United States Patent [19]
Laidlaw, Jr. et al.

[11] **3,825,918**
[45] **July 23, 1974**

[54] IMPACT SENSITIVE SECURITY WINDOW SYSTEM

[75] Inventors: **H. Gordon Laidlaw, Jr.**, Thousand Oaks; **Berton P. Levin**, Santa Monica, both of Calif.

[73] Assignee: **The Sierracin Corporation**, Sylmar, Calif.

[22] Filed: **Nov. 16, 1972**

[21] Appl. No.: **307,090**

[52] **U.S. Cl.** **340/274,** 52/616, 109/21, 161/404, 340/285
[51] **Int. Cl.** **G08b 13/04**
[58] **Field of Search** 340/274, 285; 109/21, 10, 109/49.5; 52/171, 616; 161/192, 404

[56] **References Cited**

UNITED STATES PATENTS

2,864,928	12/1958	Danford	52/171
2,921,257	1/1960	Boicey	340/274
3,180,781	4/1965	Ryan et al.	161/192
3,594,770	7/1971	Ham et al.	340/285
3,671,370	6/1972	Littell, Jr.	109/49.5

Primary Examiner—John W. Caldwell
Assistant Examiner—Glen R. Swann, III
Attorney, Agent, or Firm—Christie, Parker & Hale

[57] ABSTRACT

A security window system having a transparent structure having high resistance to penetration is described. A transparent conductive layer is provided over most of the area of the window and the resistance of the layer is monitored for sensing penetration. Preferably the layer is subdivided into a number of conductive regions for substantially increasing the sensitivity of the system to minor interruptions in the layer. Temperature and stress effects can be minimized by connecting different conductive areas of the layers as arms of a resistance bridge. An alarm may be sounded when a small steady state change in resistance is sensed or when a rapid change in resistance is sensed.

