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(71) Applicant: **ISRAEL MILITARY INDUSTRIES LTD.**
**Ramat Hasharon 47100 (IL)**

(72) Inventors:
- **Zeldin, Oran**
  **Holon 58320 (IL)**
- **Mamane, Albert**
  **Netanya 42203 (IL)**

(74) Representative: **Schoppe, Fritz et al**
**Patentanwälte**
**Schoppe, Zimmermann, Stöckeler & Zinkler**
**Postfach 246**
**82043 Pullach bei München (DE)**

## (54) In-flight power source for projectile

(57) An in-flight power source for a projectile (P) of ammunition having a heat-producing propulsion system and one or more electrically powered systems (15) operationally connected to said power source for in-flight operation of said projectile, wherein the power source comprises a pyro-electric cell (22) with pyro-electric material for producing electrical energy from heat produced as a result of launching of said projectile whereby said electrical energy is provided to said one or more electrically powered systems during flight. The pyro-electric cell may comprise a plurality of connected sub-cells.

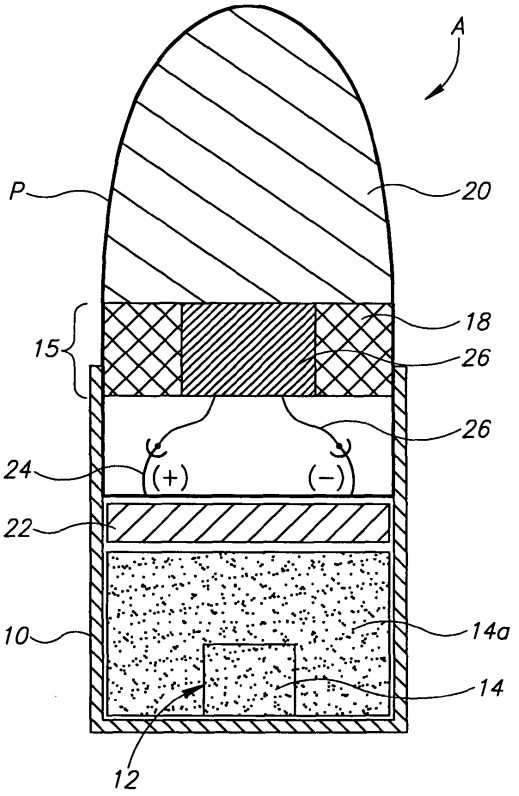


FIG.1

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## Description

### FIELD OF INVENTION

**[0001]** The present invention relates to an in-flight power source for projectiles of ammunition and to projectiles powered therewith.

### BACKGROUND OF THE INVENTION

**[0002]** Many types of ammunition that fire projectiles (e.g. shells, rounds, missiles, etc.) require power for the projectile after it is launched - for the fuze and other systems such as guidance systems, data loggers, cameras, and so on. To supply this power, such projectiles may comprise any of a variety of devices/systems, e.g. a setback generator, thermal batteries, turbo generators, piezo-electric devices, and the like.

### SUMMARY OF THE INVENTION

**[0003]** According to one aspect, the present invention relates to an in-flight power source for ammunition having a projectile comprising an in-flight power source comprising a pyro-electric cell, which produces electrical energy from heat energy.

**[0004]** Heat generated by the ammunition's propulsion system during firing heats the pyroelectric material of the pyro-electric cell and generates electrical energy. This energy is stored in the projectile by an energy storage device (e.g. a capacitor, etc.) associated therewith.

**[0005]** The term *"ammunition"* will be used in the specification and claims in its broadest sense and includes, any projectile-releasing ammunition requiring in-flight power, including for example, rockets, missiles, rounds, mortars, munitions, shells, bombs and the like, requiring an in-flight power source. The term *"projectile"* denotes the portion of the ammunition that is launched upon firing thereof.

**[0006]** According to another aspect, the present invention relates to a projectile of ammunition containing a heat-producing propulsion system; the projectile containing one or more electrically powered systems which typically includes a fuze and one or more additional electrical systems such as guidance systems and the like; an electrical energy storage device to store energy for powering the electrically powered systems; and an in-flight power source.

**[0007]** The power source of the present invention comprises a pyro-electric cell with pyro-electric material for producing electrical energy from heat. The pyro-electric cell generates and provides electrical energy to an energy storage device, whereby upon launch of the projectile, the heat produced by the launch heats the pyro-electric material to produce electrical energy which is transferred to the energy storage device thereby providing power to one or more electrically powered systems for in-flight operations.

**[0008]** In accordance with yet another aspect of the present invention there is provided ammunition having a projectile and a heat-producing propulsion system, with an in-flight pyro-electric cell power source for generating electrical energy to power one or more electrically powered systems which typically include a fuze and one or more additional electrical systems such as guidance systems and the like. The electrically powered systems are operationally connected to the power source for in-flight operation. The pyro-electric cell with pyro-electric material produces electrical energy from heat produced as a result of launching of the projectile which electrical energy is provided to the electrically powered systems during flight.

