Magneto Optical Static Event Detector

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ABSTRACT

A resettable Magneto-Optic Static Detector provides a unique way of detecting Electro Static Discharge (ESD) events for products being handled through the manufacturing processes. The device is small enough so that many of them can be packaged in a single integrated circuit (IC) for simultaneous detection of ESD events at different terminals.

SUMMARY

Introduction

Static electricity can create a wide variety of problems for electronic manufacturers. Damage can be as immediate as blown devices or can remain hidden ready to fail when received by the customer. Today, most efforts are directed toward preventing all Electro Static Discharge (ESD) events and little is directed toward monitoring of actual ESD events. Early detection of ESD events during the process set-up and trial runs can prevent very costly yield loss, reliability and warranty problems for component, PC board manufacturers, system integrators or distributors. Until now the ability to monitor ESD events has been almost impossible, and where possible has been difficult and expensive. The Static Event Detector presented in this paper provides a unique set of solutions for manufacturers of ESD sensitive devices and systems during process set-up and actual production by locating the polarity and amplitude of ESD transients experienced by the products being processed.

History of ESD Event Detection Technology

The first ESD event detectors were developed in the 1980's for use on PC boards. A current pulse in an ESD event transmitted through an antenna or external clip is amplified and processed to produce a reflectance change in the built-in Liquid Crystal Display (LCD). This detector, has an overall dimension around 1 square centimeter by 0.5 centimeter thick. The detectors are designed to detect ESD transients of one specific amplitude and are not sensitive to polarity.

A recently developed detector marketed by Electrostatic Designs employs the well-understood ESD susceptibility of a Metal Oxide Semiconductor Field Effect Transistor1 (MOSFET). An ESD transient is amplified to create sufficient energy to blow a gate oxide. Another semiconductor detector historically susceptible to ESD is Metal Oxide Capacitor (MOSCAP). Current leakage through the MOSCAP will increase significantly if the ESD amplitude is sufficient to damage the metal oxide semiconductor (MOS) structure. Motorola has developed ESD sensors that use MOSCAP's. Both Motorola and Electrostatic Design sensors have to be removed from the assembly and inserted into a readout device in order to determine whether the sensor had recorded an ESD event.

Magneto-Optic Static Detector

The Magneto-Optic (M-O) Static Detector described in this paper employs the Faraday Effect[2] principal which rotates the polarization of a beam of light when it passes through a magneto-optic thin film. This effect, also known as Faraday Rotation, is exploited to detect and optically record an ESD current transient onto a magneto-optic thin film detector. A strong magnetic field is used to alter the thin film's magnetic state that would affect the degree of polarization of visible light reflected from the film. A current pulse resulting from a direct static discharge through the detector will induce a magnetic field around the thin film conductor. The field will then switch the magnetic state of the thin film from the altered state to the neutral state which can be readily observed using a polarizing microscope. The saturation field required to complete the switching is equivalent to the collapse field in magnetic bubble memories[3]. If the magnetic field is too small, the thin film detector will remain altered. Magnetic field strength sensed within the thin film detector depends on the configuration of the conductor and its distance to the thin film detector. These factors are critical in determining the ESD sensitivity level of the pixels within the detector. Figure 1 demonstrates the principle of operation of the device.

The magnetic field lines are shown surrounding the conductor. The altered optical states of the pixels are shown schematically as a shifting of the polarization vectors. Although polarization rotations are small, less than 10% in most cases, the rotation will produce a significant contrast, which is easy to observe through the polarizing microscope. Potential applications of this device are described in section 5 below.

Reference Figure 1: "Demonstration of the Principles of Magneto-Optic Devices"

In the photograph (Figure 2) a group of pixels have been switched by an electro-static event. The polarization of the light reflected by the detector is rotated according to its optical state. These detectors exhibit three stable optical states: light rotated counterclockwise, light unaffected, and light rotated clockwise. When the current in a conductor near the active region of the detector reaches a critical level the detector will switch to its lowest or neutral state. In the photograph, the pixels of the ESD sensing die were originally all set to the counterclockwise-rotated state. The ESD current induced pixels to switch where the magnitude of the event exceeded the threshold level. Die threshold levels have three different magnitudes at both polarities and a high sensitivity polarity insensitive pixel for a total of seven separate detectors within the small outline of the die.

