

Jan. 30, 1968

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3,366,055

SEMICONDUCTIVE EXPLOSIVE IGNITER

Filed Nov. 15, 1966

2 Sheets-Sheet 1

FIG. 1

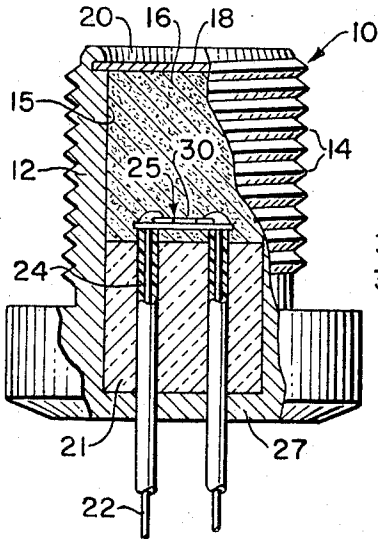


FIG. 2

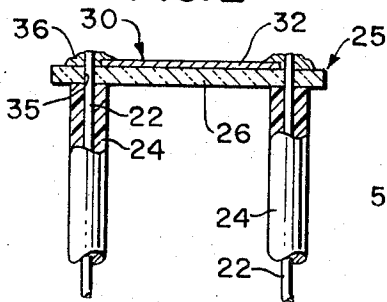


FIG. 3

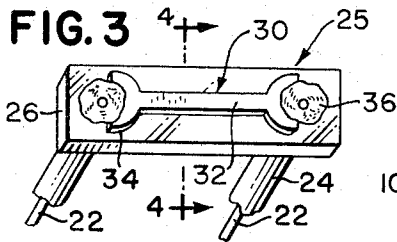


FIG. 4

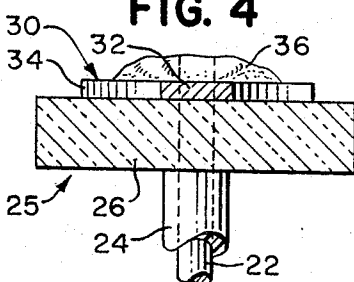


FIG. 5

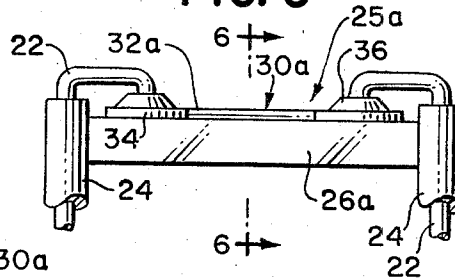


FIG. 6

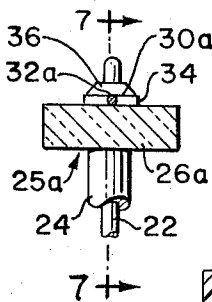


FIG. 7

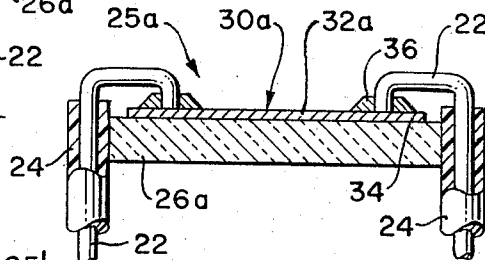


FIG. 9

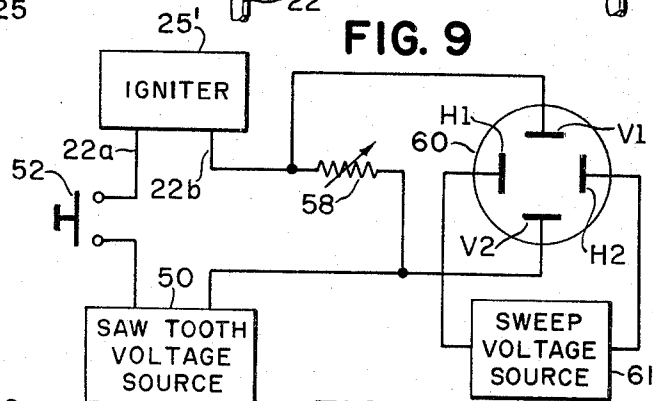


FIG. 8

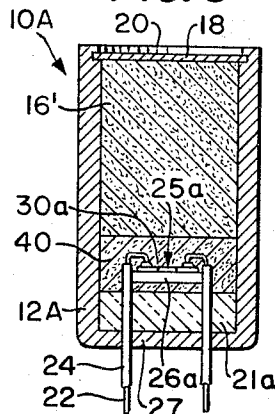
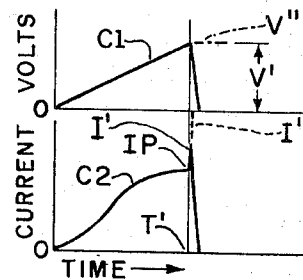


