

APPARATUS AND METHOD FOR PROTECTION OF A SUBSTRATE

This patent application is the parent application to divisional patent application no. 85-20930 filed 2nd August 1985. (Serial No. GB-A-2168363).

The present invention relates to protective covers
5 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
10 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
15 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.
20 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
25 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
30 (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 (-11.5°C) on an undisturbed sample using a standard 1:1 scale cone (cone weight 102.5g, shaft weight 47.5g), the penetration being measured after 5 seconds. In addition, the encapsulant should 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 (-11.5°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. 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 or otherwise formed in situ, when no such plane of weakness exists.

In one aspect, the present invention provides an apparatus for protecting a substrate, comprising:

an encapsulant that has been pre-formed in the absence of the substrate and that has a cone penetration value of 100-350 (10^{-1} mm) measured as herein described, and an ultimate elongation of at least 200% measured as herein described; and

means for maintaining the encapsulant in close and conforming contact with the substrate after deformation of the encapsulant into close and conforming contact with the substrate.

In another aspect, the invention provides a method of protecting a substrate by means of an encapsulant, which comprises:

5 preforming the encapsulant, the encapsulant after preforming having a cone penetration value of 100-350 (10^{-1} mm), measured as herein described, and an ultimate elongation of at least 200%, measured as herein described; and then

10 deforming the encapsulant into close and conforming contact with the substrate.

The encapsulants used in the present invention have cone penetration values of 100 to 350, with values of 150 to 350, especially 200 to 300, being preferred for methods in which the pressure exerted on the encapsulant during installation is relatively low, as
10 for example in the encapsulation of electrical terminals as described below. When the volume of the encapsulant (or each mass of encapsulant) is relatively large (e.g. more than 3 cc), the cone penetration value of the encapsulant is preferably 200 to 250. When the volume
15 is relatively small (e.g. less than 3 cc), the cone penetration value is preferably 250 to 350.

The elongation of the encapsulant is at least 200%, and substantially higher values are preferred, e.g. at least 500%, particularly at least 750%. The
20 tensile strength of the encapsulant 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 encapsulant is also significant, since it affects the ability of the encapsulant to
25 make intimate contact with the substrate. When measured at 70°F ($21^{\circ}\pm 5^{\circ}$ F (-11.5° C)) using a parallel plate rheometric test at a frequency of 1 Hz, the encapsulant 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 encapsulant 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 encapsulants include materials made by gelling curable polyurethane precursor materials (as described for example in the patents referenced 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 encapsulants 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 plasticizer, 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 the mixture of mineral and vegetable oils or the plasticizer. Suitable encapsulants can also be prepared by curing reactive silicones with non-reactive extender silicones, and the invention includes the use of any encapsulant having the desired cone penetration and elongation values. The encapsulant may contain known additives such as moisture scavengers (e.g. benzoyl chloride), antioxidants, pigments and fungicides. The encapsulant is preferably hydrolytically stable, moisture-insensitive, and substantially inert towards the substrate.

A wide variety of support members are useful in the present invention. The support member can be of any material, but preferably it is composed of an organic polymer or some other insulator. The surface of the support member

which contacts the encapsulant can if desired comprise means for promoting adhesion to the encapsulant. 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.

In some cases a conventional, e.g. rectangular, container, having side walls, end walls and a bottom wall, is a satisfactory support member. The container may be partitioned, e.g. as shown in Figure 1.

In a second embodiment, as shown for example in Figure 2, which is particularly useful when a plurality of adjacent electrical contacts are to be encapsulated, the support member comprises a plurality of individual open containers, which are connected to each other, e.g. through a flexible connection means, and each of which contains a separate mass of encapsulant. The separate containers can be applied simultaneously or sequentially to the contacts.

In a third embodiment, the support member is recoverable, preferably heat-recoverable, in which case the process for applying the protective covering to the substrate includes a step in which the support member is recovered. When using a recoverable support member, the elastic modulus of the encapsulant is particularly important. 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 encapsulant may be supported by and distributed in a flexible matrix which comprises a plurality of open interstices, the interstices having an average volume of less than 0.01 inch³ (0.16cm³), particularly less than 0.001 inch³ (0.016cm³). The encapsulant 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 encapsulant which connects segments of encapsulant 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 encapsulant on the surface of the apparatus adjacent the substrate is preferred. The ultimate elongation of the matrix is preferably less than the ultimate elongation of the encapsulant, and the ratio by volume of the encapsulant 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 encapsulant. 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.