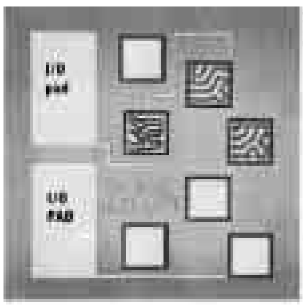


Figure 2:

Detector with unswitched domains (blank) and switched domains (striped).

Light reflected by the ESD switched detectors has been rotated with respect to the light from the detectors that remain in their original state. This effect is readily visible using a polarizing microscope. The switched detectors are seen as striped pixels; the unswitched areas are clear pixels. The contrast ratio between the bright and striped regions is greater than 50:1. These switched detectors are readily reset externally with no degradation in performance characteristics. External reset is accomplished using a high strength permanent magnet placed in proximity (less than 5mm) from the detector. The high magnetic field will rotate the polarization to a clockwise or counterclockwise direction depending on the magnet polarity.

The design performance specifications are the ESD current levels (voltage from V=IR, where R may be chosen externally) that are to be detected and the current level that is to be protected against. The minimum current needed to be observed, i.e. to switch the detector, is not a function of the conductor's material and is dependent on the conductor's width. The fuse protection level of the detector is determined by the current carrying capability of the conductor in the detector environment and by the cross sectional area of the conductor. Detector switching speed and threshold are interrelated. Characterization of detector switching as a function of ESD transient pulse width needs to be performed.

Fabrication Techniques

To produce a M-O detector, an optically transmissive magnetic film is grown over a non-magnetic optically transmissive substrate in a wafer form. The film is then patterned using photolithography processes and then etched to create individual domains. The wafer is then metallized, patterned and etched to form the thin film conductive paths that connect all the domains. After completion of processing, the wafer is sawed into individual die. The die is assembled into Electro-optic packages or directly bump attached onto the Device under Test (DUT). The sequence of wafer fabrication operations is shown in Figure 2.

Reference Figure 2 (A-E): Sequence of operations forming ESD Detectors from M-O Wafers

Simple detectors containing seven domains measure 0.5mm by 0.5mm and 0.4 mm thick. Larger detectors can contain thousands of domains. The optimum number of domains depends on the application. Detectors with smaller numbers of domains may be mounted permanently on ESD sensitive devices whereby larger detectors with larger number of domains may be used for analytical purposes or in multi-channel devices. Detector impedance on prototype devices is 12 ±2 Ω. The impedance of M-O ESD detectors needs to be minimized to prevent premature drive line destruction due to joule heating. In cases where high sensitivity to low level ESD transients is needed, line widths approaching one micron will be needed to create high magnetic fields at low current levels.

Suggested Applications

- **Detection of ESD transients in an IC Test Handler**.

Many package configurations are amenable to the use of magneto-optic detectors in qualification of assembly, test, and handling operations. Unsealed Pin Grid Array

(PGA), Ball Grid Array (BGA) and Lead frame packages have device cavities with optical access to the M-O ESD detector.

1. Detector Mount is performed using epoxy die attach adhesives. Ordinary thermal cure adhesives can be used as the detector can experience thermal transients up to 300 C without performance degradation.
2. Detector is wirebonded to the desired pin locations. Future versions of the M-O detector will be bump bond compatible. It may be necessary to test for ESD transients at many terminals. With today's technology, hundreds of terminal locations in one package are possible. In that event the following test protocol alternatives need to be considered:
   a. Mount multiple detectors at all designated locations. Handling and positioning issues may be ameliorated by the low cost of this evaluation.
   b. Mount a custom detector configuration that tests every significant pin combination. Design rules are being been established that will allow the use of multiple voltage ranges within the same chip. Potential pixel density is huge; over 100,000 pixels can occupy less than 1 cm^2 of package space!
3. Package sealing is undesirable unless the sealed package provides optical access for the detector. Fortunately, the M-O Detector is rugged, resistant to most corrosive environments and subject to change only by the external non-contact reset device.