11 Claims, 13 Drawing Figures

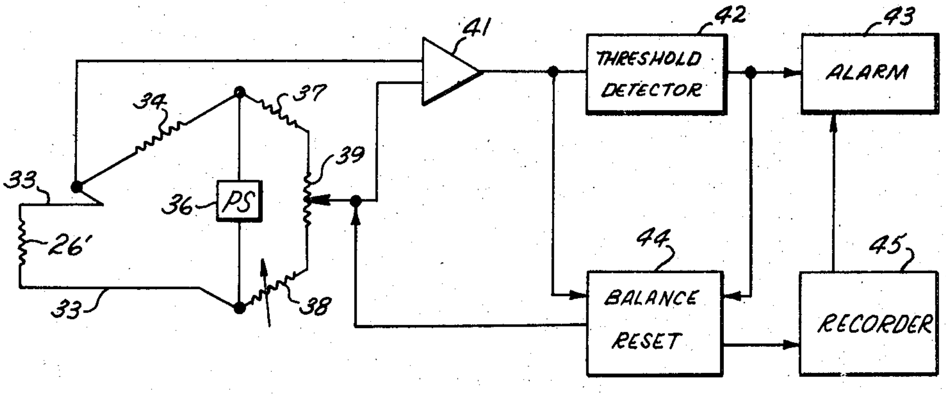


FIG. 1

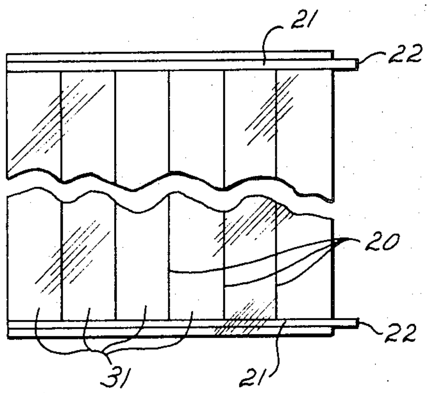


FIG. 2

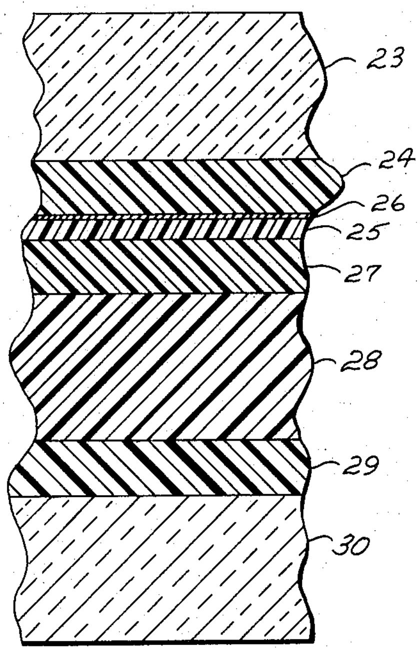


FIG. 4

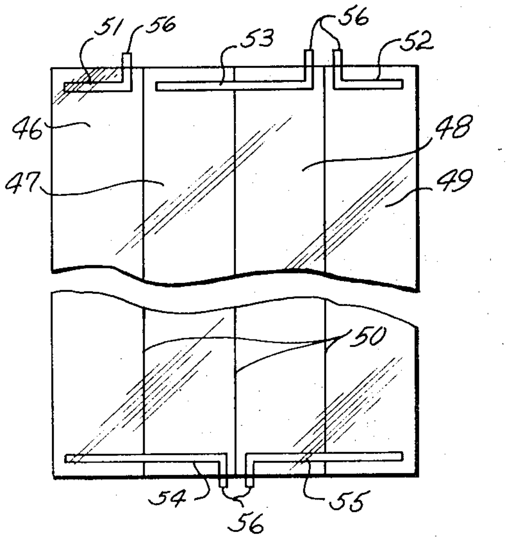


FIG. 3

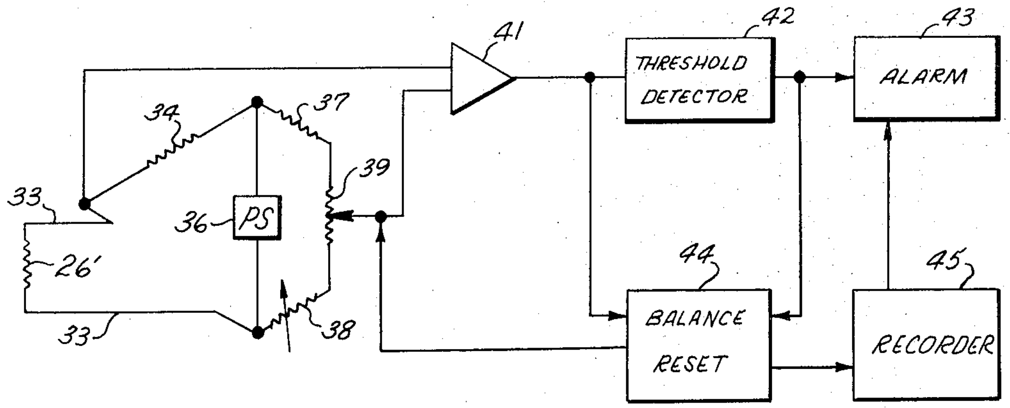


FIG_5

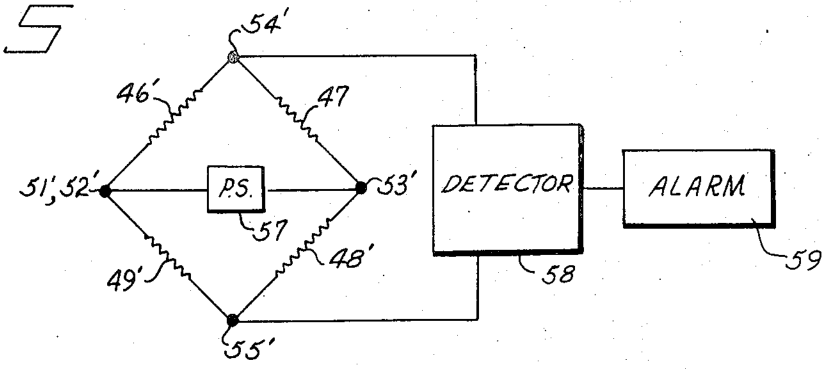


FIG_6

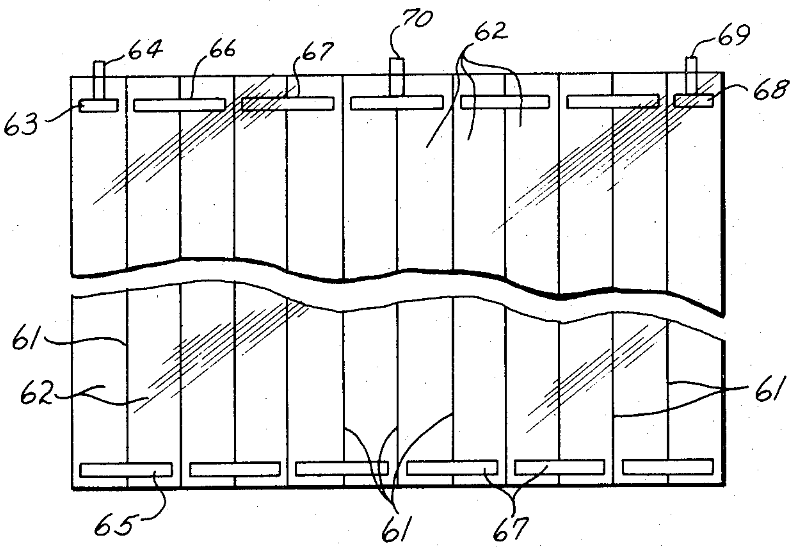
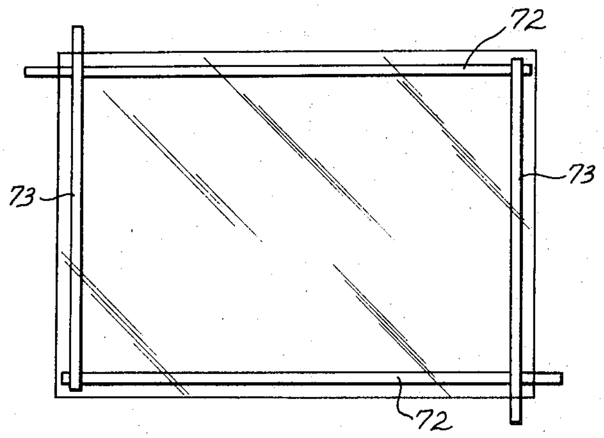