FIG. 10



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2 Sheets-Sheet 2

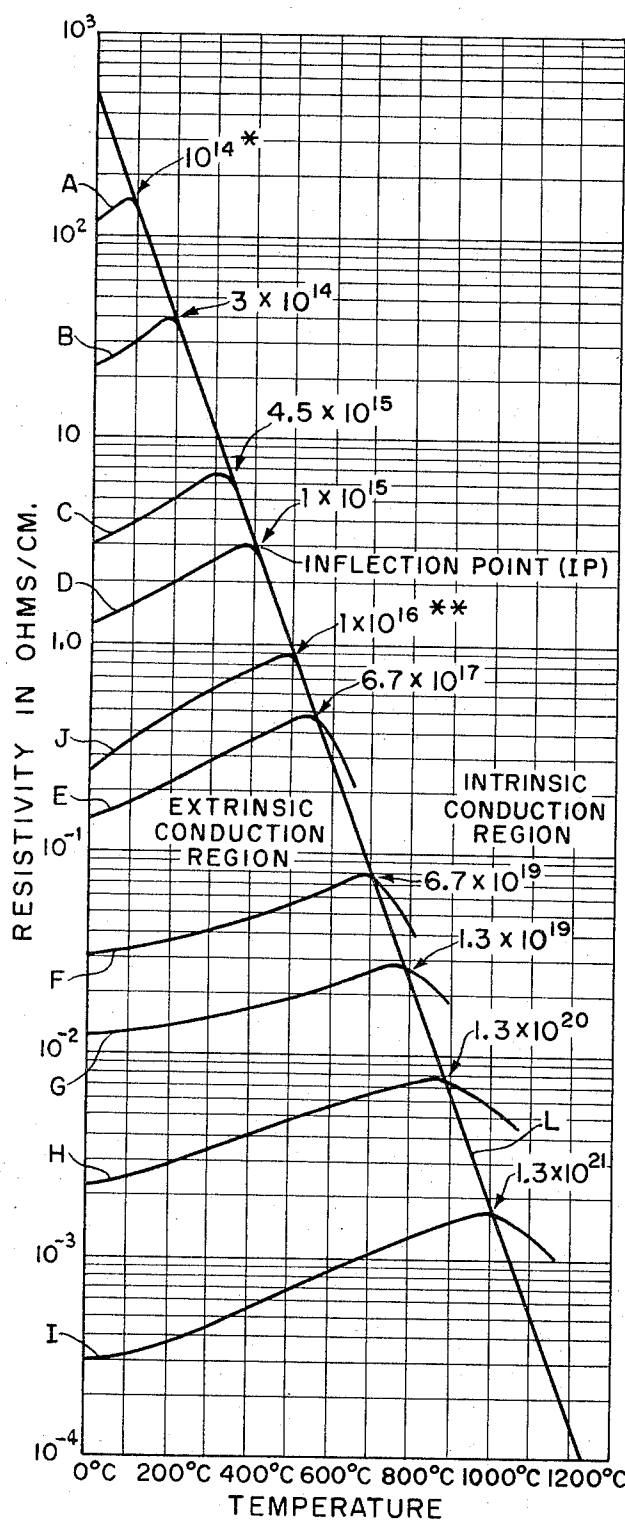


FIG. 11

A - I = p - TYPE SILICON
J = n - TYPE SILICON

* - ATOMS BORON/1CC SILICON
** - ATOMS PHOSPHOROUS/1CC SILICON

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SEMICONDUCTIVE EXPLOSIVE IGNITER
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 Filed Nov. 15, 1966, Ser. No. 594,450
 10 Claims. (Cl. 102-28)

ABSTRACT OF THE DISCLOSURE

The technical disclosure involves high explosive devices and igniters for such devices having semiconductive detonating elements. The detonating element has the characteristic of increasing in electrical resistivity when heated up to a critical point by an electric current. Then the resistivity drops sharply and the element disintegrates and releases a shock wave which detonates the high explosive.

The invention relates to explosive devices and more particularly concerns an explosive device having a semiconductive igniter for detonating a charge of a high explosive.