The test package can be characterized using commercial simulators or placed directly in the test handler. The package can be removed after the desired number of test insertions and the recorded ESD events observed. One test device can be used for multiple qualification or trouble shooting tests so long as the maximum transient amplitude lies below the fuse level of the detector.

- **Detection of ESD Transients during Magneto Resistive (MR) head processing.**

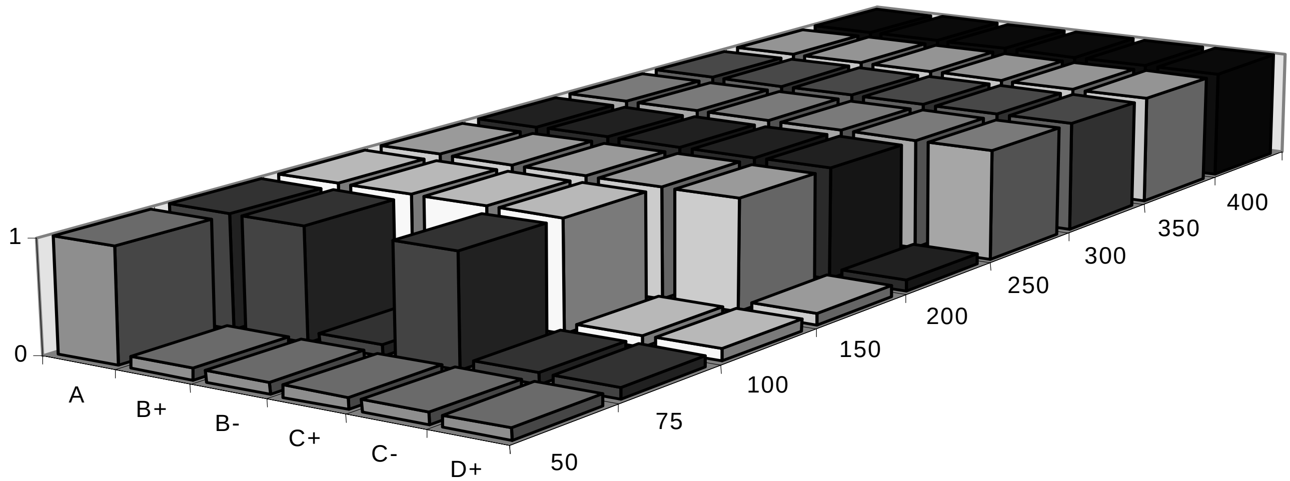
MR heads are notoriously susceptible to ESD Transients[4]. Detectors, mounted in series with the Head Assembly, can provide information on the magnitude and polarity of ESD events as the assembly is processed and integrated into the next assembly level. Detector mounting and wirebonding will need to accommodate the substrates and metalization that exist at the various assembly levels of the manufacturing flow.

- **ESD Detection in Process Holding Tools.**

Detectors can be mounted on almost any surface. Non-conductive holding tools can be metalized using selective electroless plating techniques. A sense plane is formed on a section of the tool surface where suspected ESD events occur. A ground plane is established to direct the ESD event to ground. The detector is mounted and wirebonded between the two planes. Transients that contact the sense plane, travel through the detector to the ground plane, and will thereby be detected.

Experiment

An experiment was designed to determine the performance of the MO ESD detector in which a Key Tech Zapmaster ESD simulator was used. The detector was packaged in a 14 pin Dual In Line (DIP) package and placed directly on the test socket. A single Machine Model pulse of a predetermined potential was applied to the pin connected to one of the I/O pads while the other I/O pad was connected to ground. The pulse polarity was then reversed. The detector was removed and visually inspected under a polarizing microscope after each pair of zaps. Table 1 and Figure 4 demonstrate that the M-O detector has the potential to determine both polarity and amplitude of ESD events.