FIG_7



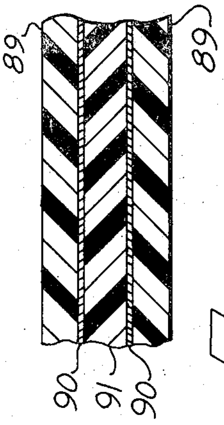


FIG_10

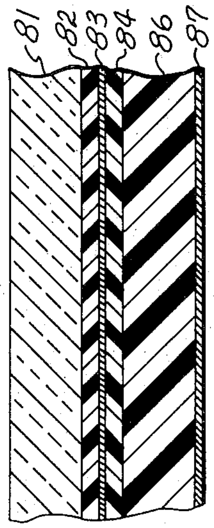


FIG_9

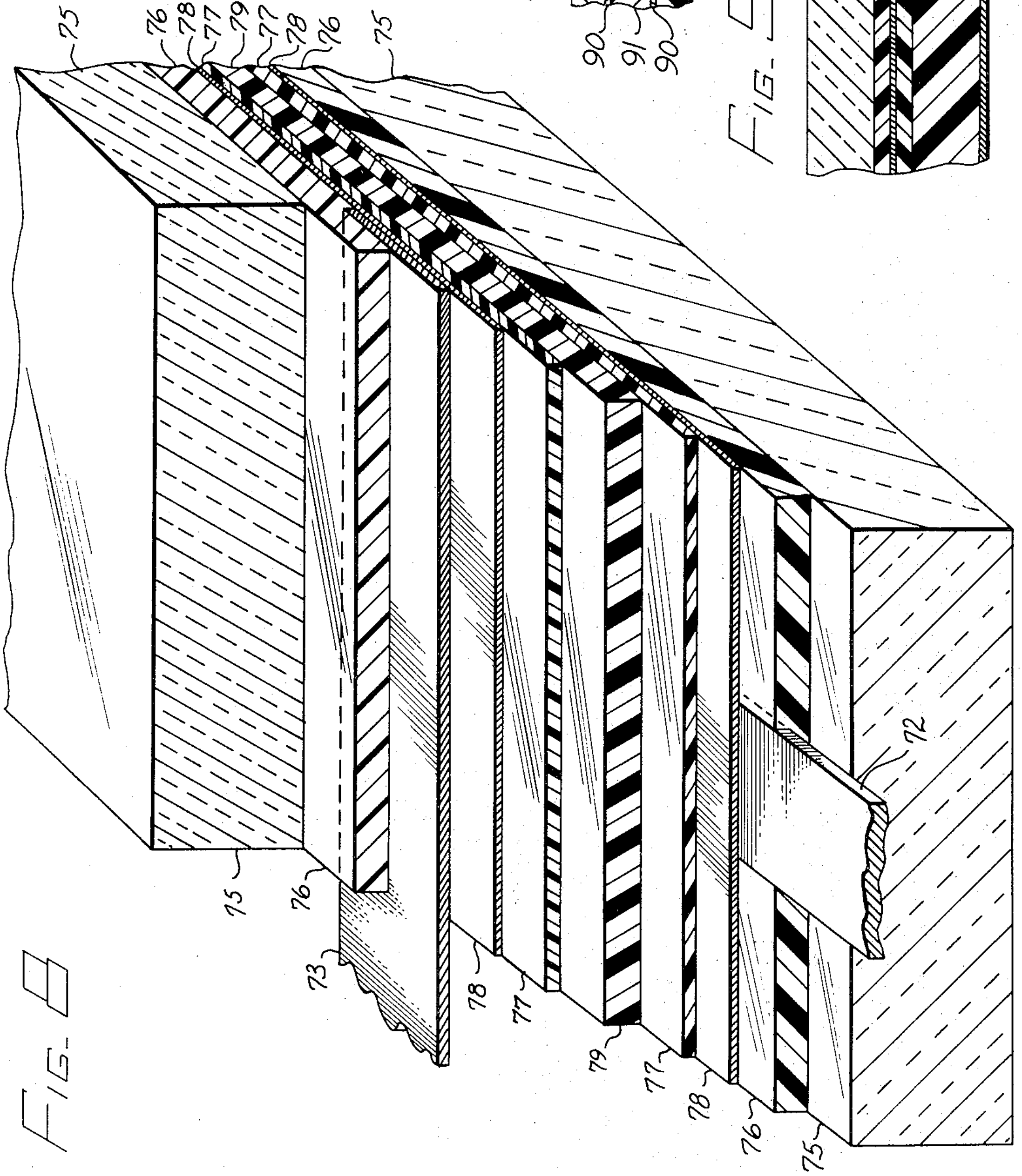


FIG_8

FIG. 11

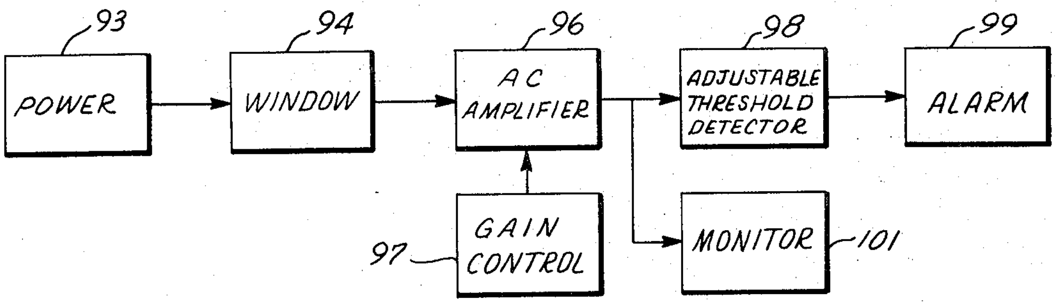


FIG. 12

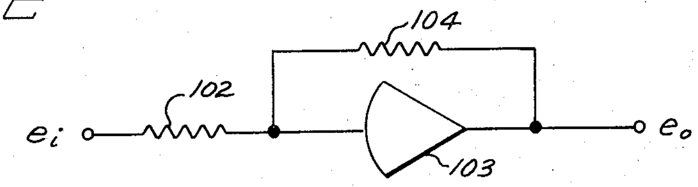
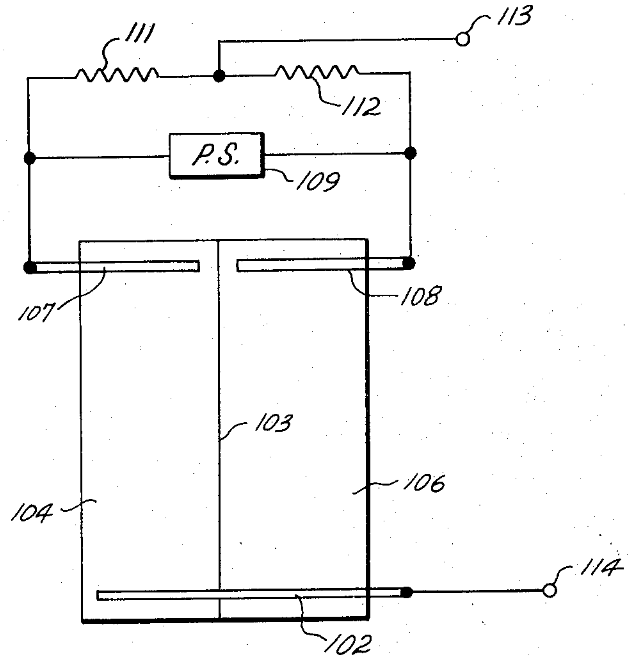


FIG. 13



IMPACT SENSITIVE SECURITY WINDOW SYSTEM

BACKGROUND

This application is related to copending U.S. Patent applications Ser. No. 307,096, entitled "Laminated Security Window System" by Roger E. Nelson, et al; Ser. No. 307,095, entitled "Laminated Security Window" by Berton P. Levin et al; and Ser. No. 307,089, entitled "Improved Security Window" by Clyde L. Lucky; each of which was filed 11/16/72 and claims subject matter disclosed herein and which is assigned to Sierracin Corporation, assignee of this application.

In many situations it is desirable to have a transparent window that is relatively impenetratable. Such windows may be used in prisons, hospitals, museums, zoos, computer rooms, laboratories, or in store fronts where theft or vandalism may be a problem. They are useful any place where maximum natural lighting, visual access and physical security are requisite. Jewelry counters and laboratory hoods are other suitable locations. Bars can be added adjacent ordinary glass; however, this is in many cases undesirable for a variety of reasons. Thus, in a prison or hospital or similar institutions, bars may have a significantly undesirable effect on persons within the institution. Bars detract from the pleasure of visitors to zoos or museums. In stores and the like where protection is desired against entry, the presence of bars is highly undesirable because of the adverse effect of potential customers. Collapsible window grates are little better.

Windows that are highly resistant to penetration can be formed with thick layers of glass or preferably with laminated glass sandwiches which may include layers of tough, impact resistant plastics, such as the polycarbonate plastics. Tempered glass is desirable in some situations in case of breakage. Thus, for example, in some institutions persons may deliberately break windows to obtain slivers of glass to use as weapons or to ingest in a suicidal act. Tempered glass is desirable for such situations since it does not shatter like ordinary glass but breaks into relatively small fragments substantially free of all sharp edges.

In addition to resistance to penetration it is often highly desirable to provide sensing of efforts to penetrate so that an alarm can be sounded locally or at some remote station. Thus, for example, penetration of a prison window indicates either an escape attempt or an effort to convey contraband. Sensors in the individual prison windows can be monitored in a central location for detection of such unlawful activities. Similarly, in stores or the like, breakage of a window commonly precedes a burglary attempt. For this reason, burglar alarm systems commonly include means for sensing breakage of the window.

A very common technique for sensing breakage of a window is to adhere a conductive tape such as thin aluminum or lead foil directly to the glass around the periphery of the window. Such strips are unsightly and are preferably avoided, particularly in store windows and the like where an attractive appearance is highly desirable. Omission of the obvious alarm strips may also be desirable in some institutional windows. The alarm strips have another disadvantage in that they are essentially a binary device that is either intact or broken. When such a tape is broken the alarm system is inoperative until someone gets to the window and bridges a break in the tape. There is no way of resetting such an alarm from a remote location.

It is therefore desirable to provide a security window system having an alarm built into it which is sensitive to attempts to penetrate the window and which can be reset from a remote location. It is desirable to have a signal from the window that is related to the degree of penetration, which in this context can be considered to be an analog change as compared with the binary change that occurs upon complete interruption of an electrical path. Preferably such a security window is substantially free of apparent visual indications of the presence of the alarm. For most uses the window is preferably resistant to penetration with the impact resistance of polycarbonate and the resistance to sawing that is characteristic of glass.

BRIEF SUMMARY OF THE INVENTION

There is, therefore, provided in practice of this invention according to a presently preferred embodiment a security window system wherein a transparent electrically conductive layer is provided over most of the area of the window and is connected to means for giving an output signal in response to a transient change in resistance in excess of some predetermined magnitude. Preferably the predetermined magnitude is adjustable for detecting a strain in the window that is a predetermined fraction of the strain at window penetration.

