

ARTICLE AND METHOD FOR PROTECTION OF A SUBSTRATE

The present invention relates to protective covers for substrates, for example, electrically conductive substrates.

A wide variety of substrates require protection from adverse environmental conditions, including moisture, insects, dirt, plant life and corrosion deposits. In some cases, especially when electrical contacts are to be protected, it is desirable to provide a removable protective cover over the substrate, so that it is possible easily to reenter and work on the sealed substrate. It is known to use greases to protect electrical contacts, the grease being contained in a container which is applied to the electrical contact(s) - see for example U.S. Patent No. 3,897,129 (Farrar). However, the grease is a thixotropic fluid, which places limitations on the ways in which it can be used. Furthermore, when reentry to the sealed contact is required, when the container is removed, grease remains coated on the contact(s) and must be cleaned off before electrical work can begin. It is also known to encapsulate electrical contacts within a container by means of a two-part liquid composition prepared by mixing ingredients which will react slowly together. Before the ingredients have gelled, the mixture is poured into the container, where it cures in situ to form a hard gel - see U.S. Patent Nos. 4,375,521 (Arnold) and 4,102,716 (Graves). However, this procedure involves preparation

of the liquid composition at the site, delay while the composition gels, and the need to provide a container around the contact(s), into which the composition can be poured. Furthermore, when reentry to the encapsulated contacts is required, the gelled composition cannot easily be removed.

We have now discovered that excellent encapsulation of electrical contacts (and other substrates, for example one or more discrete or modular conventional electrical connectors) can be obtained through the use of gels (and like compositions) which have been pre-formed in the absence of the substrate. The encapsulant is adherent to a support member, and the support member and the substrate to be encapsulated are pressed against each other, thus deforming the encapsulant into close and conforming contact with the substrate. Preferably, at least a part of the deformation is elastic deformation. The preferred properties of the encapsulant depend upon the substrate to be encapsulated, as further discussed below, but we have found that in all cases, it is essential for the encapsulant to be relatively soft by comparison with the gels formed in situ in the known processes. Thus the gels formed in situ have cone penetration values of less than 75, whereas the encapsulants used in this invention have cone penetration values of 100 to 350. Cone penetration values given in this specification are expressed in units of 10^{-1} mm and are measured by ASTM D217-68 at 70°F (21°C) ± 5°F (3°C), on an undisturbed sample using a standard 1:1 scale cone (cone weight 102.5g, shaft weight 47.5 g), the penetration being measured after 5 seconds. In addition, the encapsulant should preferably have an elongation of at least 200%. Elongation values given in this specification are ultimate elongations measured by

ASTM D638-80 at 70°F (21°C) ± 5°F (3°C), using a type 4 die to cut the sample and at a speed of 50 cm/minute.

The encapsulant can be adherent to any suitable support member. The support member is produced by a flexible matrix. Especially when it is desirable that the encapsulant should be removable from the electrical contact or other substrate which it is protecting, the encapsulant preferably has an adhesive strength to the substrate that is less than its adhesive strength to the support member and that is less than its cohesive strength, so that the encapsulant can be cleanly removed from the substrate merely by separating the support member and the substrate, leaving little or none of the encapsulant on the substrate. When the encapsulation of the substrate involves pushing at least part of the substrate through the encapsulant so that the encapsulant is parted and then flows back to form a seal on the other side of the substrate, the seal is a plane of weakness which will in many cases separate cleanly when the encapsulant is removed. This is in contrast to the situation when an encapsulant is gelled in situ, when no such plane of weakness exists.

GB-A-2133026, from which this application has been divided, relates to apparatus comprising a support member and an encapsulant, in which the support member is provided by, for example, individual open containers, or a crimp barrel of an electrical connector. In the present invention, the support member is provided by a flexible matrix which is impregnated with an encapsulant material, hereinafter referred to as an impregnant, having a defined cone penetration.

In one aspect, the present invention provides an article for protecting a substrate, comprising: (a) a flexible matrix which comprises a plurality of open

interstices, the interstices having an average volume of less than 0.01 inch³ (0.16 cm³); and (b) an impregnant, comprising a plurality of interconnected segments which lie within the interstices of the matrix, and having a cone penetration value, measured as herein described, of 100 to 350 (10⁻¹ mm); the matrix and the impregnant being such that when the article is stretched the matrix reaches its ultimate elongation before the impregnant reaches its ultimate elongation.

In another aspect, the invention provides a method of protecting a substrate, which comprises pressing together the substrate and an article according to the invention such that impregnant is deformed into close and conforming contact with the substrate.