Zap Voltage	Domains and Designed Thresholds					
	<50V	+50V	-50V	+100V	-100V	+150V
	A	B+	B-	C+	C-	D+
50	switched	not switched	not switched	not switched	not switched	not switched
75	switched	switched	not switched	switched	not switched	not switched
100	switched	switched	switched	switched	not switched	not switched
150	switched	switched	switched	switched	switched	not switched
200	switched	switched	switched	switched	switched	not switched
250	switched	switched	switched	switched	switched	switched
300	switched	switched	switched	switched	switched	switched
350	switched	switched	switched	switched	switched	switched
400	switched	switched	switched	switched	switched	switched

Table 1: Summary of MM zap test results

Conclusion

A new static event detector has been described. It exhibits a number of distinct advantages over existing devices. One drawback is that the position of the detector must be exposed and visible. It may have useful applications in the areas of process line set-up, troubleshooting and detection of potential ESD problems. The detector is fabricated on an extremely small scale using readily available semiconductor techniques resulting in an economic advantage as many chips can be produced per wafer. Because of its size, only a small space is needed for the ESD detector on a device, printed circuit board or hybrid assembly.

It can be designed into a variety of package configurations with or without transparent windows including hermetically packaged TO-type and surface mount. Bare die can be used in hybrid, MCM or custom packages providing that an optical access exists for the readout unit. It is also completely passive, thus requires no power supply. Both reset and readout of the detector can be accomplished remotely; i.e. no physical contact with the detector is required to read the polarity and voltage and to reset the detector after an ESD event.