A particularly preferred matrix is 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 support member, is 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 apparatus 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.

In a fourth embodiment of the invention, the support member is an electrical connector which can connect two or more electrical wires and/or an insulating member adapted to surround and retain the connector, the encapsulant being disposed within the connector and/or insulating member. The apparatus of this embodiment can be used to connect two or more electrical wires by a process which comprises

- (a) inserting end sections of the wires into an apparatus that comprises:
 - (i) an electrical connector;
 - (ii) an insulating member that surrounds and retains the electrical connector; and
 - (iii) an encapsulant as defined within the insulating member; and
- (b) exerting pressure on the electrical connector through the insulating member, thereby connecting the electrical wires and encapsulating the electrical connection within the encapsulant.

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The connector can be a crimp connector which can be permanently deformed by pressure, e.g. an in-line crimp splicer, a B-wire connector or a pigtail connector. Such connectors generally comprise a tubular member
5 composed of a ductile metal, e.g. copper, aluminum or brass, and an insulating sleeve which surrounds the metal member and through which the necessary crimping force can be transmitted; suitable materials for the sleeve include polyamides and polyvinylidene fluoride.
10 When the connector is crimped, the encapsulant does not have an adverse effect on the quality of the electrical connection.

The connector can also be a modular connector in which a plurality of pairs of wires are connected simultaneously. The connections can be permanent or
15 reenterable. In the latter case, the insulating member can comprise two portions which are movably joined together, e.g. in the form of a clam shell, with respective portions of the connector mounted on each portion.

The end sections of the wires can be stripped of
20 insulation before being inserted into the connector, which mechanically deforms the end sections so that they are in physical as well as electrical contact. Alternatively the insulation can be left on the wires, in which case the connector must comprise an insulation displacing
25 member which, when the connector is crimped, displaces insulation on the end sections and effects electrical connection between the wires.

In all the embodiments of the invention, the surface(s) of the encapsulant which do not contact
30 the support member can be covered by a release sheet which is removed before the protective apparatus is

used. Such a release sheet may be unnecessary or even disadvantageous when the encapsulant lies wholly within a container-shaped support member. On the other hand, when the encapsulant protrudes from the support member, and especially when the encapsulant 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 members are to be stored together.

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

Apparatus of the present invention can readily be prepared by (1) placing in or on a support member a curable liquid composition which, when cured, will have the desired cone penetration and elongation values and (2) curing the liquid composition.

The invention is illustrated in the accompanying drawings. Referring now to Figure 1, this is an exploded view of an apparatus 10 of the invention which is secured to a terminal block 24 having a plurality of terminals 20. The apparatus 10 comprises a plurality of masses of encapsulant 12 contained within a partitioned housing 14.

As indicated by numeral 16, the inside surfaces of the partitions comprise means for promoting adhesion of the encapsulant to the housing. The masses of encapsulant 12 have been elastically deformed into close and conforming contact with the terminals 20, and are maintained in compressive contact therewith by nut-and-bolt assembly 36 (which is a means for maintaining as referred to above) which acts on all the masses of encapsulant via the housing 14. If the assembly 36 is undone, and the apparatus 10 is removed from the terminal block 10, the encapsulant is cleanly removed from each of the terminals. This is a very valuable feature because the terminals are immediately ready for electrical connection or disconnection. Furthermore the sequence of protection and removal can be frequently repeated.

Referring now to Figure 2, this is an exploded view of another apparatus of the invention which is secured to a terminal block 24 having a plurality of terminals 20. The apparatus comprises a plurality of individual bell-shaped housings 38, each of which contains a mass of encapsulant 12 and which are joined together by means of a flexible ribbon 42. Within each of the housings 38 is a split retaining nut member 40 which engages the threaded part 26 of the corresponding terminal. When the housing is pressed onto the contact, the encapsulant 12 is elastically deformed around the terminal 20 and the end portion engages the member 40, thus maintaining the encapsulant 12 in compressive contact with the terminal 20. The housings 38 can be removed individually, so that other terminals are not affected, or can be removed together.