DRAWINGS:

These and other features and advantages of the present invention will be appreciated as the same becomes better understood by reference to the following detailed description of presently preferred embodiments when considered in connection with the accompanying drawings wherein:

FIG. **1** is a face view of a security window including an alarm sensor;

FIG. **2** is a fragmentary cross section of the window of FIG. **1**;

FIG. **3** is a schematic diagram of a sensing circuit for the window of FIG. **1**;

FIG. **4** is a face view of another embodiment of security window;

FIG. **5** is a block diagram of a sensing circuit for the window of FIG. **4**;

FIG. **6** is a face view of another embodiment of security window;

FIG. **7** is a face view of still another embodiment of security window;

FIG. **8** is a partially cut-away section of the window of FIG. **7**;

FIG. **9** is a fragmentary cross section of another embodiment of security window;

FIG. **10** is a fragmentary cross section of another embodiment of security window;

FIG. **11** is a schematic diagram of another penetration sensing system;

FIG. **12** is a schematic diagram of another resistance sensing technique; and

FIG. **13** illustrates another embodiment of security window and a schematic circuit connected thereto.

DESCRIPTION

FIG. **1** is a face view of a security window and FIG. **2** is a fragmentary cross section showing the laminated layers thereof. In face view the security window appears much like an ordinary transparent window except that it may appear somewhat tinted or have slightly less light transmission than an ordinary clear glass window. In addition, very narrow isolation lines **20**, described in greater details hereinafter, may be seen in the face of the window. Ordinarily these lines are very minute and not noticeable except on close examination. Metallic bus bars **21** are imbedded along opposite side edges of the security window. A short tab **22** from each of the bus bars typically extends beyond the edge of the window for making electrical contact. The bus bars are preferably imbedded corrugated copper strips as described in U.S. Pat. No. 3,612,745. Other suitable bus bar arrangements will be apparent to one skilled in the art, such as the external bus bars of U.S. Pat. No. 3,529,074. Typically, when the security window is used it is mounted in a frame so that the edge portions are all hidden and the bus bars **21** are thereby hidden by the opaque frame. This is desirable so that the appearance of the security window essentially matches the appearance of an ordinary glass window.

The various laminations forming the cross section of the security window are illustrated in the fragmentary view of FIG. **2**. A sheet of tempered glass **23** forms one face of the window. As will be apparent thereinafter it is preferred that this face be the one from which penetration is most likely to occur. Typically the tempered glass layer is about one quarter inch thick. A transparent resilient plastic interlayer **24** is securely bonded to the glass sheet **23**. This interlayer is the same as that typically employed in laminated automobile glass, for example. A layer 0.030 inch thick of polyvinyl butyral makes a suitable interlayer that is conveniently bonded to the other layers of the laminated window by conventional heat and pressure laminating techniques.

A carrier film **25** having a metal layer **26** on one face thereof is bonded to the plastic interlayer **24**. It is relatively unimportant which face of the carrier film has the metallic layer thereon. The carrier film is, for example, a film of polyethylene terephthalate about 0.005 inch thick. The metal layer **26** is an extremely thin layer of a metal such as nickel, gold, silver, aluminum, copper or the like which can be vacuum metallized onto the carrier film. Such vacuum deposition of thin metal films is a conventional process widely used for preparing electrically heatable windows. The metal coating is deposited in a sufficiently thin layer that it is transparent and absorbs relatively minor amounts of incident light so that the overall transmission characteristics of the window are not substantially diminished. The metal layer is sufficiently continuous to have a substantial electrical conductivity.

By employing a thin carrier film the metal layer may be vacuum deposited on the carrier film by a continuous process whereby large sheets of carrier film are coated and subsequently cut to a desired size. Relatively uniform resistance throughout the metal layer can be achiever by such a vacuum metallizing treatment. The conductive layer **26** extends over most of the area of the security window. If desired for inhibiting environmental access to the metal layer it may be deleted from the peripheral areas of the carrier film. About the only requirement is that the conductive layer extend near enough the edges of the security window to make good electrical contact with the bus bars **21** (FIG. **1**) adjacent the edges of the sheet and extend over most of the area of the window where penetration may be likely to occur. Ths bus bars are imbedded in the laminate between the interlayer **24** and the carrier film **25** so as to be in electrical contact with the metal film.

Another inlerlayer **27** is bonded to the opposite side of the carrier film **25** from the first interlayer **24**. These interlayers are substantially identical. An impact resistant plastic ply **28** is bonded to the second interlayer **27**. A variety of transparent impact resistant plastics are suitable for use in such a security window. Methyl methacrylate resin may be employed, for example. It is preferred, however, to employ a polycarbonate resin for the plastic ply. This material is commercially available under the trademark Lexan from General Electric and under the trademark Merlon from Mobay Chemical Company. The polycarbonate sheet is extremely impact resistant and has a high transparency. Thus, even if the tempered glass layer **23** is broken the polycarbonate layer **28** normally resists impact penetration. Such a polycarbonate sheet, for example, may be about one quarter inch thick.

Another polyvinyl butyral layer **29** is bonded to the other side of the impact resistant ply **28**. This interlayer is substantially identical to the first two. Finally a second sheet **30** of tempered glass is bonded to the third interlayer **29** and forms the other face of the laminated security window. This second layer of tempered glass is also about one quarter inch. The glass and plastic layers have differing coefficients of thermal expansion and when temperature cycling is expected it is desirable to provide stress relief around the periphery of the window. A suitable edge separator technique is provided in copending U.S. Pat. application Ser. No. 111,993 by Jan B. Olson, entitled "Interlayer Stress Reduction in Laminated Transparencies" and assigned to Sierracin Corporation, assignee of this application. The polycarbonate layer may be subject to attack by plasticizers in the polyvinyl butyral layer and it is usually desirable to employ a polycarbonate sheet with a barrier layer on its faces. Such a coated polycarbonate material is available from General Electric under their trade designation MR-4000. Any of a variety of conventional transparent melamine, phenoxy or urethane resins form suitable barrier layers.

The security window illustrated in FIG. **1** is highly resistant to penetration since the tempered glass has substantial impact resistance. Even if the glass layer is broken by scratching or sharp impact the polycarbonate layer has much higher strength and ordinarily has sufficient impact resistance to prevent penetration. Tempered glass breaks into a large number of relatively small particles and these particles remain bonded to the interlayer. The presence of such a mass of glass fragments on the surface of the window does a great deal to inhibit sawing or other cutting of the polycarbonate plastic.

There are substantial advantages to having a security window formed with a glass face layer and a polycarbonate plastic layer laminated together in combination with an alarm as herein described. It will be noted that the carrier film where the conductive layer forming the analog sensor of the alarm circuit is located is separated from the glass and polycarbonate layers by a relatively soft and flexible polyvinyl butyral interlayer. If the frangible glass layer is broken, as by a sharp localized blow or a deep scratch which may trigger fracture of tempered glass, the glass fragments are largely held in place by adhesion to the interlayer. The cracks from the glass seldom penetrate the resilient interlayer and hence do not interrupt the thin metal film. Thus the mere face that the glass is broken does not necessarily trigger an alarm. The same is not true of a system wherein the alarm sensor comprises a lead tape around the periphery of the window or an electrically conductive film applied directly to the glass. In such a system a crack propagating to the edge of the window normally results in breaking of the lead tape or conductive film and triggering of an alarm.

