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INITIATOR WITH A P-N PELTIER THERMO-ELECTRIC EFFECT JUNCTION

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This invention relates to improvements in electric firing initiating devices and, more particularly, to electric initiators which are highly resistant to premature firing by alternating current including current induced by radio frequency radiations.

The invention relates to electrical firing initiating devices which generally include a casing in which is disposed a heater device in contact with a heat sensitive ignition composition or matchhead, which, in turn, is embedded in or located adjacent an explosive charge.

Electrical firing initiating devices are commonly employed to initiate various explosive compositions used in conventional blasting caps, in ordnance applications and as igniters for reaction motors of the liquid, gas or solid propellant types. In general, such initiators are designed to be actuated by direct current. The art has long recognized the dangers inherent in premature discharge of electric initiators by accidentally induced alternating currents and this danger is particularly acute in the application of such devices to space vehicles where radio frequency initiated guiding systems and control means are employed together with electrical firing initiating devices.

It is, therefore, a primary object of this invention to provide a direct current initiated electric initiator safeguarded against premature or accidental initiation by alternating currents induced therein.

A further object is to provide improved alternating current protected electric initiators without substantially reducing the degree of sensitivity of the electric initiator to initiation by direct current of a predetermined polarity.

Another object is to provide an improved method of making components for electric firing initiating devices and, in particular, to compacted semiconductor elements.

These and other objects and advantages are provided by an electric initiator safeguarded against premature ignition by alternating current induced therein which generally comprises a pair of electrical conductors selectively connectable at one end to a source of firing initiating direct current of predetermined polarity, semiconductor means having a P-N junction electrically connected to the pair of electrical conductors, a heat sensitive ignition composition in heat exchange relationship to the P-N junction of the semiconductor means, and heat absorbing means in contact with the semiconductor means and remote from the heat sensitive ignition composition and the P-N junction.

The invention will be more particularly described with reference to the illustrated embodiments thereof shown in the accompanying drawings wherein:

FIG. 1 is a schematic diagram of an electric initiator embodying the principles of the present invention; and

FIG. 2 is a fragmentary diagrammatic view of apparatus suitable for construction of the semiconductor employed in the electrical initiator illustrated in FIG. 1.

It is known when direct current is passed through a junction of dissimilar materials such as P-type and N-type semiconductors, Peltier heating or cooling occurs at the junction depending on the direction of current flow. This heating or cooling is in addition to ordinary Joule heating which also occurs regardless of the direction of current flow. When alternating current is passed through

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such a junction substantially only Joule heating occurs.

If no Joule heating occurs at the junction of the dissimilar materials when alternating current is passed through the junction, an absolutely alternating current proof electric initiator could be devised. However, Joule heating occurs thus requiring a modification in the design of electrical initiators employing semiconductor means to take into account the following requirements which oppose each other: the P-N junction of the semiconductor means which is in heat exchange relationship to a heat sensitive ignition composition, for many applications, must be brought to the ignition temperature of the heat sensitive composition within a few milliseconds by the application of a reasonable direct current of the proper polarity; and the electrical initiator must tolerate relatively high alternating currents without developing sufficient Joule heat to bring the heat sensitive ignition composition to its ignition temperature.

These requirements are satisfactorily met in a thermoelectric initiator wherein the semiconductor means having the P-N junction is of small cross-section and the free ends of the semiconductor means are connected to heat absorbing masses or heat sinks.

The principles of the invention will be more readily apparent to those skilled in the art from the following detailed discussion of the invention when referenced to FIG. 1 of the drawings, wherein 10 generally designates an improved electric initiator constructed in accordance with the teachings of the present invention. The electric initiator 10 may include a pair of dissimilar materials 14 and 16 interconnected along faces A and A' to provide a junction, or the junction may be provided in a single semiconductor crystal as is known in the art.