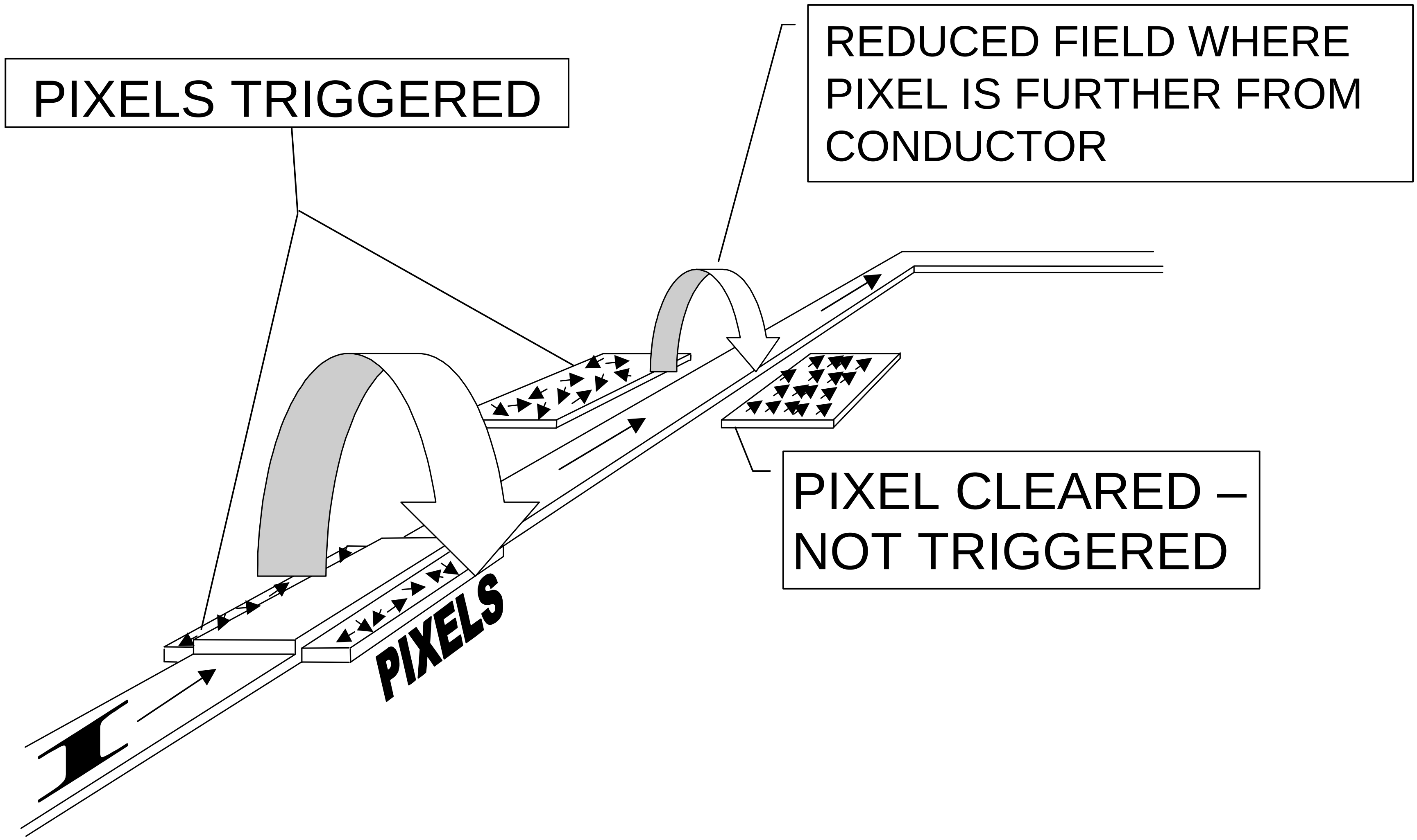


FIG. 1 – PRINCIPLES OF MAGNETO-OPTIC ESD DEVICE

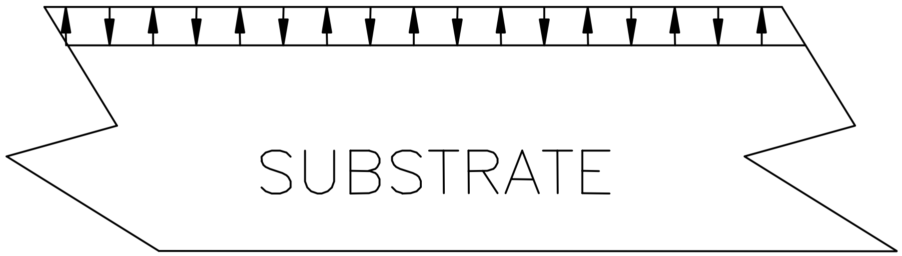


FIG. 2A — MAGNETO-OPTIC WAFER
READY FOR PROCESSING.

