SELF-DESTRUCTIBLE MOLDED ARTICLES

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Field of Search 109/36, 35, 1, 317/101; 174/68.5; 149/2, 19, 42, 38, 20, 21

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Primary Examiner—Carl D. Quarforth
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ABSTRACT
This disclosure is directed to on-command, self-destructible, fibrous-reinforced molded structures, e.g., printed circuit assemblies, comprising a plastic-fibrous matrix containing encapsulated material capable of rapid yet non-explosive combustion, e.g., incendiary or pyrotechnic material. The major surfaces (faces) of said structures can be provided with an electroconductive portion(s), or conductive face, e.g., metallic, materials (facing sheets) can be secured thereto. One of the facing sheets can constitute or contain a printed circuit. All of the incendiary material must be encapsulated to render it inactive at ambient conditions until the desired time for ignition and achieve other advantages. Moreover, the structures can be provided with an igniter(s) to communicate with at least a portion of the encapsulated incendiary composition. A predominant portion of the molded structure is incendiary material and the burning temperature can be controlled in a satisfactory manner by controlling the concentration of incendiary, esp. fuel.

10 Claims, 1 Drawing Figure
SELF-DESTRUCTIBLE MOLDED ARTICLES

This application is a continuation-in-part of U.S. Pat. application Ser. No. 715,605 filed in the name of Hugh W. Cookell on Mar. 25, 1968, now abandoned.

Frequently it is desirable, or necessary, esp., in military applications, to destroy or disfigure specific structures and/or equipment so that their identity and function remain anonymous. In such cases the time required for destruction may be of paramount importance. Also it is often necessary that the material or structure which is to be destroyed contains within its structure the materials and method for its destruction. Structures having these capabilities are oftentimes referred to as integral, on-command, self-destruct systems.

While it is possible to prepare such systems using explosive compositions wherein an explosive charge or charges are placed on various portions of or proximate to the device to be destroyed; such systems frequently result in the non-selective destruction of the surrounding installation with danger to personnel. Consequently there has developed a need for an integral, on-command, self-destruct structures whereby only that desired portion(s) to be destroyed is actually affected by the destruct mechanism. This in turn requires a controlled or limited destruction to take place.

The present invention constitutes what is believed to be a marked advance in that it enables the attainment of a very rapid, on-command, selective self-destruct capability thus reducing risk of personnel injury as destruction takes place. This allows the personnel to supervise destruction with minimal hazard. Hence it has been discovered that by employing the aforesaid fibrous-reinforced plastic structure containing totally encapsulated yet non-explosive pyrotechnic or incendiary composition, the desired objectives are achieved while largely avoiding the disadvantages attendant to prior structures. Moreover, the present invention enables the self-destruct function to be conducted uniformly by the use of an encapsulated pyrotechnic component(s) which can be uniformly distributed within the matrix to achieve uniform, safe and inert distribution of otherwise reactive components thus increasing reliability of the self-destruct system. Also the use of encapsulation offers a convenient system to enhance control over both the general temperature level and rate of burning at which the selective destruction takes place. With the fibrous molded articles of the present invention containing the substantially uniformly distributed encapsulated pyrotechnic or incendiary components; the complete structure can be rapidly reduced to a token quantity of ash thus destroying all desired electronic circuits and components without creating a hazard to extraneous structures, related components, or personnel in the immediate vicinity. Such self destruct structures can be made comparatively safe regardless of where they are used.

The sole FIGURE of the drawing shows a partially exposed schematic view of an exemplary on-command self-destructible circuit board structure in accordance with this invention.

In the drawing a circuit board 1 is comprised of a plastic matrix 2 having a multitude of chopped fiberglass or other fibrous reinforcing members 3 and a profusion of minute, individual, generally spherically shaped, randomly yet substantially uniformly distributed capsules 4 containing incendiary material which is capable of rapid yet non-explosive combustion when ignited through one or more igniters 5 which afford communication with said combustible material. One or more surfaces of the structure can be provided with an electroconductive portion(s) such as a printed circuit, a portion of which is illustrated at 6. The printed circuit can be formed from a metallic foil, e.g., copper foil, which is laminated to the plastic surface(s) desired followed by removal of the non-circuit areas by known procedures, e.g., by covering (masking) the circuit forming areas and etching the non-circuit areas. Of course, other printed circuit deposition or forming procedures, e.g., conventional sputtering or evapora
tive deposition through stencils, masks, etc., can be used. Any desired circuit pattern or array can thus be provided. If an etching technique is used, the metal foil layer(s) to be etched can be joined to the plastic by heat and pressure during molding, e.g., using a thermoplastic or thermosetting matrix resin; or an extraneous laminating adhesive can be used, as where the matrix is first molded without the foil and then the metal foil is adhesively secured thereto.