The dissimilar materials may comprise P-type and N-type semiconductors 14 and 16 maintained in contact with each other or connected together by a suitable electrical conductive connector 18. The opposite faces B and B' of the semiconductors are in contact with heat absorbing masses 20 and 22, the free ends of which are connected to electrical conductors 24 and 26 which, in turn, are connected to a suitable source of properly polarized direct current generally designated 28. Switch means generally designated 30 are provided in one of the conductors 24 or 26 or both for selectively connecting the initiator to the initiating source of current.

A sensitive initiator composition 32 is maintained in heat exchange relationship to the P-N junction or the connector 18 where an electrical conductive connector is employed in the device. Further, the initiator includes a jacket or casing 34 which surrounds at least the junction portion of the semiconductor means and maintains a suitable explosive composition 36 in contact with the heat sensitive initiator 32.

The junction forming materials 14 and 16 may comprise suitable P and N doped lead or bismuth tellurides, doped mixtures of bismuth telluride with antimony telluride, doped bismuth selenide, strontium titanate, germanium, and the like. Semiconductors having high Peltier coefficients are preferred and particularly good results have been obtained with the lead and bismuth tellurides.

Where the P-N junction is provided by connecting together P and N type semiconductors and an electrical conductive material 18 is inserted at the junction, the electrical conductive material may comprise a conductive silver epoxy adhesive, a bismuth-tin solder, a gallium-copper amalgam, a fine mesh metallic powder and the like.

The heat conductive members or heat sinks 20 and 22 may comprise any good heat and electrical conductive material such as copper, aluminum, silver and the like.

The primer spot, matchhead, or heat sensitive initiator

composition 32 may comprise mercury fulminate or, for example, lead azide.

The casing 34 may be constructed of metal, plastic or other material and where an electrical conductive material is employed for the casing 34, the casing is insulated from the pair of electrical conductive heat sinks 20 and 22 by insulating means 38.

In the assembly of devices of the type described it is desirable to maximize the ratio of the maximum tolerable steady state alternating current to the minimum direct current for ignition of the explosive composition in, for example, 10 milliseconds. In general, for a given voltage drop between faces B and B' of the semiconductors, both the generation of Joule heat and the rate of heat conduction to the heat sinks 20 and 22 vary inversely with the thickness of the semiconductors. However, for a predetermined current, the Peltier heat developed in the unit is generally independent of the thickness of the semiconductor elements and the rate of heat conduction to the heat sinks 20 and 22 during the transient period is always less than the heat conduction to the sinks during the steady state condition. Therefore, it has been found desirable to maintain the semiconductors 14 and 16 relatively thin. Decreasing the thickness of the semiconductors has a substantial effect on the magnitude of the alternating current required to produce a given temperature rise at the junction since for a given temperature the rate of heat conduction to the heat sinks 20 and 22 is inversely proportional to the distance the heat must flow.

Semiconductor segments 14 and 16 of from about .01 to, for example, .08 cm. in thickness and of about 1/4 inch to, for example, 3/16 inch in diameter have been found to provide very satisfactory results. Using semiconductors within this range, copper heat sinks 20 and 22 of about 1/4 inch in length and from 1/4 inch to about 1/16 inch in diameter will provide protection through a substantial range of frequencies where the required temperature rise for initiation of the igniter is in the order of about 200° C. and this temperature is to be developed by the application of a predetermined polarity direct current in not more than about 10 milliseconds.

Example

Commercial doped P- and N-type bismuth telluride semiconductor stock was sliced into thin segments about .05 cm. in thickness and about .16 cm.² in cross-sectional area. A pair of sliced segments were bonded together with a bismuth-tin solder and heat sinks were soldered to the opposite faces of the semiconductors with each of the heat sinks comprising a bar of copper .16 cm.² in cross-section and about 0.6 cm. in length. For test purposes a thermocouple was attached to the bismuth-tin solder connection between the P- and N-junction of the semiconductors and connected to recording apparatus. It was found that it required approximately twice as much alternating current as polarized direct current to produce a steady state temperature rise of 200° C. above ambient at the junction.