**[0009]** Advantages of the present invention include:

1. The pyro-electric cell has a high energy capacity (energy per unit volume).
2. The pyro-electric cell has a very rapid excitation time (on the order of micro-seconds).
3. The pyro-electric cell may be disposed at the outside of the projectile (e.g. joined to the bottom of the projectile) or it may be disposed inside the projectile as is presently typical, thereby allowing for flexibility of design.
4. The pyro-electric cell can be utilized as a safety indicator for electronically signaling the fuze that firing/shooting was performed and that the fuze may start its explosion sequence (assuming the appropriate safety conditions have been met), since only an actual shot/launch will initiate voltage.
5. The pyro-electric cell is relatively low cost, light weight and low volume. A large number of pyro-electric sub-cells can be arranged / assembled therein (i.e. the sub-cells with pyro-electric material are connected in series within a small volume).
6. The pyro-electric cell can be designed to suit (conform to) the particular application without changing the size of the cell; e.g. by changing the material and/or using a different number of sub-cells therein.
7. The pyro-electric sub-cells can be compressed and made rugged thereby allowing it to withstand a very high firing acceleration.

**[0010]** Non-limiting examples of pyro-electric material that can be used include LiNb03, LiTaO3, triglycerine sulfate, LiNbOs, ZnO, polyvinylidene fluoride and the like, or a combination thereof.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** The invention may be more clearly understood upon reading of the following detailed description of non-limiting exemplary embodiments thereof, with reference to the following drawings, in which:

**Fig. 1** is a cross-sectional view of ammunition of the present invention comprising a pyro-electrically pow-

ered in-flight power source;

**Fig. 2** is a schematic diagram illustrating an interface for the in-flight power source of the present invention with the ammunition; and

**Fig. 3** is a schematic representation of a pyro-electric cell power source in accordance with the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

**[0012]** Referring first to Fig. 1, there is schematically depicted an ammunition round **A** comprising a casing **10** and a projectile **P** held by the casing; a propulsion system **12** with a charge, e.g. gun powder **14** surrounded by additional gunpowder **14a.** The projectile **P** contains electrically powered systems **15** such as a fuze **16** and additional electrical systems **18** and a warhead **20.**

**[0013]** The projectile further comprises an in-flight power source, constituted by a pyro-electric cell **22** with connectors **24** connected to the fuze **16** and other additional electrical systems **18.** The pyro-electric cell **22** is disposed outside at the bottom of the projectile **P** and as such does not take up space within the projectile itself. Regardless, it should be understood that the pyro-electric cell **22** could be disposed within the projectile **P,** thus adding flexibility to the design of the projectile. The pyro-electric cell **22** is operationally connected to the electrically powered systems **15** via cables **26,** for example.

**[0014]** Fig. 2 is a diagram illustrating an exemplary interface for the pyro-electric cell **22** with the ammunition round **A -** in particular the interface with the electrically powered systems **15.** For such purpose, the projectile **P** typically further includes an energy storage device, e.g. a capacitor **28;** a load **30;** a ground **32;** a diode **34;** and optionally a switch **36.** The load **30** represents the fuze **16** and/or other components or devices in the electrical systems **18** of the electrically powered systems **15** that require power after the projectile **P** is launched, for example, guidance systems, electronic fuzes, data loggers, cameras, and so on (not shown). It should be understood that such components can be devised in a variety of configurations and options.

**[0015]** The aforementioned pyro-electric cell **22** acts as an electrical power source and essentially replaces typical known in-flight power sources. A heat source **38** is schematically depicted in Fig. 2 as a source of heat energy for the pyro-electric cell **22,** and this heat is produced and supplied by the propulsion system **12** and associated gunpowder **14** and **14a** upon launching of the projectile **P.**

**[0016]** Fig. 3 illustrates an exemplary configuration of the pyro-electric cell **22** comprising a plurality of pyro-electric sub-cells **40** arranged in series. By such an arrangement, the number of sub-cells **40,** and thus amount of energy produced, can be tailored to the expected energy required in flight. In other words, the pyro-electric cell **22** can be designed to suit the particular in-flight application without changing the size of the cell; e.g. by changing the pyro-electric material and/or changing the number of sub-cells **40** therein. The sub-cells **40** can be compacted and made rugged in a variety of methods whereby a compact pyro-electric cell **22** can be produced.

