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NASA CASE NO. LAR 15387-1

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## AWARDS ABSTRACT

### A PROCESS FOR PREPARING AN ULTRA-THIN, ADHESIVELESS, MULTI-LAYERED, PATTERNED POLYMER SUBSTRATE

NASA Case Number: LAR 15387-1

Conventional flexible patterned circuit boards and cables (FPCs) consist of a strong dielectric film such as Kapton<sup>®</sup>, Upilex<sup>®</sup> and Mylar<sup>®</sup>. This dielectric film may be coated with an adhesive and laminated to the conductive foil. Such adhesives are prepared from polyesters, polyimides, modified epoxies and acrylics. A cover layer is then bonded to the patterned conductive foil with an adhesive similar to the base film adhesive, but with characteristics optimized for covering. This affords a thin flex cable or single layer flex circuit. Multi-layer patterns or circuits are then subsequently bonded together with a bond-ply adhesive. Alternatively, a conductor can be deposited directly on the base dielectric. This patterned base film is then bonded to a cover layer with the appropriate adhesive. Conductive feed-throughs (vias) are formed by either exposing a conductive layer and using a conductive adhesive or by plated through hole technology and barrels to create a conductive via to an adjacent conductive layer. The use of adhesives to fabricate FPCs not only increases the number of processing steps, but can also lead to deformation due to a mismatch in the coefficient of thermal expansion (CTE). Adhesives can also cause drill smear to occur. The excessive thickness which results from the adhesive causes the end weight films to be heavier and more rigid than adhesiveless FPCs. In addition, some FPCs which use conventional adhesives have been found to not pass the UL<sup>®</sup>VO flammability specification. As a result, these FPCs cannot be used in elevated temperature environments.

By the present invention, a process is provided for preparing an ultra-thin, adhesiveless, multi-layered, patterned polymer substrate. These substrates may be either rigid or flexible and may be used for ultra-thin cables or circuit boards. In preparing a rigid cable or circuit board, a substrate is provided. A polymeric solution is applied to the substrate. The polymeric solution comprises a self-bonding, soluble polymer and a solvent. The polymer solution is dried on the substrate, forming a polymer coated substrate. A conductive metal is applied onto the polymer coated substrate to form a metallized, polymer coated substrate. The metallized, polymer coated substrate is patterned. The process of applying the polymeric solution to the patterned, metallized, polymer coated substrate and subsequently drying, metallizing, and patterning is repeated at least one time to form a multi-layered, patterned, metallized, polymer coated substrate. As a final step, a cover coat solution is applied to the ultra-thin, adhesiveless, multi-layered, patterned, metallized polymer coated substrate and is dried. As a result of this process, these multi-layered, patterned polymer substrates are ultra-thin and do

not require high temperature and pressure to promote adhesion. Since there is no adhesive, these multi-layered, patterned polymer substrates can be easily laser ablated, thus eliminating the need for conventional drilling of holes.

The novelty of this invention is found in the process itself, where there is no adhesive required to prepare these patterned substrates. The non-obviousness is found in the use of a soluble polymer to prepare these substrates and how the polymer is applied to the substrate.

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A PROCESS FOR PREPARING AN ULTRA-THIN, ADHESIVELESS,  
MULTI-LAYERED, PATTERNED POLYMER SUBSTRATE

Origin of the Invention

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The invention described herein was made by employees of the United States Government, and may be manufactured and used by or for the Government without payment of any royalties thereon or therefor.

10 Background of the Invention

1. Field of the Invention

15 The present invention relates to multi-layered, patterned polymer substrates. In particular, it relates to a process for preparing an ultra-thin, adhesiveless, multi-layered, patterned polymer substrate.

2. Description of the Related Art

20 Conventional flexible patterned circuit boards and cables (FPCs) consist of a strong dielectric film such as Kapton®, Upilex® and Mylar®. This dielectric film may be coated with an adhesive and laminated to the conductive foil. Such adhesives are prepared from polyesters, polyimides, modified epoxies and acrylics. A cover layer is then bonded  
25 to the patterned conductive foil with an adhesive similar to the base film adhesive, but with characteristics optimized for covering. This affords a thin flex cable or single layer flex circuit. Multi-layer patterns or circuits are then subsequently bonded together with a bond-ply adhesive. Alternatively, a conductor can be deposited directly on the base

dielectric. This patterned base film is then bonded to a cover layer with the appropriate adhesive. Conductive feed-throughs (vias) are formed by either exposing a conductive layer and using a conductive adhesive or by plated through hole technology and barrels to create a conductive via to  
5 an adjacent conductive layer.