The device was found to require approximately 40 amp. of direct current to raise the temperature at the junction 200° C. above ambient in .08 second.

The device was tested employing as the alternating current source both 2 megacycle and 60 cycle currents.

Slicing and surface finishing the semiconductor wafers for the initiator was found to be tedious and the thin segments were subject to falling apart when the segmentation was perpendicular to the crystalline laminates of the semiconductor stock. It was discovered that satisfactory semiconductors could be very conveniently produced by compressing fragments of the semiconductive material into the cross-sectional shape and thickness desired in the completed unit with no loss of the thermoelectric qualities of the semiconductor material.

Referring to FIG. 2, a method of producing compacted semiconductor units is diagrammatically illustrated. In

FIG. 2 there is illustrated a press 50 comprising a movable ram member 52 and a die block 54 having a depression 56 formed in a surface thereof of a dimension corresponding to the dimension of the desired semiconductor pellet. Into the depression 56 is placed a fine granular doped semiconductor material 58, such as lead or bismuth telluride, and the material is compressed at pressures in the order of at least about 50,000 p.s.i. and preferably about 100,000 p.s.i. applied by conventional press means in the direction of the directional arrow. The compressed pellet was removed from the depression 56 by applying pressure to the slide block 62, the top surface of which forms the base of depression in the die block 54.

The semiconductor pellet may be formed about an electrical conductor illustrated at 60 during the formation of the compacted wafer. Where a conductor is desired in the semiconductor unit the conductor 60 may be led into the cavity or depression 56 through a bore in the slide block 62. It is also contemplated that the heat sinks 20 and 22 may be formed with undercut notches or grooves and that the fine granular semiconductor material 58 may be compressed into the notches or grooves to provide a bond between the semiconductors and their heat sinks.

Example

Fragments of doped bismuth telluride were placed in a depression 1/4 inch in diameter and approximately 0.3 cm. in depth. Enough of bismuth telluride was placed in the cavity to provide a compacted semiconductor unit approximately .05 cm. in thickness and 1/4 inch in diameter. The fragmentary semiconductor material was placed under compression at a pressure in the order of 100,000 p.s.i. and the resulting pressed units were found to have better strength characteristics than the original material without apparent loss in thermoelectric characteristics.

From the foregoing description, it will be readily apparent to those skilled in the art that the present invention fully accomplishes the aims and objects hereinabove set forth. Those skilled in the art will also appreciate that modifications may be made in the disclosed form of the invention without departing from the scope of the appended claims. For example, the initiator illustrated in FIG. 1 may be further improved by providing radio frequency shielding about the initiator to reduce the induction of radio frequency energy to the semiconductors. Further, the method of making the compacted semiconductor units may be applied to the formation of various shapes of semiconductors and for the formation of P-N junctions between dissimilar semiconductor materials by compacting multiple layers of fragments of N-type and P-type semiconductors into a single element.

We claim:

1. An electric initiator assembly comprising a pair of electrical conductors selectively connectable at one end to a source of initiating direct current, semiconductor means having a P-N Peltier thermoelectric effect junction electrically connected to the pair of electrical conductors in series with the source of direct current, a heat sensitive ignition composition in heat exchange relationship to the P-N junction of the semiconductor means, and heat absorbing means in contact with the semiconductor means and extending in a direction remote from the heat sensitive ignition composition and the P-N junction.

2. An electric initiator assembly comprising a pair of electrical conductors selectively connected at one end to a source of firing initiating direct current, a P-type semiconductor electrically connected to the opposite end of one of the pair of electrical conductors, an N-type semiconductor electrically connected to the opposite end of the other of the pair of electrical conductors and forming a Peltier thermoelectric effect junction with said P-type semiconductor, a heat sensitive ignition composition in heat exchange relationship to the P-N junction,

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and heat absorbing means in contact with the P- and N-type semiconductors and extending in a direction remote from the heat sensitive ignition composition and the P-N junction.

