

MOISTURE-INSENSITIVE ELECTRICALLY-CONDUCTIVE PAPER

The invention concerns paper containing electrically-conductive fibers such as carbonaceous fibres.

5 United States Patent Specification No. 3 367 851 (Filreis et al) discloses a paper which is electrically-conductive by virtue of its carbonaceous fibres. Such a paper provides inexpensive heating panels and food warming trays. Although not mentioned  
10 in the patent, the electrical conductivity of the paper decreases with increased moisture content. It is theorised that the moisture causes the paper to swell, thus tending to break the paths of electrical conductivity through the carbonaceous fibres.

15 To protect it from moisture, a conductive paper may be encapsulated within an electrically-insulating moisture barrier while keeping the moisture content of the paper at a controlled low level. Especially useful in this respect is a laminate of biaxially-oriented  
20 polyethylene terephthalate film and polyethylene film. The polyethylene faces of two pieces of the laminate are bonded to the electrically-conductive paper and to each other beyond the perimeter of the paper, as shown in United States Patent Specification No. 3 774 299  
25 (Sato et al). Because that laminate is only partially resistant to water-vapour transmission, changes in ambient humidity can eventually produce changes in the moisture content of the paper with corresponding changes in its electrical conductivity.

30 According to the present invention there is provided electrically-conductive paper comprising:

(1) from 2 to 50 parts by weight of wood pulp,

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(2) from 50 to 98 parts by weight of water-dispersible synthetic wood pulp (SWP), the components (1) and (2) totalling 100 parts by weight, and

5 (3) electrically-conductive carbonaceous fibres comprising at least 80% by weight of carbon, said fibres being present in an amount providing from 1 to 35% by weight of the paper,

the SWP/wood pulp weight ratio being at least  
10 4:1 when the paper is unencapsulated and not more than 9:1 when the paper is encapsulated in an envelope which transmits less water than 15 g/m<sup>2</sup>/24 hours at 38°C and 95% relative humidity.

The electrically-conductive paper of the  
15 invention experiences little change in electrical conductivity with changes in humidity. Like the paper of the Filreis patent, the paper of the invention comprises a mixture of wood pulp of paper-making grade plus electrically-conductive carbonaceous fibres in an  
20 amount of from 1 to 35% of the weight of the paper. As disclosed in the Filreis patent, the carbonaceous fibres preferably have an average length from 0.15 to 1.1 cm and a tex (g/km) from 0.03 to 0.5.

The paper of the invention differs from that of  
25 the Filreis patent in that it also comprises synthetic wood pulp (SWP); generally the SWP/wood pulp weight ratio is from 4:1 to 49:1 when the paper is unencapsulated and from 1:1 to 9:1 when the paper is encapsulated in an envelope which transmits less than  
30 15 g of water per square metre per 24 hours at 38°C and 95% relative humidity (RH).

Preferably the SWP/wood pulp weight ratio for unencapsulated paper is from 8:1 (below which its

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electrical conductivity tends to decrease with increased humidity) to 25:1 (above which its electrical conductivity tends to increase with increased humidity). There is very little change in electrical conductivity  
5 at ratios from 12:1 to 20:1.

Preferably the SWP/wood pulp weight ratio is from 5:3 to 4:1 for paper encapsulated in an envelope which transmits less water than 15 g/m<sup>2</sup>/24 hours at 38°C and 95% RH. If the barrier transmits water at  
10 about 4 g/m<sup>2</sup>/24 hours under such conditions, the SWP/wood pulp weight ratio is preferably about 7:3.

SWP is made by treating polyolefin fibres to make them readily dispersible in water. The following patents assigned to Crown Zellerbach Corporation disclosed various processes: 3 743 570, 3 787 256, 3 848 027 and 3 891 449. Crown Zellerbach currently sells SWP in several commercial grades such as E-400, E-600, etc.

### Preparation of Electrically Conductive Paper

For ease of manufacturing an electrically-conductive paper on a commercial scale, a good basis weight is 85 g/m<sup>2</sup>. A typical requirement for specific electrical resistance is 27 ohms per square. In order to make

5 electrically-conductive paper having such basis weight and specific electrical resistance on a laboratory basis, add 2.083 g of SWP (Crown Zellerbach E-400) to 400-500 ml water and disperse in a blender at high speed for one minute. Add 0.893 g of bleached kraft softwood pulp and operate the

10 blender for ten seconds; then add 0.525 g of carbonaceous fibers and operate the blender for an additional ten seconds. Pour the dispersion into a hand-sheet mold fixture previously partially filled with water and add sufficient water to fill the fixture. Stir by hand with a

15 comb-like paddle until the fibers are uniformly dispersed and then drain the water. Remove the hand-sheet formed on the fixture's screen and dry in a paper dryer to provide an electrically-conductive paper.

To make test samples of a suitable size, cut the

20 dried sheets into rectangles 8.9 x 11.4 cm. Using a heated-platen press, adhere a 68-micrometers-thick copper foil, 1.3 cm in width along each of the 8.9-cm edges using a conductive thermoplastic adhesive. Thus there is a 8.9-cm-square area between the copper-foil electrodes. By

25 applying a temperature of 150°-175°C and a pressure of 240-690 kPa, the heated-platen press also fuses the SWP fibers of the SWP-containing conductive papers to produce an integral, semi-transparent, film-like structure. The same press conditions are suitable for then encapsulating

30 the conductive papers within a laminate of polyethylene film and polyethylene terephthalate film. Such a laminate may transmit water at about 4 g/m<sup>2</sup>/24 hr. at 38°C and 95% relative humidity.