The use of adhesives to fabricate FPCs not only increases the number of processing steps, but can also lead to deformation due to a mismatch in the coefficient of thermal expansion (CTE). Adhesives can also cause drill smear to occur. The excessive thickness which results  
10 from the adhesive causes the end weight films to be heavier and more rigid than adhesiveless FPCs. In addition, some FPCs which use conventional adhesives have been found to not pass the UL<sup>®</sup>VO flammability specification. As a result, these FPCs cannot be used in elevated temperature environments.

15 In high speed circuitry, the dielectric properties of adhesives can impede performance. The adhesives and dielectric films which make up FPCs have different CTEs which can induce stress and create wrinkling and form waves and voids during processing and use. Moreover, some adhesives have a lower glass transition temperature (T<sub>g</sub>) than the  
20 dielectric film which can result in delamination at elevated temperatures.

In order to overcome these problems, Kanakarajan et al. (US 5,298,331) prepared a flexible polyimide metal-clad suitable for use in a flexible printed circuit and tape automated bonding (TAB) which comprised at least one layer of a metallic substrate and at least one layer  
25 of an aromatic polyimide, said layer of polyimide being bonded on at least one side to said layer of metallic substrate with a peel strength of at least 4 pli through an adhesive layer of a heat-sealable copolyimide. As a further embodiment, they prepared a polyimide laminate comprising a layer of a metallic substrate coated on one or both sides with the

aforesaid copolyimide adhesive. This laminate was found to be useful as a single-clad laminate for flexible printed circuits. As a still further embodiment, they prepared an adherable all-polyimide laminate for use in making metal-clads by coating a copolyamic acid adhesive directly either  
5 on a fully cured polyimide base film, or on a partially cured polyimide gel or green film or by coextruding the copolyamic acid with the polyimide base film and then curing to form the copolyimide. Although Kanakarajan et al. solve the problem of high temperature heat stability, their flexible polyimide metal-clad is thick and requires the use of an adhesive.

10 As a result of the disadvantages of laminates comprising layers of conventional adhesives between polyimide and metal, multi-layer laminates have been proposed in which the polyimide is bonded directly to metal, i.e. without a layer of adhesive. Thus, British Patent 2,101,526  
15 discloses the bonding of a polyimide derived from biphenyltetracarboxylic dianhydride directly to metal foil by applying heat and pressure. However, it has been found that such formable polyimides have inferior thermal stability to conventional non-formable polyimides.

Several adhesiveless flex substrates have been prepared using different methods (Jerome Sallo, Printed Circuit Fabrication, vol. 17, No.  
20 10, October 1994). In the first method, electrodeposited or rolled/annealed copper foil is coated with a polyimide film to form the composite. This inherently single-sided material is made into a two-sided substrate when two single-sided layers are bonded together with bond-  
25 ply or prepreg. Since the composite must be heated to the polyimide curing temperature during the coating process, the CTE mismatch between polyimide and copper may induce stress in the structure. To combat this problem, a more heavily cross-linked less-flexible generation of polyimides was developed. Even so, the X-, Y-dimensional stability of this type of construction tends to be less than that of materials based on

bi-axially oriented polyimide films.

In a second adhesiveless manufacturing process, a bi-axially oriented polyimide film is coated with a high temperature thermoplastic polyimide adhesive. High temperature lamination to copper foil  
5 polymerizes the polyimides and completes the composite, whose minimum thickness is generally 2 mils.

The third approach begins with a bi-axially oriented polyimide film that is made conductive by the application of extremely thin copper film via evaporation, vacuum sputtering, or electroless copper deposition.  
10 Electrolytic plating builds the film on each side of the laminate to a thickness of up to 2 oz. Although these approaches are considered to be adhesiveless processes, fabricating more than a single layer requires the use of an adhesive to bond the layers together.

An object of the present invention is to provide a process for  
15 preparing an ultra-thin, adhesiveless, multi-layered, patterned polymer substrate.

Another object of the present invention is to provide a process for preparing a multi-layered, patterned polymer which does not require an adhesive, high temperature or pressure to promote adhesion between the  
20 inner layers.

Another object of the present invention is to provide a process for preparing a multi-layered, patterned polymer wherein each layer is less than one mil in thickness.

Another object of the present invention is to provide a process for  
25 preparing a multi-layered, patterned polymer which uses at least one soluble polymer.