High explosives of which pentaerythritol tetranitrate (PETN), cyclotrimethylene trinitramine (RDX), trinitrotoluene (TNT), and trinitrophenylmethylnitramine (TETRYL) are typical, must be subjected to a shock impact of 3000 to 5000 meters per second in order to detonate them for maximum explosive effect. When properly detonated such explosives develop peak shock pressures in the order of at least 1,000,000 pounds per square inch. In order to provide the large shock impact required to produce adequate detonation effects, these high explosives must be detonated by igniters or detonators which develop sufficient detonation impacts. A primer charge or a train of a primer charge and one or more booster charges are commonly used as detonators. Priming materials, often called "first fire" materials have the property of being exploded at impacts and temperatures less than those required to set off the high explosive charges. When exploded, the primers or boosters produce shock impacts of the large magnitudes required to detonate the high explosives of the types mentioned above. Primer materials commonly used include lead styphenate, lead azide and other materials having sufficient sensitivity to initiation through application of an elevated temperature, shock, friction or electric spark. Primers are usually initiated by raising their temperature by means of an electrically heated wire, often called a "hot wire." Upon initiation, the primer applies sufficient shock impact to detonate the more stable but higher power producing main high explosive charge in an explosive cartridge or other such device. Often a train of initiating charges is necessary, wherein the primer initiates a booster charge which in turn initiates another booster charge which then initiates the high explosive. Sometimes there may be three, four or more booster charges employed between the primer and the main high explosive charge. The necessity of using primer and booster charges and the desirability of eliminating the use of such charges to set off high explosives are obvious and well known.

Numerous attempts have been made to initiate a high explosive directly without the use of any primer and booster charges. One common expedient is to use an exploding bridge wire. Such a device may require 5000 or more volts in order to create an energy plasma which detonates the high explosive. However, such a device requires a very elaborate and expensive power supply and it has serious reliability problems. Among the many disadvantages of exploding bridge wires used for detonating high explosives directly are the following:

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(1) They require a great deal of energy often applied at voltages in excess of 5000 volts for heating up to detonation temperature.

(2) The energy delivered must be far in excess of the energy required merely to melt the metallic wire elements.

(3) To insure detonation, large (often excessively large) suddenly applied magnitudes of power are required.

(4) As temperature goes up, resistance of the metal wire goes up, making it more difficult to apply the extra power required.

(5) If power is applied slowly it merely melts the bridge wire and does not vaporize it as is required for producing an explosion.

(6) The properties of the metallic wires vary widely with ambient conditions and these wires are subject to oxidation and crystallization, which renders them unreliable in use.

(7) The metallic wires are susceptible to radio frequency heating in high radar fields so that spontaneous explosions may occur.

(8) The metallic wires cannot be adequately pretested nondestructively to insure they will explode when initiated.

(9) The metallic devices are not entirely reliable. Detonation at a given instant is not always assured. Misfiring and premature firing as well as delayed firing frequently occur.

In view of the difficulties and disadvantages and of other obvious objections to primer charges, primer-booster trains, hot wire devices for initiating primer charges, and of explosive bridge wires, I have turned to other means for the purpose of providing a simple, safe, reliable and easily initiated igniter or detonator for a high explosive charge.

In the present invention, no "hot wires" or exploding bridge wires are used. All initiators for explosives employing metallic wires with thermal properties selected for a particular application such as explosion, melting, etc. have been eliminated. No fuses or fuse wires are required. No primer or booster charges are used. The invention instead provides a simple crystalline semiconductive igniter or detonator which replaces all the prior initiators.

I have discovered that it is possible to juxtapose a semiconductive igniter, comprising a properly doped semiconductive element, to a high explosive charge and to detonate the high explosive upon the application to the igniter of a low voltage. This may be as low as 10 volts A.C. or D.C. The magnitude of the voltage applied is critical. At the critical voltage the semiconductive igniter explodes releasing a shock wave of sufficient magnitude to initiate the high explosive. I have discovered that for each formulation of doped semiconductor there is a certain minimum critical initiating voltage and a critical high temperature at which initiation will occur. Also there is characteristic shock impact produced upon initiation or explosion of the semiconductive igniter.

It is known that each formulation of high explosive has a different characteristic requirement for initiation temperature and shock impact. The present invention makes it possible to match each such high explosive with a suitable detonating semiconductive igniter.

According to the invention, a particular formulation of doped semiconductive material can be specified for an igniter which will positively and reliably detonate any particular specified high explosive at a minimum applied voltage. There are many other advantages in the present semiconductive igniter:

(1) The semiconductive element used in the igniter is stronger structurally and has a higher melting point than conventional igniters.