**[0017]** The pyro-electric cell **22** thus produced has: a high energy capacity (energy per unit volume); a very rapid excitation time (on the order of micro-seconds); is disposed at the outside of the projectile and as such does not take up space within the projectile itself; can be utilized as a safety indicator for electronically signaling the fuze that firing/shooting was performed and that the fuze may start its explosion sequence (assuming the appropriate safety conditions have been met); that can be designed to suit (conform to) the particular application without changing the size of the cell; e.g. by changing the material and/or using a different number of sub-cells **40** therein.

**[0018]** Further, the pyro-electric cell **22** is relatively low cost, light weight and low volume; a large number of pyro-electric sub-cells **40** can be arranged / assembled therein within a small volume and which can be compressed and ruggedized allowing it to withstand a very high firing acceleration.

**[0019]** During launch or firing of a projectile, heat is produced (given off). Using the afore-described projectile **P** of the present invention comprising the present in-flight power source, i.e. pyro-electric cell **22,** at least some of this heat is received and used by the pyro-electric cell to produce electrical energy for powering the in-flight systems (electrically powered systems **15** - e.g. the fuze **16** and other electrical systems **18)** after launch. The electricity is stored by an energy storage device (e.g. the capacitor **28)** and utilized by electrically powered systems **15,** i.e. the fuze **16** and the other electrical systems **18,** such as guidance systems, etc, mentioned above.

**[0020]** It should be understood that there are various ammunition, projectiles and in-flight power sources that can be devised according to the present invention and that the above description is merely explanatory. For example, the projectile **P** could be constituted by any of a rocket, missile, round, mortar, munition, shell, bomb and the like; and the in-flight power source, i.e. essentially the pyro-electric cell **22,** can be adapted for the systems of such projectiles that require in-flight power, *mutatis mutandis.*

## Claims

1. An in-flight power source for a projectile of ammunition having a heat-producing propulsion system and one or more electrically powered systems operationally connected to said power source for in-flight operation of said projectile, wherein the power source comprises a pyro-electric cell with pyro-electric material for producing electrical energy from heat produced as a result of launching of said projectile

whereby said electrical energy is provided to said one or more electrically powered systems during flight.

**2.** An in-flight power source according to claim **1,** wherein the pyro-electric cell comprises a plurality of connected sub-cells.

**3.** An in-flight power source according to claim **2,** wherein the sub-cells are connected in series.

**4.** An in-flight power source according to any one of the preceding claims, wherein the pyro-electric cell is disposed outside of the projectile.

**5.** An in-flight power source according to any one of the preceding claims, wherein the pyro-electric cell comprises one of: $LiNbO_3$, $LiTaO_3$, triglycerine sulfate, LiNbOs, ZnO, polyvinylidene fluoride, or a combination thereof.

**6.** An ammunition projectile, containing a heat-producing propulsion system, the projectile comprising one or more electrically powered systems; an in-flight power source operationally connected to said one or more electrically powered systems; and an energy storage device operationally connected to said power source, wherein the in-flight power source comprises a pyro-electric cell with pyro-electric material for producing electrical energy from heat produced during propulsion of the ammunition for powering the electrically powered systems while in flight.

**7.** A projectile according to claim **6,** wherein the pyro-electric cell comprises a plurality of connected sub-cells.

**8.** A projectile according to claim **7,** wherein the sub-cells are connected in series.

**9.** A projectile according to any one of claims **6-8,** wherein the pyro-electric cell is disposed at the outside of the projectile.

**10.** A projectile according to any one of claims **6-9,** wherein the pyro-electric cell comprises one of: $LiNbO_3$, $LiTaO_3$, triglycerine sulfate, LiNbOs, ZnO, polyvinylidene fluoride, or a combination thereof.

**11.** Ammunition having a heat-producing propulsion system and a projectile with one or more electrically powered systems and an in-flight power source operationally connected to said one or more electrically powered systems, wherein said in-flight power source comprises a pyro-electric cell with pyro-electric material for producing electrical energy from heat produced as a result of launching of said projectile whereby said electrical energy is provided to the one or more electrically powered systems during flight.

**12.** Ammunition substantially as herein described and with reference to the figures.

**13.** A projectile substantially as herein described and with reference to the figures.

**14.** An in-flight power source for a projectile of ammunition substantially as herein described and with reference to the figures.