In order to obtain the full measure of benefits afforded by this invention the total concentration of matrix resin (excluding capsule wall material) and fibrous reinforcement must be within a certain range compared to the concentration of matrix-confined encapsulated incendiary material. Moreover, the concentration of fibrous reinforcement versus matrix resin must also be controlled within a certain range in cases where fibrous materials are used which are resistant to burning, e.g., glass fibers, metal fibers, etc. Also the concentration of encapsulated incendiary material versus capsule cell wall material should be within fixed limits to insure adequate burning yet preserve the inertness of the incendiary material until the desired time for thermal destruction. Of the total core section (including fibrous-reinforced resin matrix plus encapsulated incendiary material, viz., everything but printed circuitry, facing sheet(s), igniting mechanisms, and electronic component(s) structure), the fibrous-reinforced resin matrix should constitute from about 15 to 45 weight percent and the encapsulated incendiary (including capsule cell wall material) should constitute from about 55 to 85 weight percent. When the fibrous reinforcement is a material resistant to burning, e.g., glass fibers; the fibrous reinforcement should constitute from 10 to 35 weight percent of the total of resin matrix plus fibrous reinforcement with the remainder being readily burnable matrix resin. When the fibrous reinforcement is a readily burnable material (at the combustion temperatures produced by the encapsulated incendiary); the matrix resin should constitute a major portion of the total of matrix resin plus fibrous reinforcement as in such cases the burnable fibrous rein
dowment material is usually a higher molecular weight plastic or resin or one having a higher melting tempera
ture (to preserve its fibrous integrity during molding and its reinforcing power thereafter) and such materials usually require the expenditure of more thermal energy to attain substantially complete combustion thereof than is required for combustion of the non-fibrous matrix resin.
As noted above the concentration of incendiary material should lie within fixed limits based on the total weight of incendiary plus capsule cell wall material. The internal phase (incendiary material) should constitute from about 50 to about 98 weight percent of the total of incendiary plus capsule cell wall.

Usually the incendiary material contains a fuel component(s) and an oxidizer component(s) with an erosion material being optionally included. Frequently it is desirable to include an erosion component to cause a moderate amount of gasification to occur to accompany burning, the gasification aiding in causing movement of the ash residue and serving to further weaken the structural integrity of the thermally destroyed structure. This contributes to the overall objective of destroying or disfiguring the electronic component and rendering its identity and function anonymous. Since this gasification tends to cool the immediate environment somewhat thus lowering combustion temperatures; when the erosion material is used, it is usually employed in low concentrations. The below table indicates the usual concentration of the encapsulated incendiary components, the total of encapsulated components closely approximating or equalling 100 weight percent of said encapsulated incendiary:

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration (Weight Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>Permissive 5 to 95</td>
</tr>
<tr>
<td>Oxidizer(s)</td>
<td>5 to 95</td>
</tr>
<tr>
<td>Erosion Material</td>
<td>0 to 15</td>
</tr>
</tbody>
</table>

A wide variety of organic plastic, resin and polymeric materials can be employed to form the combustible matrix in conjunction with the fibrous reinforcing material, the combination forming the matrix in which the encapsulated incendiary material is confined.

MATRIX RESIN(S)

Both thermoplastic and thermosetting resins can be used, e.g., in liquid or powdered form, as readily combustible matrix resins. Suitable exemplary resins include, but are not limited to the following: cellulose resins, e.g., cellulose acetate, cellulose butyrate, cellulose nitrate, nitrocellulose; polyolefins, e.g., polyethylene, polypropylene, polybutenes, ethylene-propylene copolymers including terpolymers of ethylene, propylene and a C₂ to C₈ conjugated or non-conjugated diolein, polybutadienes; polystyres, e.g., reaction products of polyhydric alcohols, such as ethylene glycol, diethylene glycol, glycerol, pentacrythritol, trimethylol propane, polybutylene glycols, castor oil, etc., with polybasic organic acids, e.g., oxalic, adipic, sebacic, phthalic, isophthalic, terephthalic, 6-amino caproic, malonic, succinic, maleic, fumaric, itaconic, etc.; polyurethanes, e.g., those prepared by reacting polyhydric materials, including those mentioned above, as well as hydroxy containing polyethers, polysteres, polyamines, etc., with polyisocyanates, usually aryl disiocyanates, e.g., toluene disiocyanate, or triisocyanates; epoxy resins, e.g., reaction products of ep halohydrins, such as epichlorohydrin, with bisphenols, such as "Bisphenol-A" (p, p'-isopropylidene diphenol). Mixtures of any two or more of the above or equivalent resins can likewise be employed.