(2) The semiconductive element can be nondestructively tested prior to detonation. This is a very valuable fea-

ture of the invention. It makes it possible to test a semi-conductive igniter both before assembly with a high explosive charge and after assembly with the charge, to determine positively the operativeness of the semiconductive igniter for detonating the high explosive charge.

(3) The unique electrical characteristics of the semiconductor can be utilized to pinpoint the temperature of the explosion or event to be initiated.

(4). The speed of response of the semiconductive igniter is faster than a hot wire or a bridge wire device.

(5) Low voltage electronic equipment can be used for initiating the semiconductive igniter.

Semiconductive materials have heretofore been used in conjunction with explosive igniters to improve their operation, but in a far different manner with vastly different results than those obtained by me. U.S. Patents 3,018,732; 3,019,732; and 3,211,096 are typical of the prior art. In every case heretofore, ignition of a primer charge is effected by an electrical flow across a gap. The semiconductor is added to obtain certain characteristics of ignition such as control of voltage or protection from stray currents. The semiconductor is merely an auxiliary to the igniter of the main explosive charge. In no case is a semiconductor utilized as the primary igniter or detonator, nor are the unusual results of the present invention obtained by any previous application of semiconductors to igniters.

A brief explanation of the basic physical principles underlying the invention will now be presented in order that the nature and mode of operation of the invention may be better understood.

There are basically two types of conduction in a semiconductor intrinsic and extrinsic. Intrinsic conduction is the thermal activation of carriers from the valence band into the conduction band. This occurs in very pure specimens of semiconductor substances where there is no interlying impurity, the atoms of which are activated at temperatures lower than the basic intrinsic band gap of the semiconductive material. The band gap for silicon material, for example, is 1.106 electron volts. Therefore, the higher the temperature the larger number of carriers are activated from the valence band to the conduction band, giving rise to a lower and lower resistance for the specimen. The resistivity (R) of a material is given by

$$R = (n_e e m_e + n_h e m_h)^{-1}$$

where n_e is the number of electrons, n_h is the number of holes in the valence band, e is the electronic charge, and m_e is the mobility of the electrons, and m_h is the mobility, or drift velocity per unit electric field for the holes. This resistivity should have a nearly $1/T_0$ temperature dependent relationship where T_0 is the absolute temperature. The temperature dependence of R (resistivity) will vary as a function of the band gap. Thus the larger the band gap, the steeper the temperature dependence of the intrinsic conductivity, which is desirable for the present semiconductive igniter.

The second type of conduction of importance is impurity conduction or extrinsic conduction, where into the basic host lattice are introduced impurity atoms which are either donors which supply excess electrons (for n-type materials), or acceptors which supply excess holes (for p-type materials). Since these acceptor and donor sites are activated by energies far smaller than the basic band gap, they are activated at much lower temperatures by virtue of the fact that the activation energy required is smaller. It is now apparent that there are two sources of carriers activated at different temperatures. At low temperatures the impurity sites contribute the majority of the carriers and are attributable to the conductivity of the material. As the temperature is raised, all the impurities of the impurity band are used up, and as the temperature is still further raised, the carriers from the valence band begin to contribute to conduction. In the region where the carriers from the impurity band are already ionized, and

in the conduction band no significant contribution from the valence band has yet been achieved, but the mobility plays a major role. The mobility also has a temperature dependence in the reverse direction; i.e., the higher the temperature, the greater the lattice vibrations and the lower the carrier mobility. For example, boron in the silicon lattice has an activation energy of the order of 0.045 electron volt and is almost completely ionized at room temperature. Therefore as the temperature is raised above this temperature, the resistance of silicon p-type will in general rise as shown in curves A-I of FIG. 11. However, at a point of inflection IP depending on the density of the boron doping, the intrinsic carriers from the valence band become predominant. From this point on the resistivity drops rapidly with temperature dependence of $1/T_0$. For n-type material in which phosphorus is the dopant the same resistivity-temperature characteristic is apparent as seen by curve J in FIG. 11.

It will be noted in curves A-J of FIG. 11 that the resistivities of all the doped semiconductors rise to the same straight line L. To the right of line L is the intrinsic conducting region. At lower temperatures to the left of line L is the extrinsic conducting region in which the resistivity depends on the impurity content and temperature of the material. Higher temperatures and decreasing amounts of boron or phosphorus cause lower resistivity. The rapid decrease of resistivity with temperature in the intrinsic range results from the increase in concentration of electrons and holes which arise from the thermal excitation of electrons from the conduction band. The point IP at which inflection occurs is precisely fixed by the relation of boron or phosphorus doping density and the energy band gap of the silicon lattice. Experimental verification of the phenomena described is to be found in "Physical Review," vol. 75, No. 5, Mar. 1, 1949, pages 865-883.