Referring now to Figure 3, this is similar to Figure 1, but with the important difference that the nut-and-bolt assembly is not present, and each of the compartments includes a split retaining nut member 40 for maintaining the encapsulant in compressive contact with the terminals. Note, in this regard, that a split retaining nut member 40, may, by reason of its geometry, cause the encapsulant 12 to undergo plastic deformation, thereby voiding the encapsulant 12 from the substrate. This voiding process which may affect the encapsulation of the substrate, is, in general, minimized by providing a force means, for example three to six ribs extending radially from the wall of the housing, wherein the encapsulant 12 does not undergo plastic deformation when the support member is pressed onto the substrate.

Referring now to Figure 4, this shows in cross-section apparatus of the invention which comprises a deformable metal connector 74 having a central stop 76, an insulating sleeve 70 surrounding the connector, and encapsulant 72 which fills the sleeve 70. This connector is suitable for connecting conductors 78 and 79. When these conductors are inserted into the connector, the encapsulant shears to allow the conductors to butt up against the stop, and seals behind them. Furthermore, when the connector is crimped, the encapsulant does not substantially interfere with the electrical connection of the wires. Furthermore, the encapsulant not only forms an environmental seal but also helps to prevent relative movement of the wires and the connector which will adversely affect the joint.

Referring now to Figure 5, this shows in cross-section another apparatus comprising a deformable metal connector 84, an insulating cap 80 surrounding the connector, and an encapsulant 82 filling the cap 80. The connector 84 comprises insulation-displacing members which make the connector suitable for connecting fully insulated conductors 86 and 88.

CLAIMS

1. Apparatus for protecting a substrate, comprising:
an encapsulant that has been pre-formed in the absence
of the substrate and that has a cone penetration value
of 100-350 (10⁻¹mm) measured as herein described, and an
5 ultimate elongation of at least 200% measured as herein
described; and
means for maintaining the encapsulant in close and
conforming contact with the substrate after deformation
of the encapsulant into close and conforming contact
10 with the substrate.
2. Apparatus according to claim 1, in which the means
for maintaining is capable of maintaining the encap-
sulant in compressive contact with the substrate.
3. Apparatus according to claim 1 or 2, having a sup-
15 port member, the encapsulant being located on the sup-
port member, and the encapsulant having an adhesive
strength to the substrate that is less than an adhesive
strength to the support member and that is less than a
value of its cohesive strength.
- 20 4. Apparatus according to any preceding claim, in
which the means for maintaining is a dynamic force
means.
5. Apparatus according to any preceding claim, in
which the encapsulant is such that when deformed into
25 contact with the substrate a seal is formed which
comprises a plane of weakness within the encapsulant.
6. Apparatus according to any preceding claim, in
which the encapsulant is elastically deformable.



7. Apparatus according to claim 3, wherein said support member comprises a plurality of individual open containers, which are connected to each other and each of which contains a separate mass of encapsulant.

8. Apparatus according to claim 7, wherein the individual containers are connected to each other by a flexible connecting means.

9. Apparatus according to claim 3, wherein said support member is composed of an organic polymeric material and is in the form of a housing that includes side walls, end walls and a bottom wall.

10. Apparatus according to claim 3, wherein at least part of said support member is heat-recoverable.

11. Apparatus according to claim 3, wherein said support member comprises:

(a) an electrical connector which is adapted to receive electrical wires and electrically connect electric wires received therein and

(b) an insulating member adapted to surround and retain said connector;
said encapsulant being disposed within at least one of said electrical connector and said insulating member.

12. Apparatus according to claim 11, wherein the electrical connector is surrounded and retained by said insulating member and is adapted to be mechanically crimped through said insulating member.

13. Apparatus according to claim 11 or 12, wherein the connector is adapted to received insulated electrical wires and comprises an insulation-displacing member which, when the connector is crimped around insulated electrical wires placed within the connector, displaces insulation on the electrical wires and effects electrical connection between the wires.