FI BROS REINFORCEMENT

The fibrous reinforcement can be composed of a variety of inorganic and organic materials in various forms. Thus twisted or untwisted, grouped or ungrouped, filaments, strands, slivers; fibers; roving; woven and non-woven fabric, including chopped forms thereof, can be utilized of such diverse materials as glass; metal(s) and alloys thereof, e.g., aluminum, magnesium, steel; and natural or synthetic organic materials such as, nylon, cotton, canvas, rayon, Dacron (polyester fiber made from polyethylene glycol terephthalate), scrim cloth, nitrocellulose, ethyl cellulose; etc. Also the fibrous reinforcement, esp., when employed in the form of woven cloth, can have a coating or sizing applied thereto thus polyurethane coated nylon cloth can be used as fibrous reinforcement.

The fibrous reinforcement media is characteristically of a material, or combination thereof, which has a melting point higher than the temperature employed during molding in order to preserve the reinforcing value thereof. According to one preferred embodiment of this invention, glass fibers are used for reinforcement in the form of woven fiberglass cloth (usually coronized) having a thickness of about 0.010 inch per ply, or as single or plural ply fabric or web reinforcement, or as slivers ("whiskers"), viz., ungrouped or loosely grouped monofilaments from about 0.0625 to about 0.5 inch long and obtained by cutting chopping or otherwise severing loosely woven glass fiber cloth. These sever pieces of glass cloth are readily distributed in random manner yet substantially uniformly within the resin matrix. According to another embodiment of this invention organic fibrous reinforcement can be employed in the form of one or more layers of woven fabric, e.g., polyester fabric extending the entire extent or substantially the entire extent, of the destructible circuit board, esp. of substantially flat shapes, to reinforce the resin, e.g., epoxy or polyester, matrix. In conjunction therewith intermediate thin, e.g., 0.0005 to 0.005 inch thick, plastic, e.g., polyester, facing sheets (between the matrix resin or woven fabric and the electroconductive metal layer) can be used to attain more uniform dielectric properties and enhance resistance to dielectric breakdown when the circuit board is required to withstand heavy voltage loads, e.g., of the order of greater than 20 kilovolts, e.g., 30 to 50 kilovolts.

ENCAPSULATED INCENDIARY MATERIAL

A wide variety of incendiary and pyrotechnic compositions can be encapsulated and employed in accordance with this invention. Suitable exemplary encapsulated incendiary and pyrotechnic compositions which can be used include, but are not limited to, the following: encapsulated metallic fuel compounds (aluminum, magnesium, titanium, beryllium, lithium, sodium, phosphorous, silicon, alloys of two or more of these metals, etc.); encapsulated oxidizers, e.g., alkali metal perchlorates, such as KClO₄, NaClO₄, nitrates such as NaN₃, AgNO₃, etc.; encapsulated erosion materials, such as fluorcarbon liquids, esp. highly and fully fluorinated C₄ to C₉ tertiary amines and highly
3,697,668

and fully fluorinated C₅ to C₆₈ cyclic ethers including, of course, those having an alkyl substituent(s) on a ring carbon atom(s), as well as mixtures containing at least two such amines, two such ethers or at least one such amine and one such ether. An exemplary C₅ to C₆₈ ter- tiary, fluorocarbon amine is heptacoafluorotributyl amine, viz., (CF₃)₃N which has a boiling point of 170° C., and is commercially available from the 3M Com- pany under the trade designation "FC-43." An exemplar C₅ to C₆₈ fluorocarbon cyclic ether perfluoro cyclic ether commercially available mixture of C₅F₃O per- fluorocyclic ether isomers having a boiling range of 97° to 107° C. and marketed by the 3M Company under the trade designation "FC-75." Extremely reactive liquid and/or solid components can be encapsulated and em- ployed in accordance with this invention to achieve tailored combustion temperatures and burning rates. Without encapsulation many of these materials, either because of their liquid form and/or extremely reactive nature with respect to one another, oxygen or ambient moisture, cannot be formulated into stable incendiary materials. Using encapsulation to contain the reactive component(s) enables both totally solid and liquid- solid hybrid formulations to be used with excellent storage life and system stability. Thus the present in- tention allows use of materials capable of burning with greater rapidity and combustion efficiency whereas such materials were previously largely unavailable (because of their instability, reactive nature, etc.) for uses requiring dormancy from the time of intimate as- sociation until the time of ignition. Hence the present invention affords an effective structural system for em- ploying potentially explosive pyrotechnical chemicals such as sodium, magnesium and aluminum in the presence of oxygen, which pyrotechnics have not been widely employed previously in self-destruct mechanisms due to the frequent necessity of combining them only at the time when destruction is desired. In the past the use of such unencapsulated materials was accompanied by definite safety hazards. Also when one attempts to use unencapsulated inorganic oxidizers, ambient moisture can result in solvation of the oxidizer yielding an electrolyte solution which not only can cause leaching out of the oxidizer but also deleteriously affects the performance of the electrical circuitry, e.g., of the deposited printed circuits.