3. An electric initiator assembly comprising a pair of electrical conductors selectively connectable at one end to a source of firing initiating direct current, a P-type semiconductor electrically connected to the opposite end of one of the pair of electrical conductors, an N-type semiconductor electrically connected to the opposite end of the other of the pair of conductors and forming a Peltier thermoelectric effect junction with said P-type semiconductor, a heat sensitive ignition composition in heat exchange relationship to the junction between the P- and N-type semiconductors, and heat absorbing means in contact with the P- and N-type semiconductors and extending in a direction remote from the heat sensitive ignition composition.

4. An electric initiator assembly comprising semiconductor means having a P-N Peltier thermoelectric effect junction, a heat sensitive ignition composition in heat exchange relationship to said P-N junction, heat absorbing means in contact with the semiconductor means and extending in a direction remote from the heat sensitive ignition composition and the P-N junction, and electrical conductor means for selectively connecting a source of firing initiating current to said semiconductor means.

5. A Peltier thermoelectric effect electric initiator assembly comprising a P-type semiconductor, an electrical conductive element interconnecting said P- and N-type semiconductors, a heat sensitive ignition composition in heat exchange relationship to said electrical conductive element, a metallic heat absorbing member connected to the free end of the P-type semiconductor, a metallic heat absorbing member connected to the free end of the N-type semiconductor, and electrical conductor means for selectively connecting the free ends of said metallic heat absorbing members to a source of firing initiating direct current.

6. An electric initiator assembly comprising a pair of electrical conductors selectively connectable at one end to a source of firing initiating direct current, a compacted P-type semiconductor electrically connected to the opposite end of one of the pair of electrical conductors, a compacted N-type semiconductor electrically connected to the opposite end of the other of the pair of electrical conductors and forming a P-N Peltier thermoelectric effect junction with the P-type semiconductor, a heat sensitive ignition composition in heat exchange relationship to the P-N junction, and heat absorbing means in contact with the compacted N- and P-type semiconductors and extending in a direction remote from the heat sensitive ignition composition and the P-N junction.

7. An electric initiator assembly comprising a pair of

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electrical conductors selectively connectable at one end to a source of firing initiating direct current, a compacted P-type bismuth telluride semiconductor electrically connected to the opposite end of one of the pair of electrical conductors, a compacted N-type bismuth telluride semiconductor electrically connected to the opposite end of the other of the pair of electrical conductors and forming a P-N Peltier thermoelectric effect junction with the P-type semiconductor, a heat sensitive ignition composition in heat exchange relationship to the P-N junction, and heat absorbing means in contact with the compacted N- and P-type semiconductors and extending in a direction remote from the heat sensitive ignition composition and the P-N junction.

8. An electric initiator assembly comprising a pair of electrical conductors selectively connectable at one end to a source of firing initiating direct current, a compacted P-type lead telluride semiconductor electrically connected to the opposite end of one of the pair of electrical conductors, a compacted N-type lead telluride semiconductor electrically connected to the opposite end of the other of the pair of electrical conductors and forming with the P-type semiconductor a P-N Peltier thermoelectric effect junction, a heat sensitive ignition composition in heat exchange relationship to the P-N junction, and heat absorbing means in contact with the compacted N- and P-type semiconductors and extending in a direction remote from the heat sensitive ignition composition and the P-N junction.

9. An electric initiator assembly comprising a pair of electrical conductors selectively connectable at one end to a source of initiating direct current, compacted semiconductor means having a P-N Peltier thermoelectric effect junction electrically connected to the pair of electrical conductors, a heat sensitive ignition composition in heat exchange relationship to the P-N junction of the compacted semiconductor means, and heat absorbing means in contact with the compacted semiconductor means and extending in a direction remote from the heat sensitive ignition composition and the P-N junction.

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