

The present invention relates to a pyrotechnic detonator having coaxial connections, of the projected-layer type.

5 Such detonators (also known by the name "slapper-detonator" or "Exploding Foil Initiator") may be used especially to trigger the operation of warheads or of motors of rockets, of missiles and of any other guided projectile, or of gas generators (in this case, the detonators are called igniters because of their use).

10 In the field of detonation, that is to say the explosives field, solid warheads may be initiated, for example, by a violent projection of a material onto an intermediate charge so that the impact of the material on the intermediate charge causes initiation of the latter.
15 The projection of the material is caused by the explosion of a vaporizable metallic film generally obtained by two different methods:

- either by the flow of an electric current pulse;

20 - or the absorption of a pulse of light energy generated by a laser.

The invention relates more particularly to the first type of method, in which use is made of a conductor element on which has been placed the material which is to
25 be projected. In order to trigger the operation, an electrical discharge, of very short duration but of very high intensity, is sent into the electrical element. The material is then projected against the intermediate charge and causes its initiation.

30 A first category of this type of detonator, described in French Patent Application No. 87 08813 filed on 23 June 1987, is equipped with an electrical element consisting of two strands connected at their end and placed sufficiently close to each other in order to
35 constitute a low-inductance conductor. This electrical element leaves at least one of the walls of the device laterally in order to be connected to an external electrical supply. This flat connection is difficult to make and is very fragile. Moreover, the embodiment of

such a system raises integration, size, impermeability and hermeticity problems.

Another category of detonators, described in the same patent application, possesses an electrical element whose supply is produced using two electrodes placed perpendicularly with respect to the electrical element. In this system, the size, even if it is small compared to the embodiment of the first type of detonator, is still large. There are also impermeability and hermeticity problems which are not solved in this system and which can encourage events tending to cause the system to deteriorate, for example corrosion of the conductor element.

In order to remedy this situation, the Applicant Company has provided, in French Patent Application No. 89 07675 filed on 9 June 1989 (FR-A-2,648,223), a projected-layer pyrotechnic detonator or igniter having coaxial cylindrical connections. Such a structure has many advantages, especially the impermeability of the fusible part allowing prolonged storage, a rigid construction, quite a simple assembly and manufacture, and a relatively low cost. Such an igniter remedies the drawbacks mentioned above.

The subject of the present invention is a detonator stemming from the same principles, but appreciably improving the previous device, especially from the standpoint of simplicity, ruggedness and cost, by virtue of a lighter and more compact structure.

According to the invention, a pyrotechnic detonator having coaxial connections, such as that defined by Claims 1 to 16, is therefore provided.

According to another aspect of the invention, provision is also made for a method of fitting a detonator, such as one provided hereinabove, characterized in that it comprises the steps consisting in:

- assembling the socket and a sealing cylinder by high-temperature soldering of the cylinder to the metallized inner surface of the socket;
- assembling the socket and a flanged ring by

low-temperature soldering of the ring to the metallized outer lateral surface of the socket;

- soldering the said assembled socket to the said [sic] anvil by means of the flange of the ring;

5 - fitting the said [sic] flexible cylindrical contact piece over the said outer lateral surface of the socket;

10 - installing in succession, inside the socket, the said layer of material, the barrel and the said [sic] pyrotechnic means; and

- sealing the whole unit by means of a cap with compression of the said elements installed in the socket, by laser welding the said cap to the sealing cylinder.

15 The invention will be better understood and other characteristics and advantages will appear with the aid of the description hereinbelow and of the appended drawings in which:

- Figure 1 shows, seen in section, a first embodiment of a detonator according to the invention;

20 - Figure 2 is a view from above of the anvil of the detonator of Figure 1; and

- Figure 3 is a sectional view of a second embodiment of an element of the detonator according to the invention.

25 The detonator according to the invention is a projected-layer detonator (or "slapper detonator" or EFI ["Exploding Foil Initiator"]). It includes in a known manner, as was briefly indicated previously, an electrical circuit such that a current pulse of a few thousands of amps, generated in a few tens of nanoseconds, 30 causes volatilization of part of a metallic conductor (fusible bridge) and formation of a metal plasma. The extremely violent expansion of the confined metal plasma is used to project, onto the face of a secondary explosive charge, a projectile consisting of a plastic disc of 35 a few tens of micrometres in thickness and of a diameter of the order of one millimetre. The secondary explosive charge of the detonator is caused to detonate by the impact of the projectile on the explosive with a very high impact velocity.

Figure 1 represents in section one embodiment of a detonator according to the invention, based on these operating principles. This detonator essentially comprises a cylindrical metallized anvil 1 carrying a fusible bridge 112, an axisymmetrical socket 2 made of dielectric material, electrical projected-layer actuation means comprising the fusible bridge, a layer of material 13 and a mechanical confinement obtained by means of a barrel 3 which includes a hole 30, pyrotechnic means 4, 5, 6 and a cap 8 sealing the assembly. The socket/anvil assembly is assembled by means of a piece 12 in the form of a flanged cylindrical ring.