The resistance sensor extending over most of the area of the window therefore serves to detect penetration of the window. When a hole is made in the window of a sufficient size to interrupt a portion of the conductive layer, the alarm will be triggered. Mere cracking of the window or surface damage will not ordinarily trigger the alarm. Detection of penetration is what is sought and this is provided by the composite laminated window with a conductive layer embedded therein.

Referring again to FIG. **1**, the conductive layer is in electrical contact with the bus bars **21** along opposite edges of the window. A resistive connection is thereby provided between the two bus bars. The isolation lines are actually extremely fine scribe lines made in the face of the carrier film on which the conductive layer is deposited. Since this conductive layer is extremely thin a scribe line that is nearly invisible to the naked eye is sufficient for interrupting the electrical continuity of the film. A scribe line can be made with a shallow sharp groov that extends into the carrier film a tiny distance, but not even this is needed. The metal layer is so thin that almost any abrasion is enough to interrupt it without marring the carrier film.

If an effort is made to penetrate the security window the electrically conductive layer must also be penetrated. Any interruption of the conductive layer having a component in a direction parallel to the bus bars will cause an increase in the resistance of the conductive layer. As pointed out hereinafter the resistance between the two bus bars **21** can be monitored and any significant change in resistance employed for triggering an alarm. Any such sensing system has a predetermined sensitivity. If the sensitivity threshold for triggering an alarm is too small, a significant number of false alarms may be sounded. On the other hand if the threshold of sensitivity for triggering the alarm is too high, a rather large penetration of the window may occur before an alarm is sounded. It has been found that a sensitivity threshold in the area of about one to two percent change in resistance is suitable for triggering an alarm, although higher or lower changes are also suitable thresholds.

If a security window is made with a continuous conductive layer over most of the area of the window without any electrical isolation lines subdividing it into a plurality of conductive areas, the change in resistance as a function of the magnitude of the interruption of the conductive layer may be unduly low. When the entire window beneath the two bus bars constitutes a continuous conductive layer, each point on each bus bar is in direct electrical contact with every point on the other bus bar. Current flow between the two bus bars can therefore occur over a substantial area and destruction of a minor portion of the conductive layer may have a relatively minor affect on the total resistance. Thus, for example, in one test wherein the distance between the bus bars was 1.67 times the width of the conductive layer in a direction parallel to the bus bars, a straight line cut was made through the conductive layer in a direction parallel to the bus bars. A cut extending more than 20 percent of the way between the side edges of the conductive layer increased the resistance less than 1.1 percent. A circular interruption in the conductive layer having a diameter of about 17 percent of the width of the conductive layer caused an increase in resistance of only about 2.6 percent.

When isolation lines are scribed through the conductive layer in a direction extending between the bus bars the conductive film is divided into a plurality of conductive areas that are electrically in parallel with each other. Then when a sufficient cut is made parallel to the bus bars to completely sever one of such parallel conductive areas a jump in resistance occurs. Thus, for example, a conductive layer was subdivided into six conductive areas by five scribed isolation lines. As a straight line cut proceeded across one of the parallel conductive areas a nominal gradual change in resistance occurred. When one of the six parallel conductive areas was completely severed between adjacent isolation lines, an increase in resistance of about 20 percent was observed. Since a similar length cut in a film without isolation lines would produce a resistance change of less than about **1%** the value of the parallel conductive areas can be readily seen. In addition to increasing the sensitivity of the security window to relatively small penetration, the sensitivity of the circuit for detecting a change in resistance can be readily correlated with the resistance change that may occur when one conductive area of a selected width is severed.

Since the isolation lines are aubstantially invisible the security window may have its conductive layer subdivided into any desired width of conductive area for predetermined sensitivity. In a typical window 30 inches wide the conductive layer is divided into four segments, each 7½ inches wide. Addition of only two more isolation lines cuts the width of each area to only 5 inches for very high sensitivity to penetration. If desired a large number of electrical isolation lines can be extended between the bus bars so that the conductive layer is divided into a number of narrow parallel conductors. A penetration of the window interrupts a number of such narrow conductors and the resistance change is the usual change due to deleting some of the resistors in a parallel array of resistors.

The array of resistors in electrical parallel is considered to extend over most of the area of the window since penetration at any point will interrupt one or more resistors. This may be true even when the resistors become narrower than the electrical isolation lines between them. Thus, if desired, one could form narrow strips of conductive material on the carrier film with clear areas between the strips and have a structure differing only in scale from the arrangement illustrated in FIG. **1**, for example.

FIG. **3** is a schematic illustration of a system for detecting penetration of the security window. Very broadly the penetration of the conductive layer causes an analog change in the resistance of the window which is a function of the extent of penetration, and the magnitude of this change may be used for triggering an alarm. The resistance of the conductive layer **26** is represented by the resistor **26'** is the schematic illustration of FIG. **3.** This resistance is connected to the detecting circuit by electrical leads **33** including the window bus bars and whatever additional leads may be desired for conveying signals to a remote location. The thin film resistor **26'** is connected in a bridge with a resistor **34** as an adjacent arm of the bridge. A power supply **36** applies an electrical signal to the resistances **26'** and **34**. The electrical signal is also applied to a fixed resistor **37** and a variable resistor **38** connected in series with a tapped resistor or potentiometer **39**. These additional resistors **37, 38** and **39** form the other two arms of a bridge. The variable resistor **38** may be employed for a coarse adjustment of the bridge balance. Resistor **37** can be adjustable for bridge balance, too, or both resistors **37** and **38** may be coupled for coarse bridge balance.

An amplifier **41** is connected between the adjacent bridge arms **26'** and **34** and is also connected to the tap on the potentiometer **39**. Adjustment of the tap can serve as a fine adjustment of the bridge balance.

The bridge excitation provided by the power supply **36** can be either a voltage or current arrangement. Similarly the power supply can be either AC or DC as may be desired in a particular application. Similarly the signal applied by the bridge to the amplifier **41** can be either a differential signal, that is, with neither bridge tap grounded or connected to a circuit common, or it may be a single ended signal with either of the bridge connections grounded or connected to a circuit common. Many variations in the bridge excitation and unbalance detection will be apparent to one skilled in the art.

The output of the amplifier **41** is applied to a conventional threshold detector **42** which senses when the null balance of the bridge is outside of a predetermined limit. A wide variety of threshold detectors may be suitable, depending on the signal selected from the amplifier in a particular embodiment. When the threshold detector notes that the bridge is out of balance beyond the preset limit an alarm **43** is triggered. Any desired alarm may be used such as a bell, klaxon, light or the like. The alarm can be adjacent the window or remotely located. One can even dispense with the threshold detector and apply the amplifier output directly to an audio alarm, such as, for example, a loudspeaker. When the sound of the loudspeaker reaches some arbitrary level as noted by an individual in the vicinity this can also serve as an alarm.