Summary of the Invention

By the present invention, a process is provided for preparing an ultra-thin, adhesiveless, multi-layered, patterned polymer substrate.

5 These substrates may be either rigid or flexible and may be used for ultra-thin cables or circuit boards. In preparing a rigid cable or circuit board, a substrate is provided. A polymeric solution is applied to the substrate. The polymeric solution comprises a self-bonding, soluble polymer and a solvent. The polymer solution is dried on the substrate,  
10 forming a polymer coated substrate. A conductive metal is applied onto the polymer coated substrate to form a metallized, polymer coated substrate. The metallized, polymer coated substrate is patterned. The process of applying the polymeric solution to the patterned, metallized, polymer coated substrate and subsequently drying, metallizing, and  
15 patterning is repeated at least one time to form a multi-layered, patterned, metallized, polymer coated substrate. As a final step, a cover coat solution is applied to the ultra-thin, adhesiveless, multi-layered, patterned, metallized, polymer coated substrate and is dried. The cover coat solution comprises a self-bonding, soluble polymer and a solvent.

20 A similar process is followed when forming a flexible cable or circuit board, with the polymer coating being removed from the substrate. The polymer coating can be removed either prior to applying the conductive metal onto the polymer coating or after the polymer coating has been patterned for the first time.

25

Description of the Preferred Embodiments

The process of the present invention can be used to prepare either rigid or flexible cables and circuit boards otherwise known as multi-



layered, patterned polymer substrates. As a result of this process, these multi-layered, patterned polymer substrates are ultra-thin and do not require the use of an adhesive in their preparation. Ultra-thin is defined as each patterned layer being less than one mil thick. Unlike prior  
5 adhesiveless processes, this process does not require high temperature and pressure to promote adhesion. Since there is no adhesive, these multi-layered, patterned polymer substrates can be easily laser ablated thus eliminating the need for conventional drilling of holes. The key to the invention lies in the use of a soluble polymer and how this polymer is  
10 applied to the substrate.

In preparing rigid cables and rigid circuit boards, the following process is used. A substrate is provided. Although any substrate may be used which is known to those skilled in the art, the preferred substrate is selected from the group consisting of: a polymer, a metal and a ceramic.  
15 The choice of the substrate is dictated by the end use, the drying conditions and the solvent used in preparing the polymeric solution.

A polymeric solution is applied to the substrate. The polymeric solution comprises a self-bonding, soluble polymer and a solvent. The polymeric solution chosen should not have an adverse effect on anything  
20 that it is coating. It is important that when subsequent layers of the polymeric solution are applied to the previously dried polymer coating that the solvent does not redissolve the polymer. Nor should the polymeric solution damage the chips or substrate on which it is being deposited. The polymer chosen for the preparation of the cable or circuit  
25 board must have the dielectric properties required to meet the requirements of the final end product. Examples of polymers which are considered to be suitable for the process of the present invention include: a polyimide, a polyurethane, an epoxy, a polyester, a polyolefin, a polybenzimidazole, a polyquinoxaline, a polyarylene-ether, a polyarylate,

a polycarbonate, a polyphenylene sulfide, a polysulfone, a polyaryletherketone, and a polyphenylene oxide. As a preferred embodiment, a polyimide is suitable for this process and as a most preferred embodiment, a polyimide comprising 4,4'-oxydiphthalic anhydride, 3,4,3',4'-biphenyltetracarboxylic dianhydride and 3,4'-oxydianiline. Furthermore, the polyimide may be endcapped with a monoanhydride or a monoamine which may or may not be able to undergo an additional cross linking reaction. The polymeric solution may be applied to the substrate by standard coating techniques or it may also be applied by melt extrusion.

The polymeric solution must be dried prior to metallizing. Upon drying of the polymeric solution, a polymeric coating forms on the substrate. Any method of drying known to those skilled in the art may be used to dry the polymeric solution. Examples of these methods include but are not limited to: placing the coated substrate under infrared lamps, heating the polymeric solution, or placing the coated substrate in an air circulating oven. In some instances, once the polymeric coating is dried it may be further heated to allow for complete removal of the solvent and/or additional curing in the case of thermosetting polymers.

The polymer coated substrate is metallized by applying an electrically conductive metal onto the polymer coated substrate using techniques such as evaporating, electroplating or directly coating the polymer solution onto a metal substrate. The conductive metal does not have to be solderable. As a preferred embodiment, the conductive metal is selected from the group consisting of: copper, platinum, paladium, aluminum, silver, nickel and gold. As a most preferred embodiment, the conductive metal is copper.