In view of the foregoing considerations I have found that useful explosive igniter devices based on the inflection point IP as the reference point, can be manufactured. The higher the doping level of the semiconductive material the higher the temperature at which this point of inflection occurs. By matching the inflection point with the autoignition temperature of any selected high explosive to be detonated, one can fabricate an igniter of semiconductive material which will predictably detonate the particular explosive selected. Depending on the desired electrical characteristics, mechanical characteristics and initiation temperature, a suitable semiconductor material can be selected. Examples for p-type and n-type silicon are presented in FIG. 11. However, other substances than silicon and other dopants can be used. For example, tellurium doped with selenium could be used. Regardless of the material selected the basic phenomena described above apply. The basic criterion of the igniter is that it have a sharp drop in resistivity at a given inflection point determined by some physical phenomena inherent in the crystalline structure. This point of inflection occurs at a temperature which is used as a reference temperature. The igniter embodying this crystalline structure can be built, tested to check this reference temperature and installed as part of an explosive device with the assurance that it will fire when the crystalline structure reaches the reference temperature. Since the crystalline structure can be non-destructively tested, a completely fabricated explosive device including an igniter according to the invention can be tested to determine positively that the device will explode when the igniter reaches the critical temperature.

It is therefore a primary object of the invention to provide an explosive device including a semiconductive explosive igniter or detonator which will detonate a high explosive directly without a primer charge.

Other objects are to provide an explosive semiconductive igniter: which is more reliable in operation than conventional igniters; which will initiate an explosion in less time with a given voltage than prior igniters so that a

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higher power shock impact wave is developed; which will detonate a high explosive at lower voltages and with less applied energy than prior igniters so that simpler power sources can be used; which is independent of ambient temperature, pressure and humidity conditions; which is not susceptible to undesired radio frequency or microwave heating and consequent spontaneous detonation; and which can be reliably pretested nondestructively.

A further object is to provide an explosive igniter employing a semiconductive crystalline structure in which detonation is effected at a predetermined critical reference temperature and critical minimum voltage, resulting in extremely rapid disintegration and vaporization of the crystalline structure and instantaneous release of stored energy.

Another object is to provide a properly formulated and conditioned solid-state material of semiconductive type including a properly selected elemental crystalline material and a properly selected dopant in correct proportions, and embodying the same in an explosive device including a high explosive charge, to serve as a detonator for the high explosive.

The invention will now be described in detail with particular reference to the drawings, wherein:

FIG. 1 is a longitudinal sectional view of an explosive device embodying the invention.

FIG. 2 is an enlarged side view partially in longitudinal section of the igniter employed in the device of FIG. 1.

FIG. 3 is an oblique top view of the igniter of FIG. 2.

FIG. 4 is a further enlarged cross sectional view taken on line 4—4 of FIG. 3.

FIG. 5 is a side view of another igniter according to the invention, which can be used in the device of FIG. 1.

FIG. 6 is a cross sectional view taken on line 6—6 of FIG. 5.

FIG. 7 is a longitudinal sectional view, with parts broken away, taken on line 7—7 of FIG. 6.

FIG. 8 is a central longitudinal sectional view of another explosive device embodying the invention.

FIG. 9 is a diagram of a circuit for testing an igniter nondestructively.

FIG. 10 is a chart of pulse diagrams used in explaining nondestructive testing of an igniter.

FIG. 11 is a chart used in explaining the invention, and showing a plurality of temperature-resistivity curves characteristic of certain semiconductive materials used in the invention.

Referring now to the drawing, there is shown in FIG. 1 an explosive device 10 of general application, for example, a squib, cartridge, etc. The device has a tubular casing 12 which may be provided with an external thread 14 for screwing into a suitable mounting. The casing has a cylindrical cavity 15 in which is a high explosive charge 16. A thin metal disk 18 closed the open end 20 of the casing. The charge 16 is adjacent to the disk which is blown out when the charge explodes. There is a ceramic block 21 at the base of the cavity. Through the block extends a pair of wires 22 covered by plastic insulation 24. The wires extend parallel to each other out of the closed end 27 of the casing. The inner ends of the wires are connected to a semi-conductive igniter 25 embedded in the high explosive charge near block 21. The igniter 25 is best shown in FIGS. 2—4. The igniter includes a plastic, glass or ceramic base plate 26 on which is applied a semiconductive element 30. This element has a thin filamentary central section 32 which is rectangular in cross section. The element terminates in wider ends 34. The wires 22 extend through holes 35 in plate 26 and terminate near ends of element 30. Solder beads 36 are applied to ends of wires 22 and to ends 34 of element 30 to constitute a direct electric circuit through the element.

