.89 E-10 (1/ohm cm). Thus the percentage decrease in a.c. conductivity, due to impregnation, was 18.34%.

Table 3 shows the electrical properties of both the unimpregnated and impregnated deinked recycled paper sheets at a.c. frequency of 2000 Hz (at room temperature 30, 70, and 110 °C). It is evident from Table 3 that the dielectric constant increased due to impregnation. This was true at all investigated temperatures. At room temperature (30 °C), the dielectric constant for unimpregnated sheets was 2.77, while that of the impregnated sheets increased to 3.93. Thus the percentage increase in dielectric constant, due to impregnation, was 41.87%. The a.c. conductivity decreased due to impregnation. This was true at all investigated temperatures. At room temperature (30 °C), the a.c. conductivity of unimpregnated paper sheets was 2.18 E-10 (1/ohm cm), while that of the impregnated paper sheets decreased to 1.60 E-10 (1/ohm cm). Thus the percentage decrease in a.c. conductivity, due to impregnation, was 26.60%.

Table 4 shows the electrical properties of both the unimpregnated and impregnated deinked recycled paper sheets at a.c. frequency of 20,000 Hz (at room temperature 30, 70, and 110 °C). It is evident from Table 4 that the dielectric constant increased due to impregnation. This was true at all investigated temperatures. At room temperature (30 °C), the dielectric constant for unimpregnated sheets was 2.43, while that of the impregnated sheets increased to 3.47. Thus the percentage increase in dielectric constant, due to impregnation, was 42.79%. The a.c. conductivity decreased due to impregnation. This was true at all investigated temperatures. At room temperature (30 °C), the a.c. conductivity of unimpregnated paper sheets was 4.54 E-10 (1/ohm cm), while that of the impregnated paper sheets decreased to 2.93 E-10 (1/ohm cm). Thus the percentage decrease in a.c. conductivity, due to impregnation, was 35.46%.

It is worth mentioning that the dielectric constant decreased gradually by increasing the a.c. frequency. Starting from 10,000 Hz, the dielectric constant was not affected by increasing the a.c. frequency i.e it became virtually constant. This was true for the unimpreganated and impregnated paper sheets, at all investigated temperatures.

Breaking length of the deinked recycled paper sheets increased greatly due to impregnation by linseed oil. The breaking length of the unimpregnated paper sheets was 1310 m, while that of the

Table 2
Electrical properties of unimpregnated and impregnated of paper sheets, made from deinked recycled newsprint, at a.c. frequency of 200 Hz (at room temperature 30, 70, and 110 °C)

	Unimpregnated paper sheets	Impregnated paper sheets
Dielectric constant at 30 °C	3.03	4.31
Dielectric constant at 70 °C	2.95	4.28
Dielectric constant at 110 °C	2.92	4.28
a.c. conductivity at 30 °C (1/ohm cm) E-10	1.09	0.89

Table 3
Electrical properties of unimpregnated and impregnated of paper sheets, made from deinked recycled newsprint, at a.c. frequency of 2000 Hz (at room temperature 30, 70, and 110 °C)

	Unimpregnated paper sheets	Impregnated paper sheets
Dielectric constant at 30 °C	2.77	3.93
Dielectric constant at 70 °C	2.73	3.91
Dielectric constant at 110 °C	2.71	3.92
a.c. conductivity at 30 °C (1/ohm cm) E-10	2.18	1.60

Table 4
Electrical properties of unimpregnated and impregnated of paper sheets, made from deinked recycled newsprint, at a.c. frequency of 20,000 Hz (at room temperature 30, 70, and 110 °C)

	Unimpregnated paper sheets	Impregnated paper sheets
Dielectric constant at 30 °C	2.43	3.47
Dielectric constant at 70 °C	2.40	3.46
Dielectric constant at 110 °C	2.38	3.46
a.c. conductivity at 30 °C (1/ohm cm) E-10	4.54	2.93

impregnated paper sheets increased to 2687 m. The percentage increase in breaking length due to impregnation was 105.11%. Linseed oil is a drying oil. When it is exposed to air it solidifies to give a strong film. This is the reason for the increase in the breaking length of the impregnated paper sheets. The atmospheric oxygen attacks the double bonds of the polyunsaturated fatty acids present in linseed oil. This leads to cross-linking of the fatty acids chains, and hence solidification of the oil (Parker, 1997).

Density of the deinked recycled paper sheets increased due to impregnation. The density of unimpregnated paper sheets was 0.290 g/cm^3, while that of impregnated paper sheets increased to 0.472 g/cm^3. The percentage increase in density due to impregnation was 62.76 %.

4. Conclusions and summary

The present work introduces for the first time deinked old newsprint – an abundant raw material which is cheaper than virgin wood pulps – as a new resource of electrical purposes paper. Impregnation, of deinked recycled old newsprint paper, by linseed oil enhanced the breaking length of paper and remarkably improved its electrical properties i.e., the dielectric constant increased greatly and the a.c. conductivity decreased significantly due to impregnation. Even at elevated temperatures, the improvement in electrical properties of paper, due to impregnation, was sustained.

Impregnated deinked recycled old newsprint paper, produced in this work, finds its use as specialty electrical purposes paper. Finding new uses for recycled paper and increasing the rate of recycling is beneficial to the environmental efficiency of the whole paper industry. The present work shows that the electrical properties of deinked recycled old newsprint paper and its linseed oil impregnated counterpart, are close to the electrical properties of paper made from the more expensive virgin wood pulps and their linseed oil impregnated counterparts (Willis & Raju, 2003; Mobarak et al., 1999a; Mobarak et al., 1999b; Mohsen & Mobarak, 1996; Mobarak et al., 1996a; Mobarak et al., 1996b; Casey, 1962).

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