The metallized, polymer coated substrate is patterned using

standard photolithography techniques. Patterning can take place using either an additive or subtractive metal deposition process. If an additive process is used, only selected areas on the polymer coated substrate are metallized. In using the subtractive process, the polymer coated

5 substrate is metallized on the entire surface. If patterning after deposition, a photo resist (either wet or dry) may be spin coated, dipped or applied with rollers onto the metallized, polymer coated substrate. The artwork pattern (circuitry) and metallized, polymer coated substrate are first exposed to an ultra-violet light source to transfer the pattern

10 onto the polymer coated substrate. Next, the pattern is fully developed using a standard developer which is compatible with the photo resist. The pattern is then etched and after etching, the patterned polymer coating is rinsed and the residual photo resist is removed to yield the first layer of the ultra-thin, adhesiveless, multi-layered, patterned, metallized,

15 polymer coated substrate.

At least one more layer of a polymeric solution is applied to the ultra-thin, adhesiveless, multi-layered, patterned, metallized, polymer coated substrate. The polymeric solution may be the same as that applied in the first layer or it may comprise a different polymer and

20 different solvent. If a different polymeric solution is used, it is important that the solvent of the second polymeric solution does not attack the first layer (or base polymer). In addition, the second polymeric solution must adhere well to the base polymer. Next, the polymeric solution is coated onto the previous layer. As was done previously, the polymeric solution

25 is dried to form a polymer coated substrate. The polymer coated substrate is metallized and patterned to form an ultra-thin, adhesiveless, multi-layered, patterned, metallized, polymer coated substrate. These steps are repeated multiple times to build the required structure of the cable or circuit board.

In forming a rigid circuit board, the patterned, metallized, polymer coated substrate is masked prior to the addition of subsequent layers of the polymeric solution. When the desired number of layers have been applied, the ultra-thin, adhesiveless, multi-layered, patterned, metallized, polymer coated substrate is populated and the cover coat solution is then applied and dried.

A similar procedure is followed in forming a flexible cable or flexible circuit board. However, the substrate is selected from the group consisting of: a removable substrate and a sacrificial substrate. A removable substrate may include a plate glass or any other rigid substrate with a release agent applied to it. As a preferred embodiment, the removable substrate is plate glass. A sacrificial substrate is a substrate that is known to dissolve or wear away when a certain solvent or heat is applied. The polymer coating may be removed from the substrate at any time during the process. For example, the coating may be removed prior to metallizing, after metallizing and prior to patterning, or after patterning. As with the formation of a rigid circuit board, the patterned, metallized, polymer coated substrate is masked prior to the addition of subsequent layers of the polymeric solution and when the desired number of layers have been applied, the ultra-thin, adhesiveless, multi-layered, patterned, metallized, polymer coated substrate is populated and the cover coat solution is then applied and dried.

The following examples illustrate the process of the present invention. These examples are merely illustrative and intended to enable those skilled in the art to practice the invention in all of the embodiments flowing therefrom, and do not in any way limit the scope of the invention as defined by the claims.

## EXAMPLES

Example 1

5           The following procedure was followed to prepare a sprayable dielectric coating. A formulated solution of 3,4,3',4'-biphenyltetracarboxylic dianhydride (BPDA)/4,4'-oxydiphthalic anhydride (ODPA) (50/50) and 3,4'-oxydianiline (ODA) 2% offset copolyimide endcapped with phthalic anhydride (10% solids in N-methylpyrrolidinone) 10 (also known as LaRC™-SI, available from Imitec, Inc.) Was applied to different substrates using an airbrush. These substrates include: glass, ceramic, aluminum, Kapton®, copper, yttrium stabilized zirconia (YSZ) and lead zirconate titanate (PZT). The coating was initially dried in air at 44°C and subsequently at 300°C. The typical coating thickness range 15 was from 0.00025 inches to 0.0005 inches. The coating was found to serve as an excellent dielectric adhesive which readily accepted the deposition of gold, nickel, chrome, copper and aluminum circuitry. The ultra-thin coating of the copolyimide formed an excellent insulative finish, allowing for the direct attachment of dissimilar materials to various 20 substrates. To test the adhesion and thermal shock stability of the patterned and coated YSZ substrate, it was immersed in liquid nitrogen until equilibrium was reached. The coating did not show any sign of cracking or delaminating from the ceramic.

25

Example 2

Thin film multi-layer flexible circuits were prepared from LaRC™-SI. The process involved preparing a film substrate from the LaRC™-SI and metallizing the copolyimide film using evaporation or sputtering and

transferring a circuit pattern to the metallized film using a standard photolithography process.