The element 30 is exposed to the high explosive 16. When an electrical voltage is applied to the element 30

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through wires 22, the element will rise in resistivity and in temperature as electric current flows through it. When the element 30 reaches its critical temperature, it will suddenly drop in resistivity and will disintegrate to release a shock wave which passes through charge 16. A sufficient shock impact is developed by the exploding element 30 to detonate a high explosive such as PETN, RDX, TNT, TETRYL or other of like explosive force. Element 30 can be made by methods such as described in U.S. Patents 3,084,300 and 3,089,108, or other methods known in the art.

Element 30 has a crystalline structure and comprises a semiconductive material such as p-type silicon which is silicon doped with an impurity such as boron. The semiconductive material can be n-type silicon which is silicon doped with an impurity such as phosphorous. It can also be made of tellurium doped with an impurity such as selenium. Other semiconductive materials and dopants can be used. Regardless of the chemical constituents or elements of the semiconductive material, the principal requirement is that it have a strong crystalline structure with a conductive band structure such that it has a sharp inflection point, or point where change occurs from extrinsic to intrinsic conduction, so that resistivity decreases sharply on change to intrinsic conduction. The temperature at which the inflection point occurs and the shock impact developed must be sufficient to detonate the particular high explosive 16 selected. Since the explosive energy is released by the igniter upon firing in a time as short as a few microseconds, it will be understood that an enormous magnitude of power is released; in other words, the rate at which it dissipates energy is very large. This accounts for the spectacular effectiveness of the igniter—its instantaneous action.

A most important feature of the invention is the capability of matching any high explosive having certain shock impact and temperature detonation requirements with a semiconductive igniter having precisely the right critical temperature and shock impact releasing properties. Thus, referring again to FIG. 11, it will be noted that each semiconductive material has a different critical temperature and maximum resistivity at the temperature where inflection point IP occurs. If for example an igniter is required to fire at 700° C. to detonate a particular high explosive, the semiconductive material represented by curve F may be selected. This is p-type silicon material and comprises silicon doped with an impurity consisting of 6.7×10^{19} atoms of boron per one cc. of silicon. Other semiconductors having substantially the same resistivity-temperature characteristic could be used instead. As a further example, if the high explosive requires a detonation temperature of 500° C., an n-type silicon having a resistivity-temperature characteristic illustrated by curve J could be used.

Curves A—I of FIG. 11 cover substantially the entire range of practical resistivity-temperature characteristics since points of inflection occurring at temperatures of less than 100° C. or more than 1000° C. will rarely be required. In any event a suitable semiconductive material can be formulated for each requirement. By preparing charts similar to FIG. 11 for other semiconductors, families of resistivity-temperature characteristic curves will be available from which a suitable formulation of semiconductive material can be selected for detonating any given explosive.

FIGS. 5—7 show another igniter 25a of different structure in which parts corresponding to those of igniter 25 are identically numbered. In igniter 25a, element 30a is mounted on base plate 26a and has a filamentary central section 32a which is circular in cross section. The wires 22 extend around the ends of plate 26a rather than through the plate. The ends of wires 22 are secured by solder beads 36 to the upper surface of the wider ends 34 of the semiconductive element 30a.

The two igniter structures illustrated are only exem-

plary. Other igniter structures could be fabricated. In any case there must be provided a semiconductive element which has a section of sufficient small cross section to assume the required high resistivity at the critical inflection point when the element fires.

FIG. 8 shows another explosive device 10A embodying the invention. Parts corresponding to those of device 10 are identically numbered. As explained previously, conventional explosive devices often have a high explosive which requires a train of primer and booster charges. This is because the primer charge develops only sufficient shock-impact to detonate a booster charge which in turn detonates a more explosive booster charge, etc., until the last booster charge detonates the high explosive of the main charge. Normally a "hot wire" i.e. an electrically heated resistance wire will be used to fire the primer charge. The present invention makes it possible to dispense with the hot wire, the primer charge and with one or more of the booster charges. As shown in FIG. 8, in device 10A adjacent to the high explosive charge 16' which may be PETN, RDX, TNT, TETRYL, or the like, there may be a booster charge 40 of less explosive character made for example of a substance such as ammonium picrate. In a conventional explosive cartridge there would be further boosters of progressively less explosive force, and a primer charge of smallest explosive force. In the device 10A however, only igniter 25a is embedded in the booster charge 40. Underneath the booster charge in casing 12a is base block 21a. When a suitable low voltage is applied to wires 22, the igniter will fire and detonate the booster charge which will in turn detonate the high explosive charge. The igniter device 25a thus provides a means for simplifying considerably the structure and composition of the explosive device while increasing its reliability and decreasing its cost and the power requirements for firing. Of course igniter 25 of FIG. 2, or an equivalent igniter structure having the characteristics described herein can be used in place of igniter 25a in device 10A.