The anvil 1 is, for example, a cylindrical piece made of alumina which includes, on its bottom, a conducting surface 10 in the form, for example, of a disc, serving as an electrical contact zone. Formed on the opposite face of the anvil 1, as represented in Figure 2, is the fusible bridge 112, an end 111 of which is connected to a peripheral circular conducting surface 110 and the other end of which is connected to the conducting contact surface 10 via at least one hermetic electrical feed-through 14 constituted, for example, by a plated-through hole filled or closed off by a conductor element. The combination 11 of the conducting surface 110 and the fusible bridge 111, 112 is obtained, for example, by metallization.

The socket 2 (Figure 1) is an axisymmetrical piece, for example made of alumina, having a cylindrical body and a guide shoulder 20. The socket 2 is connected to the anvil 1 via the flanged cylindrical ring 12, for example by soldering, the flange being soldered to the surface 110 of the anvil 1. The upper (in the position shown in Figure 1) face of the guide shoulder 20 carries a bearing surface 21 intended to transmit the necessary contact pressure to the plane connection 10 of the detonator with an external housing, not shown. A sealing cylinder 7 is fixed, for example by soldering, in the opening of the socket 2 on the side where the shoulder 20 is. This cylinder may, especially, be made of stainless

steel.

Inside the socket 2 is arranged a disc of material 13, for example made of polyimide, (the disc is known as a "flyer"). This disc is held in place against the fusible bridge on the anvil 1 by the barrel 3 which may also be made of alumina.

The pyrotechnic means are constituted by a cylindrical case 4, made of stainless steel for example, in which an explosive charge composed of two secondary explosives 5 and 6 is contained.

The assembly formed by the material 13, the barrel 3 and the pyrotechnic means 4, 5, 6 is put into compression against the anvil 1 by virtue of the cap 8 fastened to the sealing cylinder 7.

A flexible cylindrical contact piece 9 is arranged around the body of the socket 2 and of the cylindrical ring 12. This piece 9 comprises a cylindrical part, in contact with or soldered to the ring 12, and bent-over flexible blades. The piece 9 is therefore electrically connected to the end 111 of the fusible bridge via the ring 12 and the conducting surface 110 on the anvil 1.

As may be seen, the assembled detonator may be very easily inserted into a cylindrical housing which includes, at the bottom and on its inner side face, two conducting surfaces constituting the electrical supply inputs for the initiation system, and which are in contact respectively with the contact surface 10 and the blades of the piece 9 of the detonator. The detonator may also be very easily removed from the housing, for example in order to carry out tests.

The production of each of the main components of the detonator according to the invention will now be described more precisely.

The anvil 1 is obtained from a large-sized substrate made of alumina. The substrate is drilled with holes which are plugged with copper in order to produce the impermeable feed-throughs 14. In order to plug these holes, it is possible either to solder a copper pin in

each hole after the internal surface of the holes has been metallized, or to fill the holes with a screen-printing paste, using suction. After grinding both faces of the alumina substrate, these are metallized using sputtering. Firstly, a chromium bonding layer of a few tens of nanometres and then a copper layer of a few micrometres may be deposited on the side where the fusible circuit is. On the opposite face, the metallization preferably includes, in addition, a gold layer of a few micrometres in order to protect the contacts 10. The desired geometry for the circuits on the two faces is then obtained using chemical etching. Finally, each anvil is cut out from the substrate using a laser. The socket 2 is also made of alumina, which may be machined from a solid piece or obtained by sintering and then grinding. The socket is metallized on its external side face and on its internal diameter level with the guide shoulder.

The sealing cylinder 7 is high-temperature soldered to the socket and then the flanged ring 12 is low-temperature soldered to the socket.

The cylindrical contact piece 9 may be obtained from a strip made of copper-beryllium alloy from which the contact blades are cut out. The blades are then bent over, by forming, and then the strip is wound and cut to the correct length. The open annulus thus obtained is annealed in order to stabilize its mechanical properties, especially its elasticity. It may also be gold-plated in order to ensure better corrosion resistance.

The pyrotechnic means comprise a cylindrical case 4 made of stainless steel in which the explosive charge is arranged. The latter comprises a first secondary explosive 6 which receives the impact of the plastic projectile and may be made of hexanitrostilbene. Its detonation is reinforced by a second secondary explosive 5 which may be of RDX wax for example. These two explosives are loaded into the case 4 with compression to a constant height. Of course, the use of two secondary explosives is given only by way of example.