LaRC™-SI was solvent cast onto a releasable surface, such as plate glass, to afford a film ranging from about 0.0003 inches to 0.0005 inches. The copolyimide film was initially dried at 44°C then dried to a final temperature of 300°C for 30 minutes. The film was then metallized and patterned using a standard photolithography process. After the circuit was formed, multiple coats of LaRC™-SI were sprayed to isolate the newly formed circuit. The sprayed coating was then dried at 44°C and dried to a final temperature of 300°C for 30 minutes to drive off excess solvent. The dried coating was then metallized with 300 Å of chrome and 2,000 Å of gold. A circuit was patterned onto the newly coated film using the same photolithography process. The process was repeated multiple times in order to form an ultra-thin, adhesiveless, multi-layer, flexible circuit.

### Example 3

A flexible circuit was prepared using aluminum foil as the substrate. A 0.001 inch film of LaRC™-SI was hot pressed to the foil at 300°C and 100 psi for 15 minutes. Aluminum was deposited onto the copolyimide coating and patterned, using a standard photolithography process to form a flexible circuit on an aluminum foil substrate. A working electronic device was prepared by populating the circuit pattern with electronic surface mount chips. The chips were attached to the flexible circuit using silver epoxy as the adhesive-conductor (solder).

Example 4

A multi-layer circuit was prepared using a plate glass as the substrate. LaRC™-SI was cast onto the plate glass and dried at 44°C  
5 then 300°C in air for 60 minutes to drive off excess solvent and form a coating. Aluminum was deposited and patterned onto the coating using a standard photolithography process. Portions of the pattern were masked and a second layer of the copolyimide was sprayed and dried at 44°C. The masking was then removed and the film was further dried at  
10 300°C to drive off excess solvent. Next, chrome and gold were deposited onto the film and patterned using a standard photolithography process. Where the second pattern overlapped the unmasked portions of the first pattern, a conductive via was formed. The patterned film was populated with surface mount chips to form a functioning multi-layer  
15 circuit.

Example 5

Two pieces of Kapton® HN polyimide film were spray coated with  
20 LaRC™-SI and dried at 44°C and then 250°C for 1 hour in air to drive off excess solvent and to form a coating approximately 0.0005 inches thick. Pieces of aluminum foil were sandwiched between the coated sides of the Kapton® HN polyimide film and pressed at 350°C and 200 psi for 30 minutes to form a flexible thin film laminate.

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Example 6

A flexible multi-layer patterned circuit was prepared from a solvent cast film of LaRC™-SI. The film was dried in air for one hour each at

100°C, 200°C and 300°C to drive off excess solvent and form a film approximately 0.0006 inches thick. Nickel was then deposited and patterned using a standard photolithography process. The patterned film was cut into 2 inch squares and consolidated at 350°C and 200 psi for  
5 30 minutes to form a six layer adhesiveless laminate.

#### Example 7

A layer of Kapton® HN polyimide film was metallized with 300Å of  
10 chrome and 2,000Å of gold and was patterned using a standard photolithography process. A spray coating of LaRC™-SI was applied and dried at 100°, 200° and 300°C for 1 hour each in air to drive off excess solvent and to form an adhesive layer approximately 0.0005 inches thick. The coated metallized Kapton® HN polyimide film was then cut into 2  
15 inch by 4 inch rectangles and stacked in a press with the coated side facing upward. These films were then bonded together at 350°C and 300 psi for 30 minutes to form a composite laminate.

#### Example 8

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An adhesiveless, self-bonding, multi-layer flex circuit was prepared from LaRC™-SI by the following process. A solution of LaRC™-SI and N-methylpyrrolidinone (NMP) was prepared by mixing 4 grams of powdered LaRC™-SI with 24 grams of NMP. The mixture was agitated for 1  
25 minute. A stir bar was placed in the mixture, the mixture was capped and stirred for an additional 10 minutes until a homogeneous solution was formed.

Approximately 12 grams of dissolved LaRC™-SI was doctored onto plate glass. The glass was placed under infrared lamps and dried for



2 hours until the coating became tack free. Another coat of LaRC™-SI was cast on the previous layer and placed under infrared lamps for 2 hours to dry. The coating was then heated to 100, 200 and 250°C for 1 hour each in air to remove excess solvent.