TYPICAL ENCAPSULATED PROCEDURES

The capsules are produced by encapsulation and are in effect spheres having an internal phase, viz., the incendiary component(s), and an external phase, viz., the capsule cell wall material. Moreover, a mixture of two or more components can be encapsulated in the same or different capsules and capsules containing different mixtures can be mixed. Reactive components are placed in separate capsules.

A variety of both chemical and mechanical encapsula- tion procedures can be employed to form capsules containing various incendiary components. Suitable chemical encapsulation procedures can be found in U.S. Pat. Nos.2,800,457 and 2,800,458. Suitable exem- plary chemical (en masse) encapsulation procedures for use with highly reactive incendiary components, e.g., metals, oxidizers, fluorochemicals erosion materi- als, etc., will be discussed hereinbelow with respect to the use of various cell wall materials, e.g., gelatin-gum arabic (with or without other adjuvants such as copolymers of ethylene and maleic anhydride or phenolplast condensates, e.g., resorcinol-formal- dehyde) and nitrocellulose external phase materials. Other cell wall materials, e.g., other phenolplast condensates, such as phenol-formaldehyde; aminoplast condensates, such as urea-formaldehyde; polyvinyl al- cohol; ethyl cellulose; polyvinylidene chlorides ("Saran"); polycarbonates ("Lexan") chlorinated polyolefins, e.g., chlorinated polypropylene ("Parlon") ; etc., can be used however depending primarily upon the specific internal phase materials to be encapsu- lated. Moreover, each capsule or some of them can have a plurality of substantially concentric walls, e.g., a primary cell wall of gelatin-gum arabic with a secondary (outer) cell wall of nitrocellulose or ethyl cellulose. Furthermore all or a portion of the capsules can have a composite cell wall, viz., one in which a plurality of wall forming components participate in cell wall formation in the manner of intimately associated components, e.g., a composite cell wall of gelatin-gum arabic and resorcinol-formaldehyde. Capsules too small to be identified readily by the naked eye are referred to as microcapsules and the process of making them is often called microencapsulation whereas capsules large enough to be seen readily by the naked eye are termed macrocapscules and the process of making them is termed macroencapsulation. While the present inven- tion contemplates use of both types, microcapsules are usually preferable because they can be more readily distributed in the resin-fibrous matrix.

ENCAPSULATION USING GELATIN-GUM ARABIC SYSTEM

The encapsulation procedure is conducted in three basic steps: (colloidal solution) preparation of the ex- ternal phase, dispersion of the internal phase and coacervation. Subsequent to coacervation optional capsule cell wall hardening and air drying can be per- formed in conventional manner. For gelatin-gum arabic type cell walls, hardening can be effected using glu- taraldehyde. When encapsulating metals, and fluorocarbons with a gelatin-gum arabic or combined gelatin-gum arabic, ethylene-maleic anhydride copolymer external phase system; the following overall parameters are usually observed:

| Internal Phase to External Phase Weight Ratio | 20:1 to 2:1 |
| Internal Phase Droplet or Particle Size Range | 1 to 5,000 microns |
| Weight % External Phase in Coaccrete Medium | 4 to 7 |
| PH Range for Coacervation | 4 to 7 |
| Coacervation Temperatures | 32° to 55°C |

The gelatin sol is prepared by adding 25 grams of gelatin into 202 grams of deionized water. The gelatin is allowed to swell thoroughly then heated to 55° C. with continuous stirring until a clear solution is ob- tained. The pH is then adjusted to 6.5 with a 10 percent solution of aqueous sodium hydroxide.

The gum arabic sol is prepared by adding 25 grams of gum arabic into 202 grams of deionized water with stir- ring until a clear solution is secured. This solution is usually filtered to remove foreign material. Then the
pH thereof is adjusted to 6.5 with a 20 percent aqueous sodium hydroxide solution.