14. Apparatus according to claim 11 or 12, wherein the connector is adapted to receive electrical wires having end sections which are free of insulation and which, when the connector is crimped around such wires placed within the connector, mechanically deforms the wires so that they are in physical and electrical contact with the connector.

15. Apparatus according to claim 11, wherein said insulating member is provided with flexible end-guards to protect said encapsulant.

16. Apparatus according to any one of the preceding claims wherein the encapsulant has an elastic modulus measured as herein described of less than 10^7 dynes/cm².

17. Apparatus according to claim 16 wherein said elastic modulus is less than 10^6 dynes/cm²

18. Apparatus according to any one of the preceding claims wherein said cone penetration value is 150 to 350 (10^{-1} mm).

19. Apparatus according to claim 18, wherein said cone penetration value is 200 to 300 (10^{-1} mm).

20. Apparatus according to any one of the preceding claims wherein said encapsulant has an ultimate elongation of at least 500%.

21. Apparatus according to any one of the preceding claims, wherein the encapsulant is an oil-extended polyurethane.

22. Apparatus according to claim 21, wherein the encapsulant has been prepared by gelling a liquid mixture comprising 20 to 40% of curable polyurethane precursor materials and 80 to



60% of a mixture of mineral oil and vegetable oil in which the ratio by weight of mineral oil to vegetable oil is 0.7 to 2.4; the percentages being by weight based on the total weight of the polyurethane precursor materials and the mixture of mineral and vegetable oils.

23. Apparatus according to any one of claims 1 to 20, wherein the encapsulant is a plasticized polyurethane.

24. Apparatus according to claim 3, wherein the means for maintaining is secured to said support member.

25. Apparatus according to any one of the preceding claims, wherein the means for maintaining lies within the encapsulant.

26. Apparatus according to any one of claims 3 to 25, wherein the support member is generally bell-shaped, and the means for maintaining is a split retaining member that has an internal threaded portion.

27. Apparatus according to any one of the preceding claims further comprising a release member which covers an otherwise exposed portion of said encapsulant and which can be removed therefrom before covering a substrate.

28. Apparatus according to any one of the preceding claims, wherein the preforming of the encapsulant comprises gelling.

29. Apparatus according to claim 1 substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

30. A method of protecting a substrate by means of an encapsulant, which comprises:



preforming the encapsulant, the encapsulant after pre-forming having a cone penetration value of 100-350 (10^{-1} mm), measured as herein described, and an ultimate elongation of at least 200%, measured as herein described; and then deforming the encapsulant into close and conforming contact with the substrate.

31. A method according to claim 30, wherein at least a part of the deformation of the encapsulant is elastic deformation.

32. A method according to claim 30 or 31 which additionally comprises securing to the substrate means for maintaining the encapsulant in compressive contact with the substrate.

33. A method according to claim 32, wherein the means for maintaining becomes secured to the substrate when the substrate and the encapsulant are pressed together.

34. A method according to any one of claims 30 to 33, wherein the substrate comprises at least one electrical contact.

35. A method according to any one of claims 30 to 34, wherein the encapsulant is located on a support member, and the encapsulant has an adhesive strength to the substrate that is less than its adhesive strength to the support member and that is less than a value of its cohesive strength.

36. A method according to any one of claims 30-35, wherein the encapsulant is contained in at least one open container and has a cone penetration value of 200 to 300 (10^{-1} mm).

37. A method according to any one of claims 30 to 36 wherein



the encapsulant has an ultimate elongation of at least 500%.

38. A method according to claim 35, which additionally comprises removing the substrate from the support thereby causing adhesive failure between the encapsulant and the substrate.

39. A method according to any of claims 30-38, wherein deformation of the encapsulant causes formation of a seal which comprises a plane of weakness within the encapsulant.

40. A method according to claim 39, which additionally comprises causing cohesive failure of the encapsulant at said plane of weakness, allowing removal the encapsulant from the substrate.

41. A method according to any of claims 30-40, wherein pre-forming of the encapsulant comprises gelling.