5           The coating was placed in an electron beam evaporator and pumped to a vacuum ( $2 \times 10^{-5}$  torr). A total of 2,500Å of copper was evaporated on the film. A wet photo resist (Microposit available from Shipely) was spin coated on the LaRC™-SI coating at 1,000 rpm for 30 seconds, then baked at 90°C for 30 minutes. The artwork (circuitry)  
10 was exposed on the photo resist coated, metallized polymer film for 35 light units. The circuit pattern was formed when developed for 1 minute, then rinsed with deionized water. The copper was etched with a mixture of 400 mL water, 200 mL sulfuric acid and 10 mL hydrogen peroxide which had been heated to 71°C in a Pyrex beaker. After etching, the  
15 LaRC™-SI was rinsed for 3 minutes under running deionized water. The residual photo resist was removed with acetone and rinsed under running deionized water for 2 minutes.

          The LaRC™-SI coating was removed from the glass plate by soaking it in warm water. The free-standing film was then dried and the  
20 film was taped, at the corners, to a glass plate. The taped film was dried in an oven at 100°C for 1 hour.

          In a 100 mL Pyrex beaker were placed 4 grams of LaRC™-SI and 60 grams of NMP. The mixture was stirred for 1 minute, capped and stirred for an additional 10 minutes to allow for homogeneity. The  
25 LaRC™-SI solution was poured into a bottle which was affixed to an airbrush.

          All feedthrough areas and alignment targets were masked on the patterned film with electrical plating tape. A light coat (approximately 0.1 mil) of LaRC™-SI solution was sprayed, covering the entire surface of

the film. After spraying, the film was immediately placed in an oven at 50°C and dried for 15 minutes. This process repeated three times. The masked areas which covered the feedthroughs were removed, while the areas covering the targets remained on the film. The film was dried at  
5 100°C for one hour.

The film was placed in an evaporator. A total of 2,500Å of copper was evaporated on the film. Photo resist was spin coated onto the film at 1,000 rpm for 30 seconds and the film was baked at 90°C for 30 minutes. The masked areas, covering the targets, were removed and the  
10 second layer of artwork (circuitry) was aligned with the first layer of patterned film and exposed to a ultraviolet light source for 35 light units. The film was developed for 1 minute and rinsed with deionized water. The copper was etched with a heated mixture (71°C) of 400 mL water, 200 mL sulfuric acid and 10 mL hydrogen peroxide. After etching, the  
15 film was rinsed for 3 minutes under running deionized water. The patterned film was soaked in acetone for 2 minutes and rinsed under running water.

The film was dried and retaped, at the corners, to a glass plate. The taped film was dried in an oven at 100°C for one hour. The flex  
20 circuit was populated with surface mount parts which were bonded to the surface with silver epoxy.

A light coat of LaRC™-SI was sprayed onto the populated flex circuit and dried at 50°C for 15 minutes. The cover coat was applied multiple times to provide an encapsulated, multi-layered, circuit board.

25

#### Example 9

A solution of LaRC™-SI and NMP were prepared by mixing 4 grams of LaRC™-SI and 24 grams of NMP together in a Pyrex beaker.

The mixture was stirred for 10 minutes until a homogeneous solution was formed. Approximately 12 grams of LaRC™-SI solution was doctored onto aluminum foil and dried under infrared lamps for 2 hours. After drying, another layer was cast over the previous layer and dried  
5 also for 2 hours under infrared lamps. The cast film was then heated to 100, 200 and 300°C for one hour each in air. Photo resist was spin coated onto the aluminum foil and dried at 90°C for 30 minutes. Artwork was exposed to the aluminum foil for 35 light units, using an ultraviolet source, thus generating a pattern. The pattern was then  
10 developed and etched yielding a thin, flexible circuit.

A PROCESS FOR PREPARING AN ULTRA-THIN, ADHESIVELESS,  
MULTI-LAYERED, PATTERNED POLYMER SUBSTRATE

Abstract of the Disclosure:

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A process for preparing an ultra-thin, adhesiveless, multi-layered, patterned polymer substrate is disclosed. The process may be used to prepare both rigid and flexible cables and circuit boards. A substrate is provided and a polymeric solution comprising a self-bonding, soluble  
10 polymer and a solvent is applied to the substrate. Next, the polymer solution is dried to form a polymer coated substrate. The polymer coated substrate is metallized and patterned. At least one additional coating of the polymeric solution is applied to the metallized, patterned, polymer coated substrate and the steps of metallizing and patterning are repeated.  
15 Lastly, a cover coat is applied. When preparing a flexible cable and flexible circuit board, the polymer coating is removed from the substrate.