Two separate ethylene-maleic anhydride (EMA) copolymer aqueous solutions are prepared with each having a two percent by weight concentration of the respective EMA material and the pH of each solution being adjusted to 9 using 10 percent aqueous sodium hydroxide. One EMA solution if formed using an ethylene-maleic anhydride copolymer having a molecular weight of approximately 6,000, e.g., a commercially available Monsanto Company product designated "EMA-21." The other EMA solution is formed using a copolymer of ethylene and maleic anhydride having a molecular weight ranging from 60,000 to 70,000, e.g., a commercially available Monsanto Company product designated "EMA-31."

Then 200 grams of the internal phase material are dispersed in the external phase sols by charging 180 grams of the gelatin solution and 180 grams of the gum arabic solution (pH adjusted to 9) to a coacervate vessel, e.g., a three liter glass beaker, followed by the addition of 1,500 cubic centimeters of deionized water and 40 grams of the aqueous solution of the 6,000 molecular weight copolymer of ethylene and maleic anhydride. The resulting solution is heated to 45°C, while stirring, e.g., using a flat-bladed impeller. The internal phase material is then added to the heated solution and stirring is continued to achieve proper dispersion.

After dispersion, the solution pH is lowered to 5 with 10 percent by weight acetic acid aqueous solution. Thin walls appear and coacervate spheres appear in the external phase. The pH is then raised to 6 with 20 weight percent sodium hydroxide aqueous solution to de-coacervate the spheres. Then 40 grams of the aqueous solution of the 60,000 to 70,000 molecular weight ethylene-maleic anhydride copolymer is added and the pH is lowered to 5.3 with 10 percent by weight aqueous acetic acid. As the pH is lowered, capsule wall formation becomes thicker. Maximum thickness is obtained by cooling to approximately 25°C at pH of 5.3.

ENCAPSULATION USING NITROCELLULOSE SYSTEM

When encapsulating with a nitrocellulose external phase material, a phase separation inducing agent is usually employed, e.g., a commercially available, carboxy-terminated, low molecular weight, liquid polybutadiene homopolymer (molecular weight of approximately 2,500) marketed under the trade designation "Butarez." The following parameters are usually observed:

| Internal Phase to External Phase Weight Ratio | 50:1 to 1:1 |
| Size Range | 20 to 5,000 microns |
| Weight of External Phase in Coacervate Solution | 0.5 to 4 |
| Weight Ratio of "Butarez" to Nitrocellulose Solution | 0.18:1 to 0.5:1 |
| Encapsulation Temperatures | 25°C to 55°C |

The nitrocellulose solution is formed by adding four grams of nitrocellulose into 196 grams of methyl ethyl ketone followed by stirring at 25°C until a clear solution is obtained.

Then the internal phase material, 16 grams, having the desired particle size is added to the nitrocellulose solution with stirring to obtain a uniform dispersion thereof. Phase separation and encapsulation are secured by slowly adding 60 grams of "Butarez" (pre-heated to 50°C) while stirring at 25°C. At this point the capsules are formed. Usually the encapsulation medium is stirred for about 15 minutes or more to insure that equilibrium has been reached. The capsules can then be decanted from the solution, washed with a non-solvent (for the cell wall material) and air-dried. Other suitable procedures for encapsulation will be apparent to those skilled in the art.

COMPOSITE WALL ENCAPSULATION SYSTEMS

It has been found advantageous and desirable to employ a composite gelatin-gum arabic resorcinol-formaldehyde to encapsulate the fluorocarbon liquid erosion component and other liquid components where a cell wall of superior strength is desired. An exemplary procedure for depositing such a composite cell wall is given below. Further information concerning such composite encapsulation systems, including was of other pairs of component resins, can be found in U.S. Pat. application Ser. No. 701,124 filed on Jan. 29, 1968 by Bayless et al.

Into a reaction vessel of suitable size there was added 74.5 pounds of an aqueous gelatin solution containing 11 weight percent gelatin in distilled water while regulating the temperature at 40°C to 50°C. The solution was agitated with a suitable size turbine stirrer and 128 pounds of liquid fluorocarbon, e.g., "FC-43" or "FC-75," was added. The agitation was continued at a level consummate with the desired liquid droplet and resulting approximate capsule cell size.