The impregnants used in the present invention have cone penetration values of 100 to 350 (10⁻¹mm), with values of 150 to 350, especially 200 to 300 (10⁻¹mm), being preferred for methods in which the pressure exerted on the impregnant during installation is relatively low. When the volume of the impregnant (or each mass of impregnant) is relatively large (e.g. more than 3cc), the cone penetration value of the impregnant is preferably 200 to 250 (10⁻¹mm). When the volume is relatively small (e.g. less than 3 cc), the cone penetration value is preferably 250 to 350 (10⁻¹mm).

The elongation of the impregnant is preferably at least 200%, and substantially higher values are preferred, e.g. at least 500%, particularly at least 750%. The tensile strength of the impregnant is generally less, often very much less, than 20 psi (measured by ASTM D638-80 under the same conditions as the elongation).

The elastic modulus of the impregnant is also significant, since it affects the ability of the impregnant to make intimate contact with the substrate. When measured at 70°F (21°C) ± 5°F (3°C), using a parallel plate rheometric test at a frequency of 1 Hz, the impregnant generally has an elastic modulus less than 10^7 dynes/cm², preferably less than 10^6 dynes/cm², particularly less than 10^5 dynes/cm².

The impregnant is usually electrically insulating (i.e. has a resistivity of at least 10^9 ohm cm), but is not necessarily so for some possible uses of the invention, e.g. when non-electrical substrates are being protected. Suitable impregnants include materials made by gelling curable polyurethane precursor materials (as described for example in the patents referred to above) in the presence of substantial quantities of a mineral oil, a vegetable oil or a plasticizer, or a mixture of two or more of these. Thus we have obtained excellent results using impregnants prepared by gelling components which are commercially available for the preparation of polyurethane gels in situ, the gelation being carried out, however, in the presence of a suitable amount, e.g. 30 to 70 % by weight, of a suitable plasticiser, e.g. a trimellitate, or in the presence of a suitable animal or vegetable oil, e.g. 80 to 60% preferably 80 to 70%, by weight of a mixture of mineral and vegetable oils in which the ratio by weight of mineral oil to vegetable oil is 0.7 to 2.4. (The percentages are based on the total weight of the polyurethane precursor materials and mineral oil vegetable oil and plasticiser). Suitable impregnants can also be prepared by curing reactive silicones with non-reactive extender silicones, and the invention includes the use of any impregnant having the desired cone penetration and preferably the preferred elongation values. The

impregnant may contain known additives such as moisture scavengers (e.g. benzoyl chloride), antioxidants, pigments and fungicides. The impregnant is preferably hydrolytically stable, moisture-insensitive, and substantially inert towards the substrate.

A wide variety of support members can be used as the flexible matrix in the present invention. The matrix can be of any material, but preferably it is composed of an organic polymer or some other insulator. The surface of the matrix which contacts the impregnant can if desired comprise means for promoting adhesion to the impregnant. For example the surface can be physically and/or chemically modified for this purpose, as by roughening or shaping the surface or by subjecting the surface to a chemical or corona discharge treatment.

The matrix may be recoverable, preferably heat-recoverable, in which case the method of applying the protective covering to the substrate includes a step in which the matrix is recovered. When using a recoverable matrix, the elastic modulus of the impregnant is particularly important, but the elongation can be substantially less than 200%, e.g. as little as 50%, though preferably at least 100%. A particular advantage of this embodiment, by comparison with a conventional heat-shrinkable article having a layer of hot melt adhesive as sealant on its interior surface, is that additional heat input is not required in order to melt the sealant; this is particularly advantageous when the substrate is a metal pipe or other substrate which acts as a heat sink.

The flexible matrix comprises a plurality of open interstices, the interstices having an average volume of less than 0.01 inch^3 (0.16 cm^3), particularly less than

0.001 inch³ (0.016cm³). The impregnant comprises a plurality of interconnected segments which lie within the interstices of the matrix. The interconnections may be through openings in shared walls of adjacent interstices (as for example when the matrix is an open-celled foam) and/or through a surface layer of impregnant which connects segments of impregnant which lie in adjacent interstices which may or may not communicate with each other (as for example when the support member is a woven fabric). The presence of a continuous layer of impregnant on the surface of the apparatus adjacent the substrate is preferred. The impregnant, and the ratio by volume of the impregnant to the matrix is preferably at least 7.0, particularly at least 9.0, especially at least 9.5.