Once an alarm has sounded, and it has been determined that the signal is erroneous or one decides to presently ignore the unbalance, the bridge can be readjusted by means of the resistors **38** and **39** to bring it back into balance. This is quite feasible since the signal output from the bridge is analog. A change in the resistance of the conductive layer modifies the electrical signal in an analog manner. The alarm system can therefore be reset by rebalancing the bridge, all of which can be done from a remote location if desired. Such is infeasible in a window fitted with conventional lead tapes or with a conductive layer directly on the glass since rupture of the tape or layer on glass is a binary output and the circuit cannot be restored without access to the window and repair of the tape.

Some changes in the resistance of the conductive layer may occur gradually even when penetration of the window is not attempted, thus for example, temperature changes in the window may cause resistance changes in the conductive layer of a sufficient magnitude to unbalance the bridge. One can therefore provide an automatic balance reset **44** which senses an unbalance and brings the bridge back to null by adjusting the potentiometer **39**. The fact of resetting of the bridge or the magnitude of the resetting may be recorded with a conventional recorder **45**. The cumulative change in resistance recorded by the recorder **45** could be used to trigger an alarm if desired. It will be apparent, of course, that the balance reset **44** may be operated by the amplified null balance signal from the amplifier **41** so as to operate in a more analog fashion and accommodate slow drifts in the resistance balance of the bridge. Similarly, if desired the balance reset or bridge adjustment may simply control operation of the amplifier **41** to remain below the threshold signal. Electrical balance of the amplifier can substitute for actual bridge resistance balancing for alarm actuation as well. The automatic reset **44** and recorder **45** are not essential to the functioning of the system.

It will also be apparent that high degree of sophistication may also be incorporated in the balance detection system so that, for example, a single transient of resistance can be ignored and a more permanent change employed for triggering the alarm. Means may also be provided for triggering the alarm in case the bridge leads are shorted or cut, or if the power is cut off, or if any of a variety of techniques are employed for circumventing the alarm system.

As mentioned above, the resistance of the conductive layer in the window may vary with temperature and cause an unbalance of the bridge. Although this can be readily accounted for with an automatic balance resetting system, it is also quite easy to simply compensate for the temperature change by making the fixed resistor **34** in the adjacent arm of the bridge to the resistor **26'** also be a conductive layer in a window. If the temperature pattern in the two resistors is similar, any changes in resistance will be equivalent and the balance of the bridge will not be upset. The second conductive layer in a window may be in a separate window located in a position subject to similar temperature conditions or it may simply be another portion of the same window in which the layer resistor **26'** is located.

FIG. 13 illustrates in face view another embodiment of security window having a conductive layer extending over most of the area of the window. In this embodiment, there is a bus bar **102** extending along one side edge of the window for making electrical contact with one entire edge of the conductive layer in the window. An electrical isolation line **103** extends across the window transverse to the bus bar **102** and divides the conductive area of the window into two conductive regions **104** and **106**. A bus bar **107** extends part way along the side edge of the window opposite from the full length bus bar **102** and makes electrical contact with the conductive layer of the first region **104**. A second similar bus bar **108** extends the balance of the way across the window and makes electrical contact with the conductive layer in the second conductive region **106**. Each of the bus bars extends beyond the edge of the window for making electrical contact with an external circuit.

FIG. 13 also illustrates schematically a typical external circuit connected to the bus bars of the window. A power supply **109** is connected to the two similar bus bars **107** and **108**. Resistors **111** and **112** are also connected to the power supply. A first tap **113** is connected between the resistors **111** and **112** and a second tap **114** is connected to the bus bar **102** that makes electrical contact with both conductive regions **104** and **106.** The taps **113** and **114** may be connected to any conventional null balance direction circuitry as desired for triggering an alarm in response to unbalance of resistance. It will be noted that the window and external circuit illustrated in FIG. **13** are connected as a conventional bridge with the two conductive regions of the window as adjacent arms of the bridge. Either or both of the resistors **111** or **112** can be variable for balancing the bridge, or balancing can be achieved in the additional circuits (not shown) to which the window may be connected.

The two conductive regions of the window will both be subjected to similar temperature conditions and any changes in resistance in the two regions will be similar. Being in adjacent bridge arms, the resistance drift due to temperature change balances out and no bridge unbalance results. It will be apparent that if desired the conductive layer in each of the conductive regions **104** and **106** can be subdivided by isolation lines extending between the bus bars to any desired extent for enhancing sensitivity of the window to penetration.

FIG. **4** illustrates in face view another embodiment of security window having an electrically conductive layer over most of the area of the window. In this embodiment, the conductive layer is subdivided into four conductive areas **46, 47, 48** and **49** by isolation lines **50.** A first bus bar **51** is in electrical contact along an edge of the first conductive area **46.** A similar short bus bar **52** is in electrical contact with an edge of the other outside conductive area **49.** A third bus bar **53** is in electrical contact with the edges of both of the remaining two conductive areas **47** and **48** spanning one of the isolation lines **50.** Along the opposite edge of the security window from the first three bus bars is a fourth bus bar **54** in electrical contact with the edges of the two conductive areas **46** and **47.** Another bus bar **55** on this same edge of the window is in electrical contact with the edges of the remaining two conductive areas **48** and **49.** Suitable conductive tabs **56** extend from the bus bars to and beyond the edges of the window for making electrical contact to external circuits. If desired, the conductive areas between the isolation lines **50** can also be subdivided into parallel resistive areas in the same manner as the window of FIG. **1** for enhanced sensitivity.

FIG. **5** illustrates schematically the interconnection of the conductive areas. The bus bars and conductive areas of FIG. **4** are represented schematically with the same reference numerals bearing a prime in FIG. **5.** The two bus bars **51** and **52** are externally interconnected at a point **51', 52'**. This same point is connected to a suitable power supply **57** which is in turn connected to the center bus bar **53** at a point **53'** in the schematic illustration of FIG. **5.** Electrical connection is made to the opposite bus bars **54** and **55** at the points **54'** and **55'** leading to a detector **58** of changes in the electrical resistance. The detector **58** can be connected for triggering an alarm **59** when a predetermined liminal change in electrical resistance occurs in the bridge formed by the resistors (conductive areas) **46', 47', 48'**, and **49'**.

Since the four resistors or conductive areas are connected as the four arms of a resistance bridge, any resistance changes occurring in all of the conductive areas will not unbalance the bridge and no net change in resistance will be noted. As mentioned above, the conductive layer within the security window changes resistance somewhat with changing temperature. Similarly, stresses on the conductive layer which may be generated by bending on the window, for example, may change resistance. When the conductive areas are interconnected as arms of a bridge such thermal or stress changes in resistance do not cause false alarms. It will be apparent to one skilled in the art that if desired more than one window may be interconnected as arms of a resistance bridge and the conductive areas may sufficiently balance to compensate for thermal changes and the like. This is generally less desirable since the thermal changes or changes in stress between two windows is usually of much greater magnitude than similar changes within two different areas of the same window. It will also be apparent that the resistance change detector **58** should be adjustable for resetting the alarm system in case of a permanent change in the resistance balance between the arms of the bridge.