To a larger vessel there were added 493.5 pounds of distilled water at 40°C to 50°C and sequentially 74.5 pounds of an 11 weight percent aqueous solution of gum arabic (in distilled water), 16.8 pounds of a 2 weight percent aqueous solution of "EMA-21" (in distilled water with pH adjusted to 9.0), 16.8 pounds of a 2 weight percent aqueous solution of "EMA-31" (in distilled water with pH adjusted to 9.0) and the emulsified contents of the aqueous gelatin and liquid fluorocarbon material prepared above. The overall pH was then adjusted to 6.5 and agitation was maintained.

The mixture was allowed to cool slowly to 27°C over a period of approximately 3 hours at a linear cooling rate in order to accomplish uniform cell wall formation. At 27°C the cooling rate was increased by rapidly chilling to 10°C. Then 1,860 milliliters of a 25 weight percent aqueous solution of glutaraldehyde were added (to enhance capsule hardening). The capsules were allowed to harden for 12 to 16 hours and during this period the pot temperature was allowed to rise gradually to ambient temperatures while agitation was continued.

After hardening agitation was stopped and the capsules were allowed to settle and the mother liquor was decanted off and replaced with distilled water. Then with agitation 4,460 milliliters of a commercially available aqueous solution of "Neomerpin N" (a commercially available alkyl naphthalene sulfonic acid anionic surface active agent marketed by E. L. duPont deNemours and Company) having a density of 8.5
pounds per gallon with pH adjusted to 4.0 were added and the overall pH was adjusted to 4.1. The solution was then heated slowly to 35°C over a 2 to 3 hour period to promote shrinking of the capsule walls.

Agitation was then stopped and the capsules were allowed to settle. The supernatant was decanted and 163.7 pounds of a 5 percent aqueous solution of resorcinol (in distilled water) were added thereto. The mixture was allowed to react with agitation for 30 minutes. The temperature was controlled at 27°C, and the pH was adjusted to 1.0 by the addition of 50 pounds of a 10 weight percent aqueous solution of sulfuric acid. Then 57.3 pounds of a 37 weight percent aqueous formaldehyde solution was added and allowed to react over a period of 3 to 5 hours. The resulting composite capsules were washed with demineralized water two to three times to remove excess reactants followed by filtration and fluid bed drying at temperatures of 60°C to 107°C. The pH adjustments referred to above were made using 20 weight percent aqueous sodium hydroxide and 14 weight percent aqueous acetic acid solutions, respectively.

When using encapsulated incendiary compositions, it is possible to control burning rates and combustion temperatures by varying the concentration of encapsulated fuel, e.g., metals, and encapsulated oxidizer, e.g., perchlorates or nitrates, respectively. This is possible due to the superior uniformity of distribution and inert protection afforded by encapsulation. For example, to raise the burning temperature, more encapsulated fuel, e.g., aluminum, is used while the concentration of erosion material is diminished or eliminated. To increase the rate of burning, the concentration of encapsulated perchlorate or nitrate is increased. Also the use of small sized fuel, esp. metallic fuel, particles accelerates burning rate. Thus, e.g., the use of encapsulated aluminum having an average size of approximately 10 microns (before encapsulation) results in faster burning rates than with 30 micron encapsulated aluminum particles. Usually the combustion temperature level desired will be dictated by the specific type of electronic structure and the extent of destruction desired; whereas the rate of burning desired will be determined by the environment in which burning is to take place. Usually it will be desirable to burn at a combination of combustion temperatures and burning rates sufficiently low to avoid significant sputtering and wide distribution of residual ash, yet sufficiently high to reduce substantially all metallic components to their respective oxides.

As noted above, facing can be placed on one or both sides of the fibrous-reinforced resin article. These layers can be secured to the core section by conventional extraneous adhesives, e.g., subsequent to molding, or as part of the molding operation, i.e., during molding of the core section, or by other suitable methods. Suitable facing layer materials which can be employed with this invention include, but are not limited to, the following: various electrically conductive metal foils, such as, tin; copper; aluminum; palladium-clad aluminum pyrochemical foil (viz., foil comprised of a thin core of aluminum having on both its upper and lower surfaces even thinner films of palladium); steel foil, including stainless steel foil; etc.; wood facing layers; fiber and fabric reinforced adhesive facings; molded plastics; woven and non-woven glass fabric facing layers; resin-impregnated paper and other fibrous facing sheets; polyurethane-coated nylon cloth; etc. Combinations of any two or more of the above facing materials, or, in the case of conductive metal foils, alloys containing any one or more of them as a predominant component can be used. The pyrochemical metal foil combines a self-destruction capability with the adaptability of the metal cladding material, e.g., palladium, to development of a printed circuit, e.g., by etching away non-circuit portions of the palladium. When copper foil is used, usually a one to two ounce per square foot foil is employed to form the electro-conductive portion, for example by developing a printed circuit, e.g., by etching. According to another embodiment of this invention, each facing can be comprised of a plurality of layers or combinations of different or similar materials, e.g., copper deposited on “-Mylar” (polyethylene glycol terephthalate); a combination of conductive metal foil, e.g., aluminum foil, and a woven glass fabric impregnated with a suitable polyester, epoxy or other adhesive. The adhesive usually constitutes from about 10 to 50 weight percent of this invention can be readily prepared, e.g., using matrix resin in powdered form with the following illustrative
procedure: place a cleaned piece of conductive foil on the upper surface of the lower die or mold member; charge the mold with enough fibrous-matrix resin-encapsulated incendiary mixture to produce the desired thickness circuit board; place a second conductive foil on the lower portion of the upper die; close the dies and apply sufficient pressure to slightly compress the bulk volume; and apply heat and molding pressure to effect curing. Use of the matrix resin in powdered form minimizes capsule wall burning (during molding) and preserves capsule integrity. After cooling, remove and develop the printed circuit(s) in accordance with conventional masking and etching procedures.