The detonator according to the invention is fitted in two steps: assembly of the inert body (anvil, socket, contact piece, sealing cylinder) and then fitting of the plastic material 13, the barrel and the loaded case, and sealing the assembly by means of the cap.

During the first step, the sealing cylinder 7 is firstly high-temperature soldered to the socket 2 and then the cylindrical ring 12 is low-temperature soldered to the socket. Next, the assembly is soldered to the metallized anvil (soldering of the flange of the ring 12 to the surface 110). Next, the cylindrical contact piece 9 (open annulus) is transferred onto the body of the socket 2 and of the ring 12 where it is held in contact simply by virtue of its elasticity or by soldering.

During the second step, the disc of plastic material 13, the barrel 3 and the charged case 4 are inserted in succession into the assembly assembled during the first step. The cap 8 fits over the assembly and ensures sufficient compression of the elements 13, 3 and 4, 5, 6 against the anvil 1 in order to confine the copper plasma during the operation of the detonator. The cap 8 is fastened to the sealing cylinder 7 by laser welding.

By virtue of the compression of the elements 13, 3 and 4, 5, 6 by the cap 8, any play, especially in the charged case 4, is prevented and therefore excellent vibration resistance of the detonator [sic].

Moreover, one of the major advantages of the detonator according to the invention is total hermeticity. This hermeticity is ensured by the soldered joints of the ring 12 to the anvil 1 and the socket 2, of the sealing cylinder 7 to the socket 2, by the laser weld of the cap 8 to the cylinder 7 and by the hermetic electrical feed-throughs 14. The active parts of the detonator (fusible bridge 112, plastic material 13 and explosive charge 4, 5, 6) are thus protected from corrosion and ageing due to the ambient atmosphere, thereby allowing prolonged storage.

As was already mentioned, the design of the

detonator enables it to be easily installed and dismantled, thereby allowing maintenance and test operations to be performed on the electronic firing means.

5 The light weight of the detonator and its particularly compact design make it capable of withstanding the mechanical stresses that it is liable to encounter in various types of munitions.

10 Another major advantage of the detonator according to the invention is the possibility of automating its manufacture, and therefore of reducing its cost.

15 With this objective in mind, namely to reduce the manufacturing costs, an alternative embodiment of the socket has been shown in Figure 3. In Figure 3, the socket 2', the sealing cylinder 7' and the ring 12' are produced and assembled in a single operation. To do this, the socket 2' is produced from a plastic material, by injection moulding, the cylinder 7' and the ring 12' being inserts embedded in the socket.

20 Figure 3 shows, by way of example, possible shapes for the ring 12', bent over inwards at 120 on the opposite side to the flange, and for the cylinder 7' which includes outward protuberances 70 in the region where it is inserted into the socket 2'. The latter includes, as in the socket 2 of Figure 1, a guide shoulder 20' with a bearing surface 21'. The socket 2', together with the cylinder 7' and the ring 12', fulfils exactly the same functions as the alumina socket 2 assembled with the sealing cylinder 7 and the ring 12 of Figure 1.

30 The socket 2' may be made of a high-performance polymer material, for example by injection moulding a polyetheretherketone (PEEK) filled with glass fibres for good mechanical strength. Glass-fibre-filled polyethersulphone (PES) may also be used. The material chosen must withstand high temperatures (200°C minimum) and be impermeable, even when it is thin.

35 Likewise, the anvil 1 may be produced with the same materials, using the same technique. In this case,

the impermeable feed-throughs 14 and the plane contact surface 10 are then produced in the form of inserts. Only the fusible circuit and the conducting surface 110 are produced by sputtering and chemical etching.

5 The manufacture of the detonator according to the invention, with an anvil and a socket made of plastic is even more economical, while at the same time keeping the advantages already mentioned hereinabove.

10 Of course, the embodiment examples described in no way limit the invention. Without departing from the scope of the invention, it is conceivable, especially, to use a completely cylindrical socket, the piece 9, however, having to be soldered to the ring 12 or 12'.



CLAIMS

1. Pyrotechnic detonator having coaxial connections, including:

5 - projected-layer electrical actuation means composed of a barrel (3, 30), of a first cylindrical element (1) made of insulating material forming an anvil and of an assembly consisting of a fusible bridge (111, 112), on which is positioned a thin layer of a material (13), this fusible bridge being placed between the first
10 cylindrical element (1) and the barrel (3, 30);

- electrical supply means for the said actuation means, comprising at least one conducting surface (10) arranged on the bottom of the anvil (1) and hermetic electrical feed-through means (14) connecting the said
15 conducting surface (10) and one end of the said fusible bridge (111, 112) through the said anvil;

- pyrotechnic means (4, 5, 6) triggered by the said projected-layer electrical actuation means; and

- a second cylindrical element (2; 2') made of
20 insulating material, forming a socket, and hermetic assembly means between the socket and the anvil; the said detonator being characterized in that the said socket has one end bearing on the said anvil (1) and another end including a guide shoulder (20; 20'), in that
25 there is furthermore provided a flexible cylindrical contact piece (9) wound around the said socket between the said shoulder and the circular edge of the anvil and in that there are provided means (7, 8; 7') for hermetically sealing the said detonator, which means are fixed
30 at that end of the said socket (2; 2') carrying the said shoulder (20; 20') and keeping the pyrotechnic means (4, 5, 6), inside the socket, against the said barrel (3, 30).