FIG. **6** illustrates in face view another embodiment of security window. In the embodiment of FIG. **1**, the conductive areas were electrically connected in parallel. In the embodiment of FIG. **6**, the conductive areas are connected in series. Thus, as illustrated in this embodiment, a plurality of isolation lines **61** extend between opposite edges of the security window and subdivide the area into a plurality of conductive areas **62.** Electrical contact is made along a side edge of one of the outside conductive areas by a bus bar **63.** A tab **64** permits electrical connection of this bus bar to an external circuit. At the opposite end of the first conductive area from the bus bar **63** is a second bus bar **65** which makes electrical contact along the side edge of the first conductive area and also along the side edge of the second conductive area adjacent the first. That is, the second bus bar **65** spans the isolation line **61** between the two adjacent conductive areas. Another bus bar **66** electrically connects the opposite side edge of the second conductive area with the side edge of the third conductive area. These additional bus bars **65** and **66** do not have an external tab for electrical connection to circuits outside the window.

A similar series of additional bus bars connect adjacent conductive areas clear across the window. In the final conductive area a bus bar **68** makes electrical connection to both the edge of the conductive area and a tab **69** permitting electrical connection to an external circuit. Thus, all of the conductive areas within the window are electrically connected together in series. Clearly a penetration that extends through the full extent of one of the conductive areas will interrupt the continuous circuit and provide a substantially infinite increase in resistance. Such an electrical connection is not resettable from a remote location.

If desired a tab **70** may be provided on a central bus bar for making contact to an external circuit thereby permitting half of the conductive areas to be in one arm of a bridge and the other half in another arm of a bridge for temperature and stress compensation. Such a series connected security window is very sensitive to small penetrations. The same effect can be obtained without the large number of bus bars by simply ending alternate isolation lines a substantial distance from each of the opposite edges of the window respectively. A pattern of isolation lines for a series-parallel connection of conductive areas can also be used.

As mentioned hereinabove the security window is highly sensitive to penetrations that have a component extending in a direction parallel to the bus bars. If the interruption in the conductive layer is primarily in a direction between the bus bars, that is, for example, parallel to the isolation lines, little if any change in resistance is observed. Thus, for example, if the object of penetration of the security window is the passage of contraband, a narrow slit extending between the bus bars may be sufficient for the unlawful purpose without causing a sufficient change in resistance to trigger the alarm. This possibility is effectively forestalled with a security window of the type illustrated in FIG. **7**.

As illustrated in this embodiment at least the central portion of the security window has two spaced apart conductive layers extending over most of the area of the window. A first pair of bus bars **72** are provided along the opposite side edges of the security window in electrical contact with the edges of one of the conductive layers. Orthogonal to this first set of bus bars is a second pair of bus bars **73** in electrical contact with the edges of the second conductive layer within the window. The isolation lines in the conductive layers between the opposed bus bars have been deleted from FIG. **7** for enhancing clarity of the drawing. It will be readily apparent that no penetration of the window can be made that does not have a component parallel to one or the other of the two pairs of bus bars. It is therefore substantially impossible to penetrate such a window with any reasonable size hole without triggering an alarm.

The arrangement of bus bars in the window illustrated in FIG. **7** is as simple as possible and, if desired, arrangements such as illustrated in FIGS. **4** and **6** may be employed. The two conductive layers can be employed as a pair of arms in a bridge, or portions of the two conductive layers may be used as the four arms of a bridge. There is a possibility, although remote, that penetration of both layers could cause compensating resistance changes in the two layers when they are used as adjacent arms of a bridge. The two layers can be used as opposite arms of the bridge so that penetration of both layers causes an increase in sensitivity.

FIG. **8** illustrates in fragmentary cross section a laminate security window having two conductive layers therein. In this illustration successive layers are cut away to best show the location of the bus bars. In this particular example the arrangement of successive layers is symmetrical from the center of the laminate, however, it will be apparent that asymmetrical arrangements are also suitable.

Each face of the laminated security window comprises a glass ply **75.** A plastic interlayer **76** about 0.03 inch thick is bonded to each of the glass plys **75.** A carrier film **77** of polyethylene terephthalate about 0.005 inch thick and having a thin conductive metal coating **78** thereon is bonded to each of the interlayers **76.** Centrally located in the laminate is a third interlayer **79** which bonds the two carrier films together. One of the bus bars **72** is imbedded in one of the plastic interlayers **76** so as to be in electrical contact with one of the conductive layers **78.** The bus bar **72** is illustrated schematically rather than show the corrugations of the preferred bus bar hereinabove mentioned. The other bus bar **73** is imbedded in the opposite interlayer **76** so as to be in electrical contact with the other conductive layer **78.** During fabrication of such a laminated window initially flat sheets of polyvinyl butyral for the interlayers are assembled in a sandwich and during the heat and pressure cycle of lamination this relatively soft material deforms so that the respective bus bar imbeds therein. The effect of plural layers for detecting penetration can also be obtained be depositing thin metal films on both faces of the carrier film and laminating that carrier in a window with bus bars in contact with both metal layers.

FIG. **9** illustrates in fragmentary cross section another embodiment of security window suitable for use in locations where customary access is almost entirely on one side of the window. This laminated structure has a glass ply **81** on one face, such as, for example, one quarter inch tempered glass. A polyvinyl butyral interlayer **82** is bonded to the glass. A carrier film **83** having a thin conductive metal layer (not shown) thereon is bonded to the plastic interlayer **82.** A second interlayer **84** bonds the carrier film **83** to a relatively thick ply of transparent polycarbonate plastic **86.** The exposed face of the plastic ply **86** is coated with a protective layer **87** such as chemically deposited silica, titania or the like, which affords a substantial degree of abrasion resistance and protection against chemical attack on plastic.

Such an asymmetrical laminated security window may be used, for example, in an institution wherein the glass layer **81** is used on the inside where the inhabitants have access to the window. The plastic layer would be used on the outside where there is no regular day-to-day contact. Similarly in a store window or the like the glass layer may be employed on the outside with the plastic layer **87** on the inside where only store personnel may have access to it. This is desirable since the plastic ply is softer than the glass and can be scratched.

FIG. **10** illustrates a security window such as might be used for temporary purposes. In this embodiment a pair of carrier films **89** having thin conductive metal layers **90** thereon are bonded together with a plastic layer **91** which may be a polyvinyl butyral interlayer as hereinabove described or may be other suitable adhesive bonding. The relatively thick interlayer is not generally needed in such a situation since its ability to conform to the rigid glass and polycarbonate plys of the other embodiments is not a requirement. Care must be taken, of course, to insulate the two metal layers **90** from each other if both are used in active alarm circuits. Similarly the bus bars (not shown) making contact to the conductive layers **90** must be insulated. It will also be apparent that if desired a carrier film having a metal coating thereon can be adhesively bonded to a similar film which serves to protect the delicate metal layer from damage and a security window suitable for temporary use may be very inexpensively provided. Bus bars are needed to make contact with the metal layer. Such a security window made with thin plastic films has considerable flexibility and is light in weight making it quite suitable for temporary use. Such a lamination of plastic films with a conductive layer therein can be bonded on a window and connected to suitable detection and alarm circuits for forming a security window. Preferably the conductive layer in such a security window is scribed with electrical isolation lines and electrically connected in a bridge circuit in one of the manners hereinabove described.