When the matrix resin is employed in liquid form, the following illustrative procedure can be used. Heat the liquid resin (to reduce its viscosity and enhance mixing) and stir in the chopped fibrous reinforcement until the fibers are completely wet by the matrix resin; then add (while stirring) the encapsulated fuel followed by the encapsulated oxidizer and then the encapsulated erosion composition (if one is used); cool the mixture to ambient conditions and then stir in the liquid (matrix resin) curing catalyst; spread the resulting mixture between separator sheets and calendar on roll down to desired thickness (refrigerate until desired time for molding); secure the conductive foil layers on the upper and lower mold members; remove the separator sheets and place the resin-fiber-encapsulated incendiary curing agent calendared mixture over the foil on the lower mold member; heat at a low to moderate temperature to drive off residual air and moisture; close the mold and apply heat and pressure to cure; cool and process the foil into printed circuitry in unknown manner.

The invention will be illustrated in greater detail by the examples which follow. It should be understood, however, that the present invention in its broadest aspects is not necessarily limited to the specific incendiary or pyrotechnic compositions, matrix resins, fibrous materials, conductive layer materials and dimensions, procedures and igniter mechanism, etc., set forth hereinbelow in the examples.

**EXAMPLE 1 (LIQUID MATRIX RESIN)**

<table>
<thead>
<tr>
<th>Component</th>
<th>Parts by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matrix Resin and Curing Agent</td>
<td></td>
</tr>
<tr>
<td>Liquid Epoxy Resin (&quot;DER 331&quot;)</td>
<td>27.5</td>
</tr>
<tr>
<td>Liquid Curing Agent (&quot;DMP 30&quot;)</td>
<td>2.5</td>
</tr>
<tr>
<td>Chopped Fiberglass Reinforcement</td>
<td>6.0</td>
</tr>
<tr>
<td>(0.25 inch to 0.125 inch long, slivers of 0.010 inch thick per ply commercially available &quot;181&quot;) fiberglass cloth, viz., 5 Counter 8 Harness Warp Fiberglass cloth having 56 warp yarns and 53 filling yarns per inch and an average weight of about 8 ounces per square yard; see Military Specification MIL-C-9084B, 22 January 1960)</td>
<td></td>
</tr>
<tr>
<td>Encapsulated Incendiary Material</td>
<td></td>
</tr>
<tr>
<td>*Fuel (Aluminum spheres)</td>
<td>15.0</td>
</tr>
<tr>
<td>**Oxidizer (Potassium perchlorate)</td>
<td>45.0</td>
</tr>
<tr>
<td>***Erosion Material (CaF₂N &quot;FC-43&quot;)</td>
<td>4.0</td>
</tr>
<tr>
<td>liquid perfluoro compound</td>
<td></td>
</tr>
</tbody>
</table>

*Aluminum spheres of 200 to 325 mesh diameter encapsulated in nitrocellulose as hereinbefore noted.

**Potassium perchlorate granules of 100 to 200 mesh diameter encapsulated in nitrocellulose as hereinbefore noted.

**Liquid perfluoro erosion material encapsulated using the hereinbefore noted composite wall system (gelatin-gum arabic with resorcinol-formaldehyde) to produce capsules having a diameter of 100 to 200 microns.

"DER 331" is a commercially available liquid epoxy resin formed by reaction of "Bisphenol A" and 2-epichlorohydrin (Dow Chemical Company).

"DMP 30" is a commercially available tri-dimethyl amino phenol curing agent (Dow Chemical Company).