FIG. 9 shows schematically a circuit for testing a semiconductive igniter 25' nondestructively to determine its inflection and firing point so as to insure that the igniter will fire when specified minimum voltage is applied to it. A sawtooth voltage source 50 is connected at one terminal via normally open switch 52 to terminal 22a of semiconductive igniter 25'. The other terminal of the voltage source is connected to one end of a current limiting adjustable resistor 58. The other end of the resistor is connected to terminal 22b of the igniter. The sawtooth voltage source will apply a single pulse to the igniter each time switch 52 is closed. An oscillograph 60 has horizontal deflecting plates H1, H2 connected to a sweep voltage source 61, set to a sweep of about one millisecond or less. The vertical deflecting plates V1, V2 are connected to opposite ends of the resistor, since the voltage across this resistor will be proportional to the current flowing through it.

In FIG. 10, curve C1 shows the sawtooth shape of the single voltage pulse applied to the igniter when switch 52 is closed. The voltage rises from zero gradually to a maximum V' and then drops sharply to zero. Curve C2 is an oscillogram as produced by oscillograph 60. It shows the current pulse which flows through the igniter. The current rises from zero with increasing applied voltage, but not quite linearly due to the rising resistivity of the igniter as the semiconductive element of the igniter heats up. The rising resistivity is characteristic of the semiconductive element as shown by curves A-J of FIG. 11. Near the maximum applied voltage the rate of current increase drops due to the high resistance acquired by the semiconductive element which is now at a high temperature. When the voltage reaches maximum magnitude V', the semiconductive element changes from extrinsic to intrinsic conductivity. At inflection point IP, the resistivity drops sharply and the current begins to rise at

a very rapid rate. At this instant T', the voltage maximum V' has been reached and drops rapidly to zero. The current therefore also drops to zero. The appearance of sharp spike I' at instant T' is a positive indication that the semiconductive element has changed its conductive and resistive states. If the applied voltage were continued to be applied beyond instant T' as indicated by a dotted line at V'', the current would rise higher as indicated by a dotted line at I' until the semiconductive igniter exploded and released a shock wave of sufficient magnitude to detonate an adjacent high explosive.

By the arrangement described, the applied voltage is cut off before the igniter itself explodes but after it has indicated that it would explode if the applied voltage were continued. This makes it possible to test the igniter nondestructively before assembly with an explosive charge, or after such assembly as shown in FIGS. 1 and 8. This capability of being easily, quickly, economically and reliably tested nondestructively is an important advantage of the invention.

The invention thus involves a semiconductive igniter which has a number of desirable and critical features. The crystalline structure has a sharp discontinuity in its resistance-temperature characteristic. It rises in resistance with increasing temperature and then a very sharp decrease in resistance occurs. This turn-over point can be predetermined to match the temperature at which a particular explosive is to be detonated. By applying a constant voltage the crystal heats up and the current rises rapidly. Then the crystalline structure explodes and releases a shock wave of sufficient shock impact power to detonate a high explosive. FIG. 10 also illustrates what would happen if a voltage less than the critical voltage V' were applied. The resistivity and current would rise but would stop short of the inflection point IP since the igniter would dissipate the applied energy as fast as the semiconductive element heated up. Thus the semiconductive element would not reach the critical temperature at which conversion from extrinsic to intrinsic conduction takes place, and the igniter would not fire. It is apparent then that the igniter will fire only if a voltage equal or exceeding the critical voltage V' is applied for the time required to heat the semiconductive element to the inflection point. The igniter thus has the following desirable features:

(1) The igniter can detonate a high explosive directly without a primer charge.

(2) The igniter has a faster detonation response time than any conventional hot wire igniter (about ten times faster at least).

(3) The igniter uses less total energy for initiation making power supply circuitry simpler and less expensive.

(4) The igniter can be easily, quickly and economically tested nondestructively.