There is a distinct advantage in the arrangement illustrated in FIG. 2 wherein the conductive layer **26** is separated from the tempered glass ply **23** by at least the interlayer **24** and, if desired, the carrier film **25.** The plastic isolates the conductive film from the glass layer so that if the glass is merely broken most, if not all, of the conductive layer remains intact. It is a characteristic of tempered glass that a break propagates over the entire extent of the glass breaking it into a very large number of small fragments. If the conductive layer were on the glass or closely coupled thereto such breakage of the glass would completely rupture the delicate metal layer and it would appear that penetration was being attempted. With the metal layer decoupled from the glass by a relatively soft resilient intervening plastic layer mere breakage of the glass does not disrupt the conductive film to more than a minor extent. Even if an alarm might be sounded when the tempered glass is broken the alarm system can be reset to indicate when an attempt is made to penetrate the window.

The resistance of the thin metal film embedded in the laminated security window is also sensitive to strain. That is, as the film is strained, the resistance changes. Thus, for example, when the conductive layer is located off of a neutral axis of the cross section of the laminated window, a bending of the window will induce strain in the conductive layer and change its resistance. This discovery gives one an opportunity to employ the deformation of the window prior to penetration for providing an alarm signal. More particularly a transient change in resistance can be detected with a pulse or rate of change greater than some predetermined magnitude.

FIG. **11** illustrates in block diagram a system for utilizing the strain sensitive properties of the conductive film in a laminated window for providing a security alarm. A power supply **93** applies power to the conductive metal layer in a security window **94.** The excitation applied to the window by the power supply may be AC or DC, and may be either current or voltage as desired. The window **94** is also connected to an AC amplifier **96** with gain control **97.** The AC amplifier may also have a band width control, if desired, for limiting the AC range amplified. The output of the AC amplifier is applied to a threshold detector **98** which applies an out-of-limits signal to an alarm **99.**

If someone should commence striking or otherwise deforming the window in order to effect penetration, the resultant time varying signal is amplified. When the signal is within the frequency band of the AC amplified and beyond the preset threshold, an alarm will sound. Such a system is also responsive to the rate of change of penetration through a window as represented by the changing resistance. In an impact sensitive system one can use the magnitude of the pulse of changing resistance to detect a penetration or attempt at penetration. If desired the rate of change or rise time of the pulse or pulse width can be selected for triggering an alarm. The circuitry for detecting any such characteristic of changing resistance is conventional.

The sensitivity of the threshold detector **98** can be set so that the strain required to activate the alarm **99** is a large fraction of the strain that would occur in the window before breakage. Gain control **97** may effect this function. Thus, relatively minor blows on a window which are far short of causing breakage can be ignored and a pulse representing a sufficient blow to be quite near breakage of the window can be detected. One can monitor strain amplitude and detect pressures that are a large fraction of the force required to break the window. With AC amplification in the system a blow that is sufficient to raise the strain level to breakage will activate the alarm and indicate penetration. It has been noted in penetration tests of a window having a thin metal conductive film that during the penetration event very high excursions in resistance occur and thereafter the resistance settles to an equilibrium value characteristic of the response to severance of the film. Thus, for example, penetration of the security window by a high speed projectile will cause a large change in resistance as penetration occurs which can be detected by the AC amplification system. Thus the penetration can be detected by the rapid pulse of resistance change, even though the steady state resistance may not be significantly different from the original resistance.

It may be desirable to employ a strain sensitive detection system as set forth in FIG. **11** with a penetration sensing system as illustrated in FIG. **3.** In such an arrangement the input to the AC amplifier **96** may be either the output of the null balance bridge of FIG. **3** or the output of a DC amplifier **41** which may reduce the gain requirements of the AC amplifier **96.**

If desired, a continuous surveillance monitor **101** may be connected to the output of the AC amplifier **96.** This continuous surveillance monitor may have a visual or aural output so that an attendant can perceive signal changes, such as, for example, due to someone pounding on a security window. The continuous surveillance monitor can also be some means for recording the output signal for review at a later time.

A resistance bridge is of course not the only way of detecting a change in the resistance of the conductive layer. A simple and inexpensive technique is illustrated in FIG. **12.** As illustrated in this arrangement a voltage e_i is applied to a resistor **102** connected to an input of an operational amplifier **103.** A second resistor **104** is connected across the amplifier. The output voltage e_o is proportional to the input voltage and the ratio of the resistance of resistor **104** to the resistance of resistor **102.** The output voltage is thus quite sensitive to any change in the relative values of the two resistors. A conductive layer in a security window can be used for either of the two resistors in this schematic diagram, or if desired two conductive areas in a window could be used as both resistors **102** and **104** for temperature compensation. The operational amplifier can be either a single input amplifier, or can be a differential amplifier with two inputs.

One can also use ohmmeter circuits or a variety of current or voltage comparison circuits for noting a change in resistance due to window penetration. It will also be noted that the resistance values can be digitized at any point in the electrical circuit and digital techniques used for balancing, comparing and the like. If the resistance of a conductive layer is digitized it can be compared to a digital reference number and the "balance" can be maintained by changing the reference number. As much or as little sophistication as desired can be achieved with digital techniques for comparison, correction and avoidance of false alarms or tampering with the system. Many other arrangements will be apparent to one skilled in the art for detecting a variation in resistance of the security window.

Although limited embodiments of security window and alarm systems associated therewith have been described and illustrated herein, many modifications and variations will be apparent to one skilled in the art. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. An impact sensitive security window system comprising:

a transparent electrically conductive layer extending over most of the area of the window;

means for monitoring resistance of the conductive layer; and

means connected to the means for monitoring for giving an output signal in response to a rapid change in resistance such as to produce, at the output of said means for monitoring, a pulse having a predetermined pulse characteristic in excess of a predetermined threshold.

2. A security window system as defined in claim **1** wherein the means for giving an output signal comprises an AC amplifier connected to the electrically conductive layer.

3. A security window system as defined in claim **2** wherein said means for giving an output signal comprises a threshold detector connected to the AC amplifier and an alarm responsive to the threshold detector.

4. A security window system as defined in claim **2** wherein the means for giving an output signal includes means for producing an analog output signal perceptible by a person.

5. A security window system as defined in claim **2** further comprising means for adjusting the means for giving an output signal for providing an output signal only when the magnitude of the pulse exceeds a predetermined fraction of the pulse that would occur upon penetration of the window.

6. A security window system as defined in claim **5** further comprising means connected to the conductive layer for giving an output signal in response to an accumulated change in resistance in excess of a predetermined magnitude.

7. A security window system comprising:

an electrically conductive transparent layer extending over most of the area of the window, said layer having an electrical property changeable in response to strain of the window;

means connected to the conductive layer for detecting a change in the electrical property; and

means connected to the means for detecting for giving an output signal when the strain of the window exceeds a predetermined limit.

8. A security window system as defined in claim **7** wherein the means for detecting comprises means for detecting a transient change in resistance of the conductive layer in excess of a predetermined limit.

9. A security window system as defined in claim **7** wherein the conductive layer comprises a thin metal film deposited on a transparent carrier film and wherein the carrier film is laminated in the window off of the neutral axis of the window cross section.

10. A security window system as defined in claim **9** wherein the means for detecting comprises means for detecting a transient change in resistance of the metal film in excess of a predetermined limit.

11. A security window system as defined in claim **7** further comprising means connected to the electrically conductive layer for giving an output signal when the equilibrium resistance of the layer exceeds a predetermined limit.

* * * * *