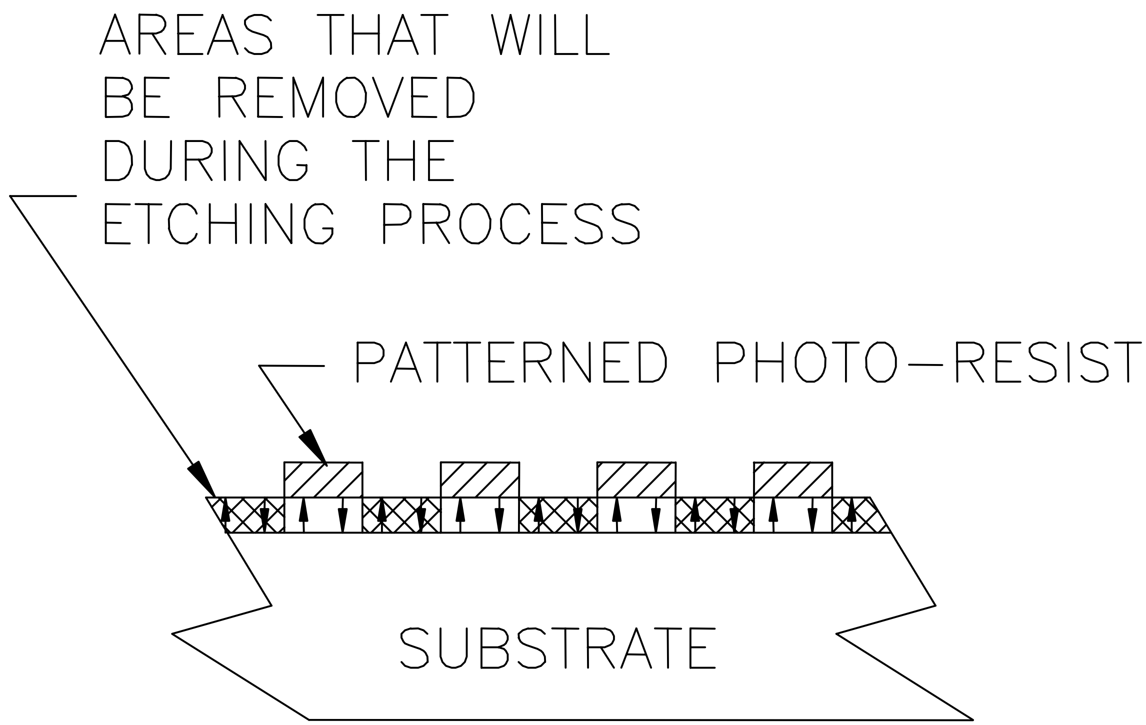


FIG. 2B — WAFER PATTERNED, READY FOR ETCHING INTO PIXELS.

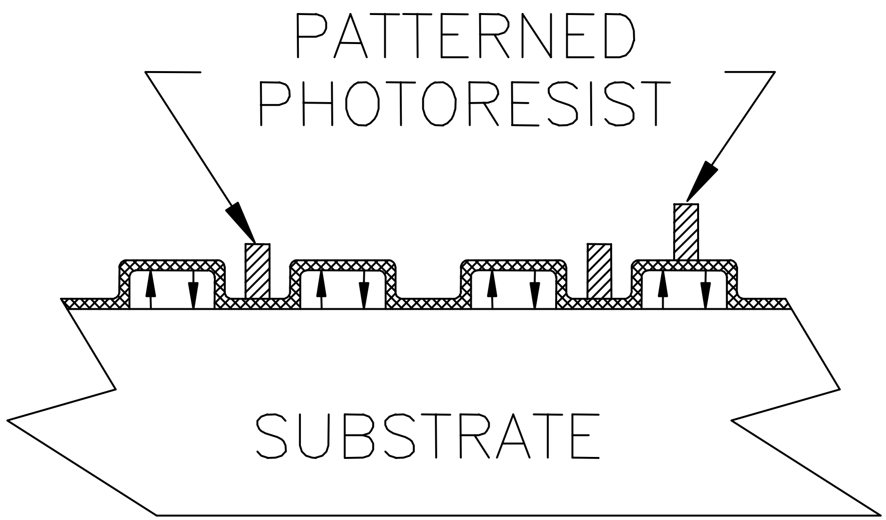


FIG. 2C — WAFER AFTER METAL DEPOSITION, PATTERNED TO FORM CONDUCTORS AND BOND PADS.