(5) The igniter has a precise trigger point which can be predetermined and which is reliably reproducible.

(6) The igniter is easier and simpler to fabricate in mass production quantities than conventional igniters.

(7) Due to the inherent nature of the semiconductive crystalline material, it absorbs insufficient ambient microwave and high frequency radiation to fire the igniter. Thus the danger inherent in conventional igniters where eddy current heating and undesired triggering occur, is avoided in the present semiconductive igniter.

(8) The inversion point in the temperature-resistance curve allows a precise reproducible point to be set where insufficient applied voltage and power will not fire the igniter, and higher voltage and power exceeding the critical minimums will positively result in firing the igniter.

(9) The igniter is a high efficiency device, since it requires a small, minimum power input and delivers all its energy in an instantaneous detonation.

(10) The frequency responsive of the igniter is very high as compared with conventional slow acting detonators.

What is claimed is:

1. An explosive device comprising: a container, a high explosive charge in said container, said charge being detonatable upon application of a shock impact of certain magnitude, and an igniter in contact with said charge to detonate the same; said igniter comprising a semiconductive element, and means for applying a voltage of at least a certain magnitude between spaced points of said element for causing a flow of current through said element, said element having a crystalline structure and being composed of a material including a selected pure substance doped with a selected impurity, said material having a predetermined concentration of atoms of said impurity per unit volume of said substance, the type of said substance and the type of said impurity being so selected that the crystalline structure during passage of said current therethrough rises in temperature and resistivity until the crystalline structure reaches a critical high temperature, said crystalline structure being in an extrinsic conductive state when below said critical temperature and changing to an intrinsic conductive state at said critical temperature, so that on reaching the critical temperature while application of said voltage is continued the crystalline structure drops abruptly in resistivity, disintegrates and instantaneously releases a shock wave of sufficient magnitude to detonate the high explosive charge directly.

2. An explosive device as recited in claim 1, further comprising a second high explosive charge in said container disposed adjacent to the first named explosive charge, said second high explosive charge being capable of exploding on being detonated to create a pressure of at least one million pounds per square inch, the first named explosive charge being capable of creating a sufficient shock impact to detonate the second high explosive charge when the first named explosive charge is detonated, whereby the first named explosive charge is detonated directly by said igniter and the second high explosive is detonated only by the shock impact created by the first named explosive charge on being detonated by the igniter.

3. An explosive device as recited in claim 1, capable of being tested nondestructively, wherein the concentration of said impurity in said material is so selected that upon cutting off application of said voltage when the crystalline structure reaches said critical high temperature and said current begins to rise rapidly and before the crystalline structure disintegrates, the initial rapid rise in said current is indicative of capability of said crystalline structure to change from extrinsic to intrinsic conductive state and to explode if application of said voltage were continued.

4. An explosive device as recited in claim 1, wherein the impurity in said material is selected from the group consisting of n-type and p-type impurities, wherein n-type and p-type represent respectively excess type and defect type conductivities of semiconductive material.

5. An explosive device as recited in claim 1, wherein said substance is selected from the group consisting of silicon, germanium and tellurium.

6. An explosive device as recited in claim 1, wherein said substance is silicon, and wherein the impurity is a chemical element selected from the group consisting of boron and phosphorous.

7. An igniter for a high explosive charge, comprising a support, and a semiconductive element on said support arranged for disposition directly adjacent to said high explosive charge, and means for applying a voltage of at least a certain magnitude between spaced points of said element for causing a flow of current through said element, said element having a crystalline structure and being composed of a material including a selected pure substance doped with a selected impurity, said material having a predetermined concentration of atoms of said impurity per unit volume of said substance, the type of said substance and the type of said impurity being so selected that the crystalline structure during passage of said current therethrough rises in temperature and resistivity until the crystalline structure reaches a critical high temperature, said crystalline structure being in an extrinsic conductive state when below said critical temperature and changing to an intrinsic conductive state at said critical temperature, so that on reaching the critical temperature while application of said voltage is continued the crystalline structure drops abruptly in resistivity, disintegrates and instantaneously releases a shock wave of sufficient magnitude to detonate the high explosive charge directly.

8. An igniter as recited in claim 7, wherein the impurity in said material is selected from the group consisting of n-type and p-type impurities, wherein n-type and p-type represent respectively excess type and defect type conductivities of semiconductive material.

9. An igniter as recited in claim 7, wherein said substance is silicon, and wherein the impurity is a chemical element selected from the group consisting of boron and phosphorous.

10. An igniter as recited in claim 7, wherein said structure has a section of filamentary form between said spaced points.

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