The matrix is preferably in the form of a sheet (this term being used to include tape), the sheet preferably having a thickness of 10 to 300 mils (0.025 to 0.76 cm), particularly 15 to 80 mils (0.04 to 0.20 cm), and the sheet preferably being extensible with an ultimate elongation which is preferably at least 50%, particularly at least 100%. The sheet can be directly applied to a substrate in a manner similar to the way an adhesive tape or Band-Aid (Trade Mark) is applied to a substrate to be protected. The sheet can be wrapped around a substrate, preferably in overlapping spiral wraps, and will form a thin, conforming and preferably continuous protective coating over the substrate.

Any stretching which the sheet undergoes during this process should be less than the ultimate elongation of the matrix and less than the ultimate elongation of the impregnant. If desired or necessary, additional means

can be used to secure the wrapping in place, but in general the sheet will adhere to itself and to the substrate, making such additional means unnecessary. Furthermore, the sheet can usually subsequently be removed, e.g. unwrapped or cut off, and cleanly peeled away from the substrate. Substrates which can be covered in this way can be of regular or irregular shape and include for example a punctured telephone cable or a splice between two cables.

In a particularly preferred embodiment of the invention, (as illustrated for example in Figure 1) the matrix comprises an open cell foam sheet of an organic polymer, e.g. a polyurethane, in particular an open cell foam having an average cell size of 5 to 30 mils (0.013 to 0.076 cm), preferably 10 to 20 mils (0.025 to 0.05 cm). Another useful matrix, (as illustrated for example in Figure 2) comprises a woven or non-woven fabric comprising fibers which are natural or synthetic and composed of organic or inorganic material, e.g. glass fibers, metal fibers or organic polymer fibers. The foam sheet or fabric may be for example 5 to 60 mils (0.013 to 0.15 cm), particularly 10 to 50 mils (0.025 to 0.125 cm), thick. When the fabric comprises metal fibers, the article may be useful, for example, in providing electrical shielding over a substrate.

Alternatively, the flexible matrix forms at least a surface portion of a block or other three-dimensional article. For example, the flexible matrix can provide the lining of a concave portion of an article designed to provide a protective cover over a substrate comprising a protruding member, e.g. an electrical contact on a terminal block. The thickness of the surface portion can be, for example, at least 5 mils (0.013 cm), preferably 5 to 60 mils (0.013 to 0.15 cm). The matrix

is preferably an open cell foam as described above. The remainder of the article can, for example, comprise resilient material, e.g. a closed cell foam, which helps to bring the article into close and conforming contact with a substrate to be protected. The article can comprise a relatively rigid outer or inner shell which provides a bearing surface for pressing the matrix against the surface to be protected.

The surface(s) of the impregnant which do not contact the support member can be covered by a release sheet which is removed before the protective article is used. On the other hand, when the impregnant protrudes from the matrix, and especially when the impregnant is sticky (as are the polyurethane gels referred to above), the use of a release sheet may be essential or highly desirable if a number of protective articles are to be stored together.

Especially when at least part of the deformation of the impregnant is elastic deformation, and the matrix does not surround the substrate, it is often necessary to provide a force member for maintaining the impregnant in compressive contact with the substrate. The force member is preferably secured to or forms part of the support member, but can be separate from it. The force member can be such that it becomes secured to the substrate when the substrate and the protective article are pressed together. For example the force member can lie within the impregnant and engage the substrate to which the impregnant is applied.

An article of the present invention can readily be prepared by (1) placing in or on the flexible matrix a curable liquid composition which, when cured, will have the desired cone penetration and preferably the preferred elongation values and (2) curing the liquid composition.

The invention is illustrated in the accompanying drawings, in which:

Figures 1 and 2 are cross-sections through articles of the invention; and

Figure 3 shows schematically, apparatus for manufacturing an article of the invention.

Referring now to Figure 1, this shows, in cross-section, an article of the invention comprising an open-cell polymeric foam matrix support member 44 and an impregnant 46 which is supported by and distributed in the foam matrix 44.

Referring now to Figure 2, this shows in cross-section an article of the invention similar to that shown in Figure 1 and comprising a woven fabric matrix support member 54 and an impregnant 52 which is supported by and distributed in the fabric matrix 54.

Referring now to Figure 3, this shows the preparation of article of the type shown in Figure 1. A foam sheet 64 is withdrawn from roll 61 and is passed through coating station 63 where a liquid mixture of gel precursors is impregnated through the foam. A release sheet 65 is then laminated to the impregnated sheet, and the laminate is passed through oven 66 where the gel is cured.

The invention is further illustrated by the following Example.

