*Available online at www.ijiere.com*
**International Journal of Innovative and Emerging Research in Engineering**
e-ISSN: 2394 – 3343 p-ISSN: 2394 – 5494

# MEMS Based Safe Arm and Fire Device (SAM)

Lalit Rawat[a], Suraj Kadam[a], Kuldeep Yadav[a], Prof. Renuka Bhandari[b], Dr. Virendra Kumar[c],
[a] Army Institute of Technology, Dighi , Savitribai Phule Pune University, Pune – 411015
[b] Professor, Army Institute of Technology, Dighi , Savitribai Phule Pune University, Pune – 411015
[c] Armament Research and Development Establishment, Pashan, Pune – 411 021

**ABSTRACT**
**Safe Arm and Firing (SAF) is basically a device which keeps the detonator safe, arm it and initiate one primary explosive necessary for initiating the secondary explosive. Previously in SAF only mechanical switches were used for the arming and safety purpose. The mechanical arms were large in size and also not safe and reliable. So to overcome these limitations this paper proposes a safe arm and fire device (SAF) that could constitute a real breakthrough for safe miniature fusing device. Thus this design presents, fabrication and characterization of new micro elctromechanical switch (MEMS) based SAF architecture, integrating initiator, electrical and mechanical protections which is based on micro pyrotechnical actuation.**

**Keywords: MEMS, Pyrotechnical actuation, SAF**

## I. INTRODUCTION

The ESAF is stud-mounted to the warheads and is suitable for use in a bomb, missile or undersea environment. A MEMS SAF is not a "sensor" or a miniaturized pyrotechnical initiator, but it combines both sensing and actuation functions in a very tiny volume and must operate with a high reliability level. It contains environment sensors, safe/ arm logic, a high voltage DC-DC converter and one or two exploding foil initiators with individual delay timers and fire sets. Mechanical arming unit with electrical safety functionalities on the same pyrotechnical initiator's chip .

An innovative concept of micro actuation was proposed by LAAS-CNRS in 1995 for a medical application using pyrotechnical energy. Later on this concept has been applied to micro propulsion [1], micro fluidics[2] and weapons[3].
Previously in SAF only mechanical switches were used for the arming and safety purpose.
Now we are proposing the MEMS switches in replacement to the mechanical switches. MEMS switches are small in size and requires the electronic circuit for the operation.

A review of the micropyrotechnics related works is done. Micropyrotechnics is the integration of an energetic material into microsystem, for which the thermal, mechanical and chemical energy released by decomposition can be exploited.[4]
In this context, the motivation of using microsystems is not only to reduce the systems dimensions but also to increase the system safety and reliability.

## II. SYSTEM DESIGN

**Electronic circuitry**

The top layer contains the electronic circuitry and power supply device. It is composed of a multi-layer circuit using a DC/DC converter and a fast switching scheme driven by a low consumption micro controller.

This small size design with 50 000 hours of lifetime is supplied by a storage battery. In this application, our micro device needs 500mW to be operated, that corresponds to a hundred to thousand factor in comparison with traditional energetic consumption in autonomous systems. Furthermore, to supply this power for the device, we have to apply an important voltage (upper than 10V) which doesn't match with standards in low-power world. As the system is embedded, the available energy is limited. The electronic has to have a maximal lifetime and has to provide 500mW to each of the five poly- silicon resistances. The selected solution for energy storage is a pre- loaded super capacity kept on load by button cell.

The whole device can be divided into three layers i.e the top layer, middle layer and the bottom layer.

The top layer consists of a DC-DC converter which converts the 5V supply to 12V which is need to derive the pyrotechnical actuators.

The middle layer consists of PIC18F1220 microcontroller which controls and governs all operations to be performed by device

**Si based safe initiator**

The bottom layer consists of the silicon layer. The main component on silicon chip is three bi stable electro-thermal MEMS switches (ON-OFF and OFF-ON switches) and one resistive igniter (micro detonator) with a highly energetic material. This layer also contains a second resistance with a gas generator energetic material called microactuator that is used to move the ceramic screen from safe to arm position. Its operation follows a very simple operation: after ignition the hot gases are generated by the energetic material decomposition that increases pressure into the micro actuator cavity as a result of which the mechanical barrier is moved from safe to arm position. The silicon chip layout is shown below.

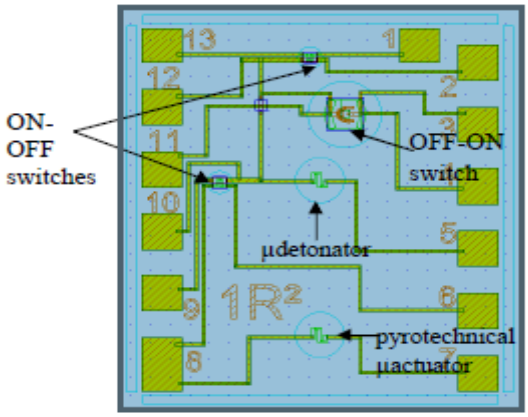


**Figure 1: Layout of the Si-based safe initiator layer [5]**

**The microinitiator and microactuator**

Both of these consists of a heating resistance on a 1mm$^2$ dielectric membrane. A thin layer of energetic material is deposited inside the cavity underneath the membrane. The heating resistance is of 120Ω.