### Detailed Description

A number of encapsulated and unencapsulated electrically-conductive papers were prepared as described above except at various ratios of SWP to wood pulp. These papers were tested for changes in electrical resistance, first by testing in air at ordinary room temperature and 45% relative humidity and then retesting following 96-hour exposure to salt spray [ASTM B-117-73]. The percent changes in resistance, averaged from a large number of samples in each case, are reported in the table.

|    | Ratio of<br>SWP to<br><u>Wood Pulp</u> | Water-Vapor Trans-<br>mission of Envelope<br><u>(g/m<sup>2</sup>/24 hr at 38°C)</u> | % Change in<br>Electrical<br><u>Resistance</u> |       |
|----|----------------------------------------|-------------------------------------------------------------------------------------|------------------------------------------------|-------|
| 10 | Sample 1                               | 50:50                                                                               | 10.9                                           | 6.4   |
|    | Sample 2                               | 70:30                                                                               | do                                             | 0.06  |
| 15 | Sample 3                               | 90:10                                                                               | do                                             | -2.2  |
|    | Sample 4                               | 50:50                                                                               | 3.9                                            | 4.4   |
|    | Sample 5                               | 70:30                                                                               | do                                             | 0.14  |
|    | Sample 6                               | 90:10                                                                               | do                                             | -4.5  |
|    | Sample 7                               | 100:0                                                                               | do                                             | -10.7 |
| 20 | Sample 8                               | 50:50                                                                               | 0.3                                            | 1.2   |
|    | Sample 9                               | 70:30                                                                               | do                                             | 0.39  |
|    | Sample 10                              | 90:10                                                                               | do                                             | -0.78 |
|    | Sample 11                              | 50:50                                                                               | Unencapsulated                                 | 27.3  |
|    | Sample 12                              | 70:30                                                                               | do                                             | 4.9   |
| 25 | Sample 13                              | 90:10                                                                               | do                                             | 2.6   |
|    | Sample 14                              | 100:0                                                                               | do                                             | -7.4  |

The electrically-conductive papers of the foregoing samples consisted only of mixtures of carbonaceous fibers and either SWP or SWP and wood pulp.

However, other materials may be additionally incorporated into the novel conductive paper, as is known in the art, e.g., glass, asbestos or other inorganic fibers, various polymeric fibers, mica flakes and carbon particles in such quantities as do not interfere with the attainment of a

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desired value of electrical conductivity or render the paper unduly sensitive to changes in humidity. By the same token, the novel conductive paper may be impregnated with nonconductive resins such as phenolic and epoxy resins which can afford added strength and integrity without interfering with the desired unchanging electrical conductivity over the full area of a piece of the novel conductive paper. However, to the extent that such impregnating is a barrier to water vapor, the proportion of SWP to wood pulp should be adjusted as indicated by the data reported for the examples.

An experimental use for the electrically-conductive paper of the invention is to heat liquid crystal displays which are used outdoors. If those displays are to be back-lighted, the paper should be reasonably translucent. Since higher proportions of SWP to wood pulp have better translucency, it is preferred for such use that the SWP/wood pulp ratio be at least 2:1.



CLAIMS:

1. Electrically-conductive paper comprising:
  - (1) from 2 to 50 parts by weight of wood pulp,
  - (2) from 50 to 98 parts by weight of water-dispersible synthetic wood pulp (SWP),

5 the components (1) and (2) totalling 100 parts by weight, and

  - (3) electrically-conductive carbonaceous fibres comprising at least 80% by weight of carbon, said fibres being present in an amount providing from 1

10 to 35% by weight of the paper,

the SWP/wood pulp weight ratio being at least 4:1 when the paper is unencapsulated and not more than 9:1 when the paper is encapsulated in an envelope which transmits less water than 15 g/m<sup>2</sup>/24 hours at 38°C and

15 95% relative humidity.
2. Electrically-conductive paper as claimed in Claim 1, in which the SWP/wood pulp weight ratio is from 4:1 to 49:1 when the paper is unencapsulated and
- 20 from 1:1 to 9:1 when the paper is encapsulated in an envelope which transmits less water than 15 g/m<sup>2</sup>/24 hours at 38°C and 95% relative humidity.
3. Electrically-conductive paper as claimed in
- 25 Claim 2, which is unencapsulated and in which the SWP/wood pulp weight ratio is from 8:1 to 25:1.
4. Electrically-conductive paper as claimed in Claim 3, in which the SWP/wood pulp weight ratio is
- 30 from 12:1 to 20:1.
5. Electrically-conductive paper as claimed in Claim 2, which is encapsulated within an envelope which



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transmits less water than 15 g/m<sup>2</sup>/24 hours at 38°C and 95% relative humidity and in which the SWP/wood pulp weight ratio is from 5:3 to 4:1.

- 5 6. Electrically-conductive paper as claimed in Claim 5, in which said envelope transmits water at about 4 g/m<sup>2</sup>/24 hours at 38°C and 95% relative humidity and the SWP/wood pulp weight ratio is about 7:3.
- 10 7. Electrically-conductive paper as claimed in Claim 5 or Claim 6, in which the envelope is provided by two pieces of laminate of biaxially-oriented polyethylene terephthalate film and polyethylene film, the polyethylene layers being fused to the paper and to
- 15 each other beyond the edges of the paper.
8. Electrically-conductive paper as claimed in Claim 1 substantially as herein described.

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