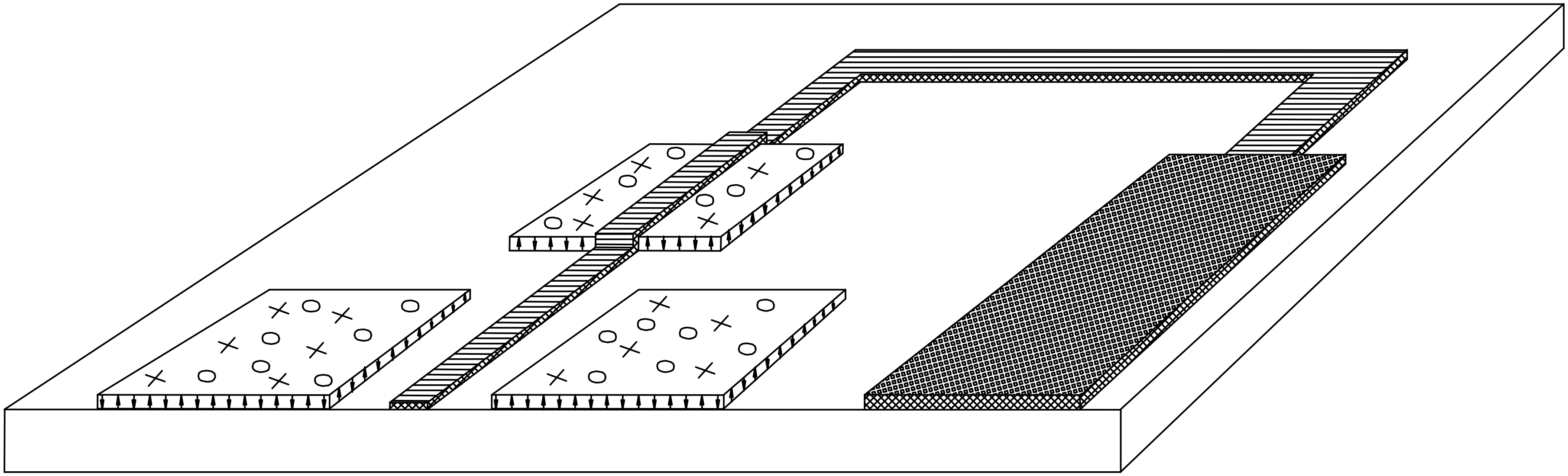


FIG. 2D — PATTERNED METALIZATION RESIDING ADJACENT TO, OR OVER INDIVIDUAL MAGNETO-OPTIC PIXELS.