**The MEMS Switches**

ON-OFF switch

The ON-OFF switch consists of a heater resistance which is melted as the sufficient current is passed through it. This switch is initially in the ON state but when the current is passed through it the heater resistance breaks and the switch goes in the OFF state.

The OFF-ON Switch

The OFF-ON switch is complementary to the ON-OFF switch. Its principle is based on a microbrazing by locally heating up to 183ºC a Sn/Pb solder microball deposited between two copper track to connect. The solder ball is deposited on top of the heater and rosin spread on whole membrane. The switch is initially in the OFF state. When sufficient current is passed through it the switch gets in ON state and the two tracks are connected.

The final block diagram of the device can be shown as:

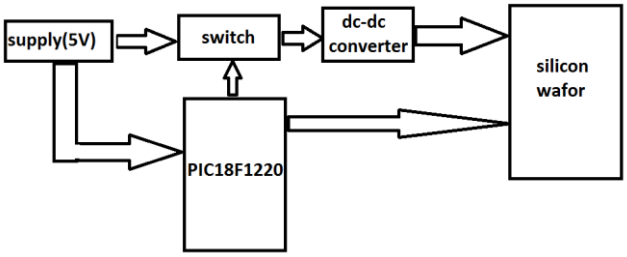


**Figure 2: Block Diagram of Device**

## III. WORKING LOGIC

The power supply will consist of a lithium ion 5V battery which will power up the microcontroller and will be given to the DC-DC converter via a switch which is controlled by microcontroller. The DC-DC converter will convert the 5V supply to 12V which will be provided to the silicon wafer. The silicon wafer consists of two on-off, one off-on MEMS switches, a pyrotechnical actuator and an initiator. The MEMS switches will protect the detonation from any external physical perturbation. The microcontroller controls how much delay is to be given between the two pyroactuators. There is also a kill switch which is used if we want to stop the detonation after its activation, but this function will be available for a certain window of time after that window it won't be able to stop the bomb from detonation. When 12v supply from DC-DC converter is provided the pyrotechnical actuator is triggered and releases the high pressurized gas which in turn shifts the MACOR layer and the device comes into armed position. Then the microcontroller gives signal to the initiator to ignite the primary explosive which leads to detonation of the bomb.

The whole operation of the device can be shown with the help of flow chart as:

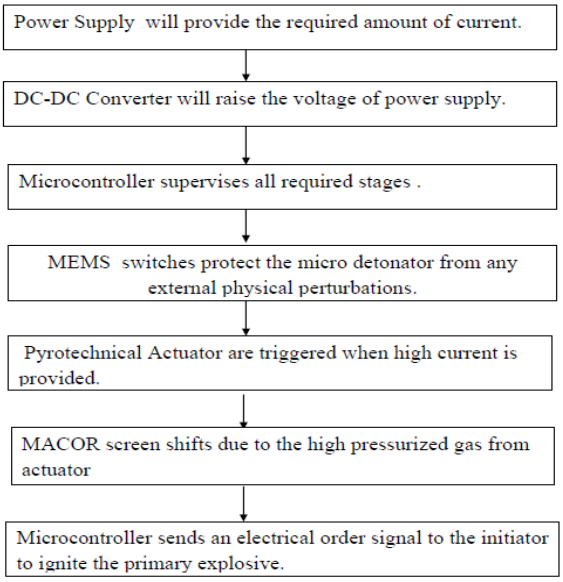


**Figure 3: Flow Chart of Design**

## IV. CONCLUSIONS

An innovative MEMS based safe, arm and fire device have been proposed designed and fabricated. It consists of multilevel stacked wafer, the bottom layer is mechanical arming function, the intermediary layer is a silicon chip consisting of electrical resistance and micro switches for electrically arming and disarming function. Top layer consist of electronic power circuitry.

## ACKNOWLEDGMENT

We are very thankful for the proper guidance, direction & opportunities given by our department. The process of completion of this project was a tedious job & required support & experience at all stage. We would like to express our gratitude towards the people who made this project possible. We would like to express our sincere thanks to our project guide Mrs. Renuka Bhandari for her keen interest in our project & helping in completing it successfully by her valuable guidance.

We would like to express gratitude to Dr. Virendra Kumar Verma, our project guide at ARDE. Despite his busy office schedule he found time to guide us and also check the progress we had made. With keen interest he helped us accomplish our project outcome.

We would also like to thank Prof. B.P. Patil, Head of the Department, Electronics and Telecommunication for providing us the opportunity and facilities in the department to develop and complete our project. We would like to thank all the faculty members for their assistance.

## REFERENCES

[1] C. Rossi 1997 Conception and realisation of a fluidic microsystem suitable for transdermal drug delivery device using 3 micro pyrotechnic actuators, PhD Thesis, INSA Toulouse, France.
[2] M. Tosin et al, A solid propellant micro thruster design – a brief discussion about its viability and application, Conference on micro nano technologies for aerospace applications, Caneus, Monterey, California, 1-5 november 2004.
[3] G.A. Ardila Rodriguez 2008 Conception, simulation and fabrication of a micro actuator based on energetic material for microfluidic actuation, PhD Thesis, Université Paul Sabatier, Toulouse, France.
[4] K. Hodge et al. 2002 MEMS arm fire and safe and arm devices, US Patent number 6,431,071B1.
[5] H.Pezous et al. /Sensors and Actuators A 159(2010) 157-167