2. Detonator according to Claim 1, characterized in
35 that the said hermetic assembly means comprise a flanged cylindrical metal ring (12; 12') fixed to the cylindrical body of the socket (2; 2') and to that surface of the anvil (1) carrying the said fusible bridge.



3. Detonator according to Claim 2, characterized in that that surface of the said anvil (1) carrying the fusible bridge includes a peripheral circular conducting surface (110), the side (111) of the fusible bridge not
5 connected to the said electrical feed-through means (14) being connected to the said conducting surface (110), and in that the said fusible bridge (111, 112) and the said conducting surface (110) are formed by a metallic layer deposited on the said anvil (1).

10 4. Detonator according to Claim 3, characterized in that the said metal ring (12) is soldered to the said circular conducting surface (110) and to the said socket (2) whose lateral surface has been metallized.

5. Detonator according to any one of Claims 1 to 4,
15 characterized in that the said hermetic sealing means comprise a sealing cylinder (7; 7') fixed in the opening of the socket (2) at the guide shoulder (20; 20') and a cap (8) fitting over the said sealing cylinder and the said pyrotechnic means contained in the said socket (2)
20 extended by the said cylinder (7; 7'), and soldered to the latter, so as to press the said pyrotechnic means, the said barrel and the said material (13) against the said anvil (1).

6. Detonator according to Claim 5, characterized in
25 that the said pyrotechnic means comprise a cylindrical case (4) in which an explosive charge (5, 6) is compressed.

7. Detonator according to Claim 6, characterized in that the said case is made of stainless steel.

30 8. Detonator according to any one of Claims 5 to 7, characterized in that the said sealing cylinder (7) is soldered to the said socket (2) whose inner surface has been metallized at its end on the guide shoulder (20) side.

35 9. Detonator according to any one of Claims 1 to 8, characterized in that the socket (2) and the anvil (1) are made of alumina.

10. Detonator according to any one of Claims 1 to 3 or 5 to 7, characterized in that the said socket (2') is



made of a plastic and in that the said ring (12') and the said sealing cylinder (7') are produced in the form of inserts embedded in the socket, the said ring (12') being soldered to the said anvil (1).

- 5 11. Detonator according to any one of Claims 1 to 10, characterized in that the said anvil (1) is made of a plastic and in that the said hermetic feed-through means (14) and the said conducting surface (10) on the bottom of the anvil are produced in the form of inserts.
- 10 12. Detonator according to either of Claims 10 and 11, characterized in that the said plastic is a glass-fibre-filled polyetheretherketone.
13. Detonator according to either of Claims 10 and 11, characterized in that the said plastic is a glass-
- 15 fibre-filled polyethersulphone.
14. Detonator according to any one of Claims 1 to 13, characterized in that the said flexible cylindrical contact piece (9) is wound around the said ring (12) and in electrical contact with it.
- 20 15. Detonator according to Claim 14, characterized in that the said contact piece (9) is soldered to the outer cylindrical surface of the said ring (12).
16. Detonator according to any one of Claims 1 to 15, characterized in that the said guide shoulder (20; 20')
- 25 of the socket (2; 2') possesses, on its face on the opposite side from the anvil (1), a bearing surface (21; 21') for transmitting the contact pressure necessary for connecting the said detonator via the said conducting surface (10) on the bottom of the anvil.
- 30 17. Method of fitting a pyrotechnic detonator having coaxial connections, according to any one of Claims 1 to 9 or 14 to 16, characterized in that it comprises the steps consisting in:
- assembling the socket (2) and the sealing
 - 35 cylinder (7) by high-temperature soldering of the cylinder to the metallized inner surface of the socket;
 - assembling the socket (2) and the flanged ring (12) by low-temperature soldering of the ring to the metallized outer lateral surface of the socket;



- soldering the said assembled socket to the said anvil (1) by means of the flange of the ring (12);

- fitting the said flexible cylindrical contact piece (9) over the said outer lateral surface of the socket (2);

- installing in succession, inside the socket, the said layer of material (13), the barrel (3, 30) and the said pyrotechnic means (4, 5, 6); and

- sealing the whole unit by means of the cap (8) with compression of the said elements installed in the socket, by laser welding the said cap to the sealing cylinder (7).