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A case study of integrating a proprietary evaluation system into the failure analysis processes of optical sensors

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ABSTRACT

This paper presents a new and novel approach in characterizing and verifying failure mechanisms of optical sensors using a patter-driven, real-time evaluation tool, whose initial purpose is to address automated characterizations and validations. The goal of this paper is to create a series of programs that are specifically aimed at understanding the optical failure parameters of optical sensors. The devices were then subjected to full failure analysis process to correlate and verify the results obtained. Preliminary results showed that this approach: (a) significantly shortens the cycle time of the FA process of optical sensors as complicated test set-ups in the automatic test equipment (ATE) can be turned into a secondary verification tool; (b) provides better understanding of the optical as well as the electrical failures of optical sensors since the programming of our automated evaluation system can be adjusted to explore different failure characterizations and evaluations; and (c) it optimizes the failure analysis process by providing the analyst with more data and information about the device failures.

1. Introduction

The whole of semiconductor failure analysis (FA) is divided into two parts: (a) the identification of the root cause(s) of failures where numerous tests including electrical characterizations, and creation of testable hypothesis comes to play [1]; and (b) the validating activities that proves or disproves the created hypothesis or affirms/rejects the results of the tests [2]. In (a), it is quite obvious that any FA process depends on good FA tools as much as it depends on excellent problem-solving methodologies and frameworks. With the right tools in place and with the right frame of mind in solving the issues associated with the failures of the device, the failure analyst can expect higher efficiency of detecting, identifying, and locating the root causes of failures. One of such tools that can be used in FA is an ams proprietary evaluation system.

This system is a powerful tool originally designed to perform fast and reliable electrical characterization of ams AG devices during their development stages, but can be programmed to perform in-depth parametric and functional characterizations of device failures for use in semiconductor and electronics failure analysis. This system has been used widely within the company for many different reasons ranging from device evaluations, to electrical characterizations of device parameters, to verification tools during test development, and to some extent, validations of customer failures. What this paper wants to achieve is to check if this pattern-driven real-time evaluation tool can also be applied in the characterization of digital failures during failure analysis. More specifically, this paper will attempt to use this evaluation tool to identify and isolate digital failures due to the inability of the optical sensors or optical semiconductors to properly convert photon energy into electrical signals or digital values.

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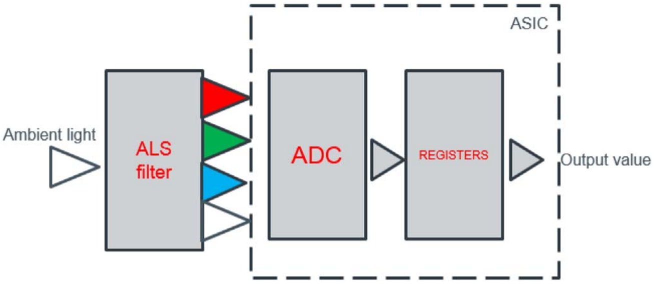

Fig. 1. Simplified diagram of how photon is converted into an output value.

2. ALS failure

Ambient light sensing (ALS) technology is used to optimize the operation of backlight LEDs under different environmental lighting conditions and through a variety of attenuation materials by approximating the responses of the human eye [3]. To be able to mimic the human eye, the optical sensor as well as the application-specific integrated circuit (ASIC) must be able to effectively and efficiently convert photon energy into electrical signals. As the photon energy is converted into analog and digital signals, these values are then stored in the registers which are later retrieved as register values for specific functions and/or application. So, ALS failures occur when the expected digital values of the specific registers are not met or are beyond the range of allowable values.

The electrical characteristics of most (but not all) of ALS fails are parametric fails and optical ratio fails. Parametric fails can exhibit in many form including failures in the analog-to-digital conversion (ADC), auto-zero conversion fails, and dark count and dark currents fails. Optical ratios on the other hand are parameters set to monitor the ability of the ALS technology to convert ambient light into the CRGB and IR components (Fig. 1).

In the simplified diagram above, there are two ways for an ALS failure to occur. First, ALS failure can happen if the filters are unable to correctly screen out the unwanted frequencies, resulting to discrepancies in the saturation levels of the related registers, shifted response of the ALS registers, leakage currents, or even dark counts and dark currents; second, ALS failure can occur if the conversion of the light frequency to the required digital signal could not be, or was not, performed correctly by the ASIC component of the device resulting to erroneous values found at the registers, incorrect response of the device to incoming photon signals, etc.

3. Failure analysis using the proprietary evaluation tool

As was mentioned, our proprietary evaluation tool can perform both analog and digital characterizations. For this paper, we are only interested in the capability of this tool to perform digital testing on optical semiconductors that have ALS failures.

Working with the digital blocks are tricky, if not time consuming and inefficient especially since the evaluating engineer would need to run all the required digital patterns and analyze each and every output for possible stuck-at failures, transition delays, path delay faults, and/or quiescent IDD failures. All of these electrical verifications can be done using one or numerous testers to obtain the relevant information required to understand the failure. The enormous amount of time, resources, and effort needed to come up with good ideas for fault isolation and elimination in order to increase efficiency in the working process. Found below is a concept map presented for how this system is used in failure analysis (Fig. 2).

Central to electrical characterization utilizing this system is the full understanding of how the device works and where could it fail, or where the failure could most likely come from. For running failures from production lots, electrical characterization can be done more efficiently if the production test pattern (or the electrical results from the production tester) is readily available. This is because with the failures already identified, isolating the digital blocks containing the suspected failure during electrical characterization with our proprietary evaluation system becomes easier. In the absence of readily available information about where the failure could have come from, like in the case of evaluation and qualification samples, this system can be used to locate and isolate the digital block containing the failures much faster with an ATPG testing speed of up to 12.5 MHz. This speed, coupled with intelligent programming, locating the incorrect vectors can still be performed at considerably faster rate compared to manually checking the individual digital blocks that could probably house the failed transistor, diodes, or resistors, among other possible components.

4. ALS failure

This ams proprietary evaluation system is an excellent tool for finding the digital block responsible for ALS failure in optical semiconductor devices. However, the effectiveness of such a system as an FA tool, like any FA tool, is highly dependent on whether or not the failure warrants the use of it. Devices with ALS failures that can be attributed to reasons other than a legitimate failure in the digital core related to the ALS function may not be good candidates for characterizations.