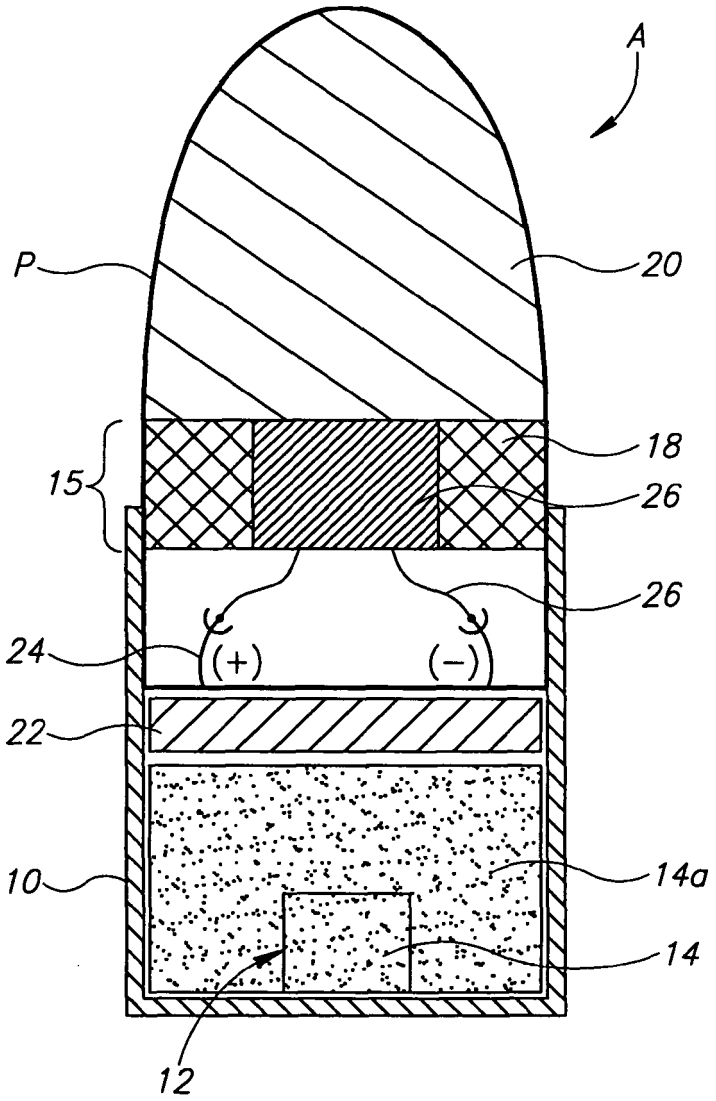


FIG.1

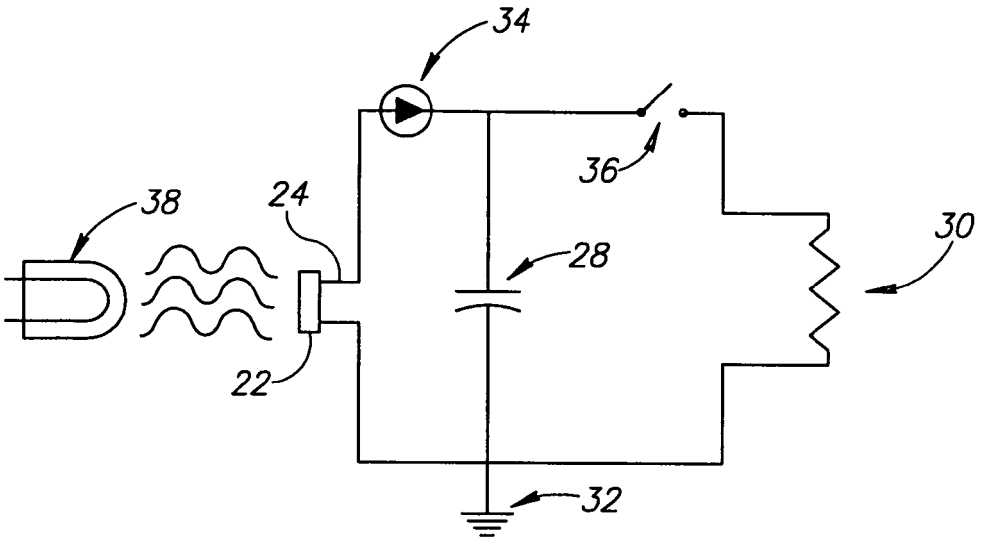


FIG.2

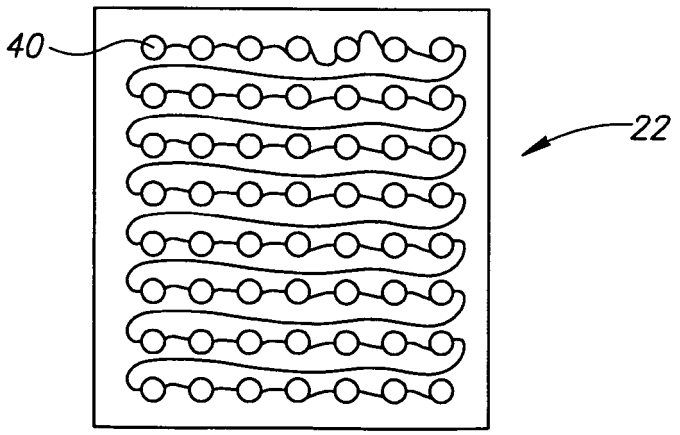


FIG.3