EXAMPLE

A commercially available polymeric foam sheet material ("Pro Wrap") was used as the matrix for preparation of this aspect of the invention. The foam

material had a thickness of 15-20 mils (0.04-0.05 cm), an average cell size of 5-10 mils (i.e. it was 2-3 cells thick), about 96% by volume of voids, and a density of about 0.044g/cc. It is believed to be a polyurethane material. A strip of the foam was placed on a surface having a release coating thereon, and was then knife-coated with a composition comprising a mixture of a commercially available polyurethane precursor ("Gella" available from Minnesota Mining and Manufacturing Co.) and about 50-55% by weight of a plasticiser for the polyurethane (n-octyl-n-decyl trimellitate). Samples were cured in an oven at 100°C. The resulting products were 40-50 mils (0.1-0.125 cm) thick. When one of the products was wrapped around a cable TV connector in an overlapping spiral, it stretched easily to accommodate the irregularities of the connector and formed an excellent sealed protective covering over the connector.



CLAIMS

1. An article for protecting a substrate, comprising:
(a) a flexible matrix which comprises a plurality of open interstices, the interstices having an average volume of less than 0.01 inch³ (0.16 cm³);
(b) an impregnant, comprising a plurality of interconnected segments which lie within the interstices of the matrix, and having a cone penetration value, measured as herein described, of 100 to 350 (10⁻¹ mm);
the matrix and the impregnant being such that when the article is stretched, the matrix reaches its ultimate elongation before the impregnant reaches its ultimate elongation.
2. An article according to claim 1, wherein the matrix comprises an open cell polymeric foam.
3. An article according to claim 2, wherein the average cell size is 5 to 30 mils (0.0125 to 0.076 cm).
4. An article according to claim 3, wherein the average cell size is 10 to 20 mils (0.025 to 0.05 cm).
5. An article according to any one of the preceding claims, wherein the matrix has the form of a sheet.
6. An article according to claim 5, wherein the sheet has an ultimate elongation of at least 50%.
7. An article according to claim 5 or 6, wherein the sheet is a tape.



8. An article according to claim 7, wherein the thickness of the tape is from 10 to 300 mils (0.025 to 0.76 cm).

9. An article according to claim 8, wherein the thickness is from 15 to 80 mils (0.038 to 0.20 cm).

10. An article according to claim 1, wherein the matrix is a fabric.

11. An article according to claim 10, wherein the matrix comprises metal fibers.

12. An article according to claim 10 or claim 11, wherein the fabric is a woven fabric and is 5 to 60 mils (0.0125 to 0.152 cm) thick.

13. An article according to any one of the preceding claims, in which at least one of the principal surfaces is provided essentially by the impregnant.

14. An article according to any one of the preceding claims, wherein the ratio by volume of the impregnant to the matrix is at least 7.0.

15. An article according to claim 14, wherein the ratio is at least 9.0.

16. An article according to claim 15, wherein the ratio is at least 9.5.

17. An article according to any of the preceding claims, wherein the impregnant has an ultimate elongation of at least 50%.



18. An article according to claim 17, wherein the impregnant has an ultimate elongation of at least 200%.

19. An article according to claim 18, wherein the impregnant has an ultimate elongation of at least 500%.

20. an article according to any of the preceding claims, wherein the impregnant has cone penetration value of 200 to 350 (10^{-1} mm).

21. An article according to any of the preceding claims, wherein the impregnant comprises an oil-extended polyurethane.

22. An article according to any of the preceding claims, wherein the impregnant comprises a plasticised polyurethane.

23. An article according to any of the preceding claims, wherein the impregnant is made by gelling curable polyurethane precursor materials in the presence of one or more of a mineral oil, a vegetable oil and a plasticiser.

24. An article according to any of claims 1 to 20, wherein the impregnant is made by curing reactive silicones with non-reactive extender silicones.

25. An article comprising an impregnated matrix according to claim 1, substantially as herein described with reference to the accompanying drawings or with reference to the example.



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26. A method of protecting a substrate, which comprises pressing together the substrate and an article according to any of the preceding claims such that impregnant is deformed into close and conforming contact with the substrate.

27. A method according to claim 26, wherein the matrix is in the form of a sheet, the method comprising wrapping the sheet around the substrate.

28. A method according to claim 27, wherein the sheet is wrapped around the substrate in overlapping spiral wraps.

29. A method according to claim 27 or 28, wherein the sheet is stretched as it is wrapped around the substrate.

30. A method according to any of claims 26 to 29, in which the substrate is a punctured telephone cable or a splice between two cables.

31. A method of protecting a substrate according to claim 1, by means of an impregnated matrix, substantially as herein described with reference to the example.