The liquid epoxy was preheated to approximately 250° F. to reduce its viscosity and the chopped fiberglass was added with stirring until the resin thoroughly wet the fiberglass. While the temperature was maintained at 250° F., the encapsulated incendiary components were added (fuel then oxidizer then erosion material) with stirring. The resulting mixture was allowed to cool to ambient room temperature (68° to 77° F.) and then the liquid catalyst was added while stirring.

The resulting mixture was then spread between two polyethylene separator sheets and calendared to a desired thickness (not counting separator sheets) of approximately 0.060 inch. The thus calendared sheet was then refrigerated to ~40° F. to retard curing and facilitate separator sheet removal.

Facing sheets 0.10 inch thick of 1 to 2 ounce per square foot electro-conductive copper foil were then adhesively secured to 0.125 inch thick aluminum cowl sheets using conventional masking tape, and the exposed surfaces of the copper were cleaned with methyl ethyl ketone. One of the thus assembled cowl sheets were placed on the lower plates of a heated press, and the calendared resin-glass fiber-encapsulated incendiary mixture (separator sheets removed) was placed on the cleaned copper foil surface. The mixture was heated on the press for 5 minutes at 225° F. to drive off residual air and moisture. Then the remaining cowl assembly (copper foil down) was placed over the heated plastic mixture and the plates were closed. Curing was conducted during molding at 250° to 300° F. and 10 to 100 p.s.i. for 1.5 to 15 hours. After removal from the mold and cooling, the cooper-faced boards were processed in conventional masking-etching procedures into printed circuits of various configurations. These self-destructible printed circuit boards were then prepared for in-situ ignition by drilling a small hole at the bottom edge of the board and inserting a conventional nichrome electrical resistance heater type igniter through the hole. The igniter was secured in position with a conventional high temperature-resistant potting compound. Electrical impulse of a small to moderate magnitude electric current, e.g., 1.5 to 15 volts, is sufficient for ignition via the terminal ends of the nichrome igniter.

**EXAMPLE 2 (POWDERED MATRIX RESIN)**

**Component**

**Parts by Weight**

| 60 | Matrix Resin                  | 20.0 |
| 5.0 | Powdered "Epoxy 917"         |      |
| 4.0 | Chopped Fiberglass Reinforcement |     |
| 4.0 | Encapsulated Incendiary Material |   |
| 25.0 | Fuel (Aluminum spheres)      |      |
| 15.0 | Oxidizer (Potassium perchlorate) | |
| 5.0 | Erosion Material (CaF₂N liquid) |    |

*Same as in Example 1.
"Epon 917" is a commercially available powdered epoxy resin formed from reaction of epichlorohydrin and "Bisphenol A." Since the above ingredients are in the free flowing dry state, except the chopped fiberglass, they can be mixed readily in a reel type feed blender or equivalent suitable mixer. When encapsulated, the liquid erosion material is in a dry, free flowable state due to the capsule walls.

The formation of these self-destructible boards is different from those of Example 1 in that a compression molding procedure and apparatus are used in the preparation thereof. Hence the bottom (female) die portion must be sufficiently deep to hold enough bulk charge mixture to yield the desired thickness molded product (in this case 0.060 inch).

The molded product is formed by placing a cleaned piece of conductive copper foil (same as in Example 1) over the upper surface of the female die. The premixed charge is then charged to the copper-lined female die. A second piece of cleaned conductive copper foil is then secured to the lower surface of the upper (male) die member, and the die is closed with sufficient pressure to compress the bulk volume slightly. The top and bottom sides of the die are then heated to 350°F and held at this temperature for a sufficient time period, e.g., 10 to 15 minutes, to melt the resin. Molding pressure is then applied to compress the product to the desired thickness, and curing is conducted at this pressure and temperatures of 350°F to 375°F for 1 to 1.5 hours. The molded composite is then removed from the mold, processed for development of printed circuitry and fitted with an igniter device as in Example 1.

While the above examples illustrate use of an electrical impulse ignition system; other ignition systems, electrical and non-electrical can be used. For example, conventional resistance heating elements, dynamite-type fuses, etc., can be utilized. The dynamite-type fuses can be triggered by a match or burning cigarette. These fuses can be installed in essentially the same manner as the pyrofuse igniter.

What is claimed is:

1. A self-destructible, fibrous-reinforced, circuit board structure comprising:
   a. a board having at least one major surface and including, (a), a fibrous-reinforced plastic matrix and, (b), a profusion of individual capsules of incendiary material which material is capable of rapid yet non-explosive combustion upon ignition,