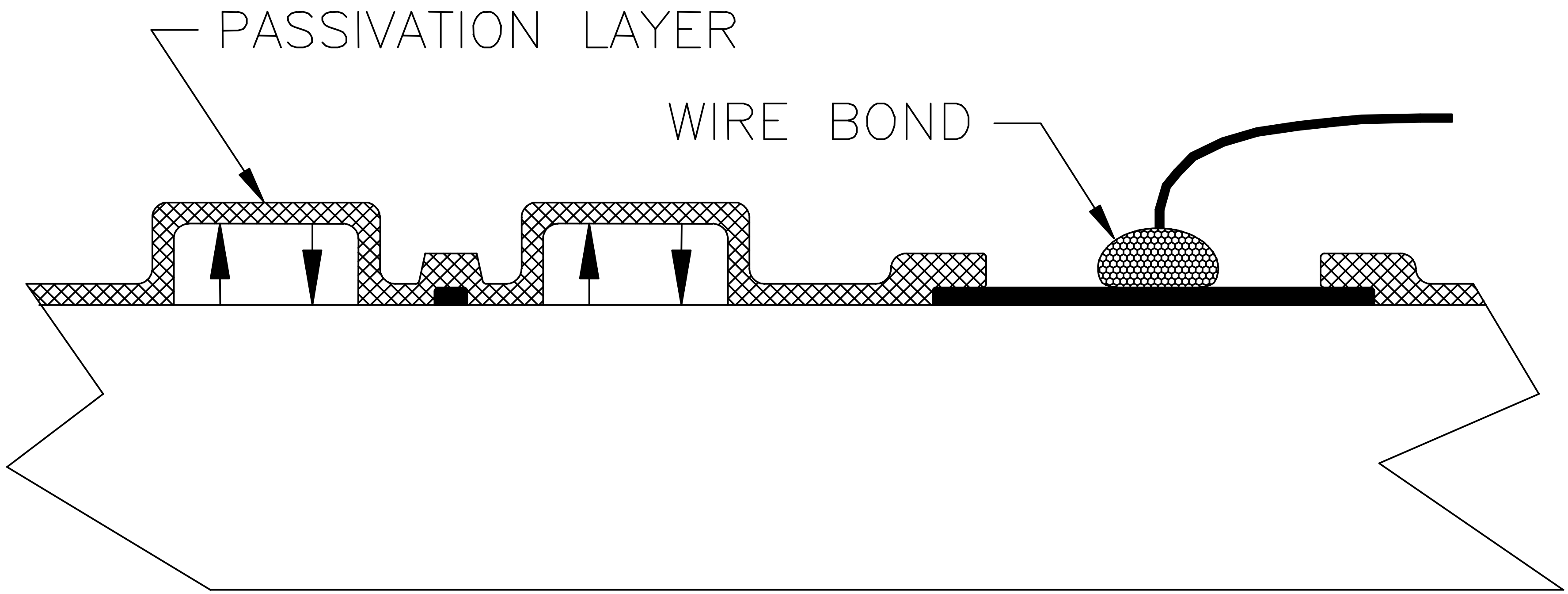


FIG. 2E – COMPLETED ESD SENSOR AFTER PASSIVATION

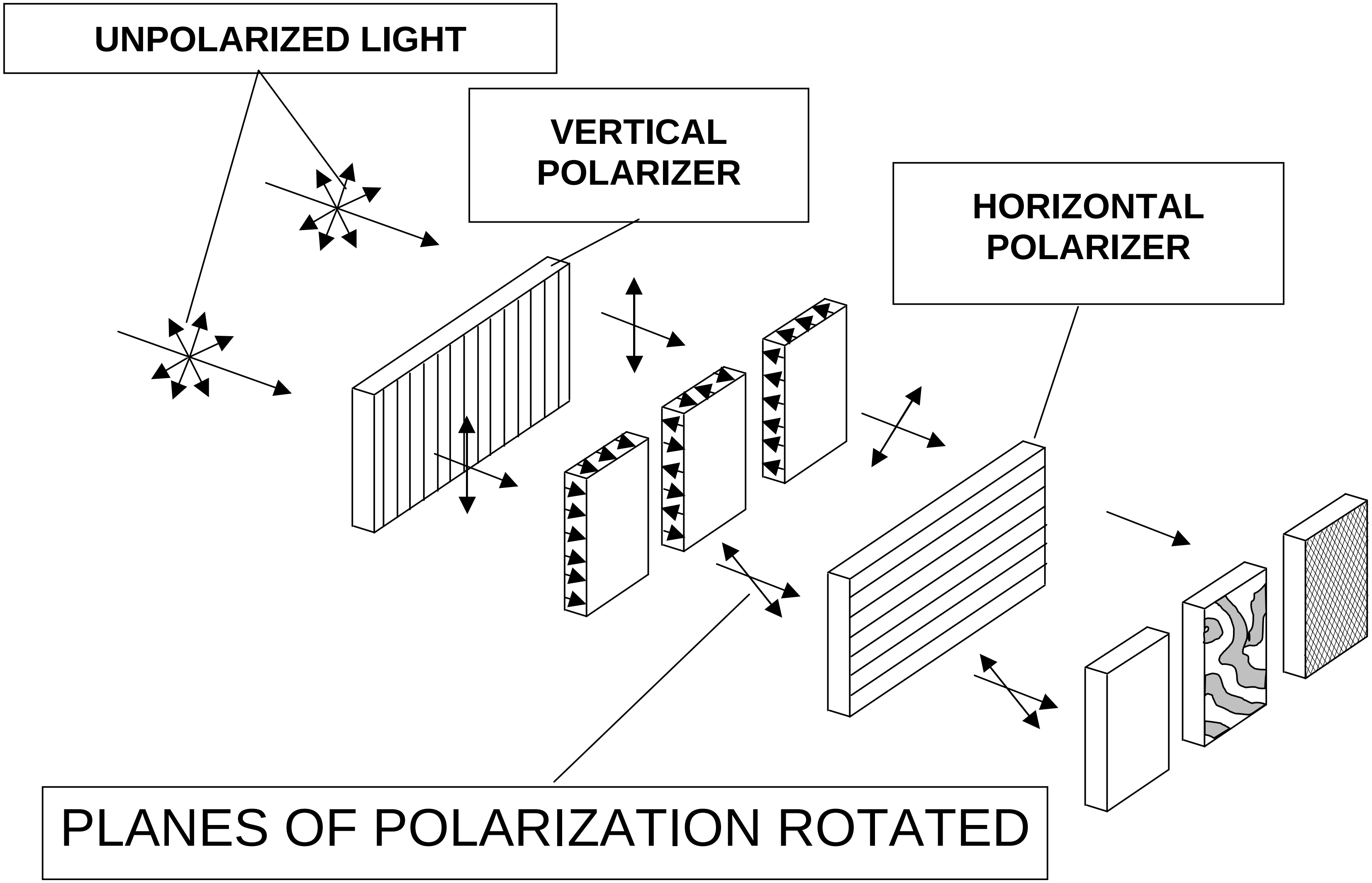


FIG. 3 – DETAILS OF MAGNETO-OPTIC ESD DEVICE FUNCTION

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