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What is Electrical Overstress? - Analysis and Conclusions

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ABSTRACT

In order to analyse the reasons for continuously high failure rates due to electrical overstress (EOS) a large number of publications published over the past 40 years in the field of EOS is investigated and evaluated. It is found that there is no common understanding on EOS. To resolve this problem criteria for a suitable EOS definition are introduced and a corresponding definition is proposed.

1. Introduction

For 40 years electrical overstress (EOS) is one of the major reasons for failures of semiconductor devices in manufacturing processes and in the field [1–7]. Although there is a broad agreement in the electronics industry that EOS failures are a persistent problem that needs to be solved and despite significant effort spent in this field, there has not been much success to reduce the overall rates of EOS failures (cf Fig. 5). It is the purpose of this paper to analyse the reasons for this lack of success and to draw conclusions in order to effectively reduce the overall EOS failure rates. To this end, no new case studies on EOS failures have been carried out. Instead, a large number of publications published over the past 40 years in the field of EOS has been investigated and evaluated. Hence, the "devices under test" in this paper are not microelectronic devices, circuits or systems but *publications* on microelectronic devices, circuits and systems. This approach allows to analyse the problem of continuously high EOS failure rates on a higher level than EOS case studies can and makes it possible to draw high level conclusions.

The selection process of the investigated publications is outlined in Section 2. The results of the analysis are presented in Section 3 in terms of the subject of the investigated publications, their definitions of EOS, reported EOS failure rates, associated failures types, failure mechanisms and EOS characteristics. The perception of EOS, its historical evolution, its relationship to ESD and a suitable definition of EOS are discussed in Section 4. Finally, conclusions are drawn in Section 5.

2. Selected publications

This investigation covers publications that refer either to the term "Electrical Overstress" or to its acronym "EOS". Publications that only use these terms but give no further indication on the meaning, the causes and the effects of EOS were ignored. In order to find relevant publications, the databases of IEEE Xplore and ScienceDirect as well as the past proceedings of the EOS/ESD symposia [8] were searched. In total 203 publications were taken into account. These publications include among others some White Papers, textbooks and standards. The earliest publication that is covered was published in 1973. The latest was published in 2014. Hence, this investigation covers the past 40 years. Note, no publications referring to "Electrical Overstress" or "EOS" were found or were available for the years 1974–77, 1979, 1981 and 1983–85.

3. Results

3.1. Subjects and devices

The major subject of the investigated publications is shown in the pareto diagram in Fig. 1. Surprisingly, publications on electrostatic discharge (ESD) are first. They mark 45% of all publications. EOS publications are second. They mark only 34% of all publications. Publications that address other subjects (eg failure mechanisms, material properties, reliability testing and computer-aided-design methodologies) represent only 21%.

The evolution of the subject of these publications over the past 40 years is shown in Fig. 2. While in the 1970s till 1980 none of the investigated ESD publications referred to EOS, the share of ESD

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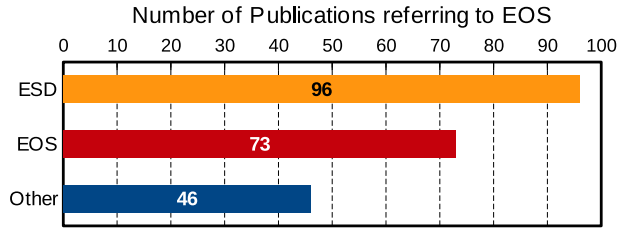

Fig. 1. Subject of the investigated publications. Note, 12 publications could not be clearly attributed to either ESD or EOS. Therefore, these publications were attributed to both categories.

publications referring to EOS increased in the early 1980s and began to push back the share of EOS publications in the same decade. In the 1990s and 2000s ESD publications clearly dominated the number of publications referring to EOS. Only in the 2010s the share of EOS publications started to increase again. In contrast, the share of publications addressing other subjects has increased somewhat in the 1990s to remain more or less constant in the following years.

The different devices that are addressed in the investigated publications are shown in Fig. 3. While 69% address semiconductor components or integrated circuits (ICs), 8% address electrical systems and 23% address other devices or fields, eg magnetic recording heads, micro-electromechanical systems (MEMS), material properties, ESD control, stress tests and failure analysis (FA).

3.2. EOS definitions

Fig. 4 shows a histogram of the meanings of EOS as implied or defined by the investigated publications. Surprisingly, there are only a few papers (indicated by the bottom bar), that really *define*

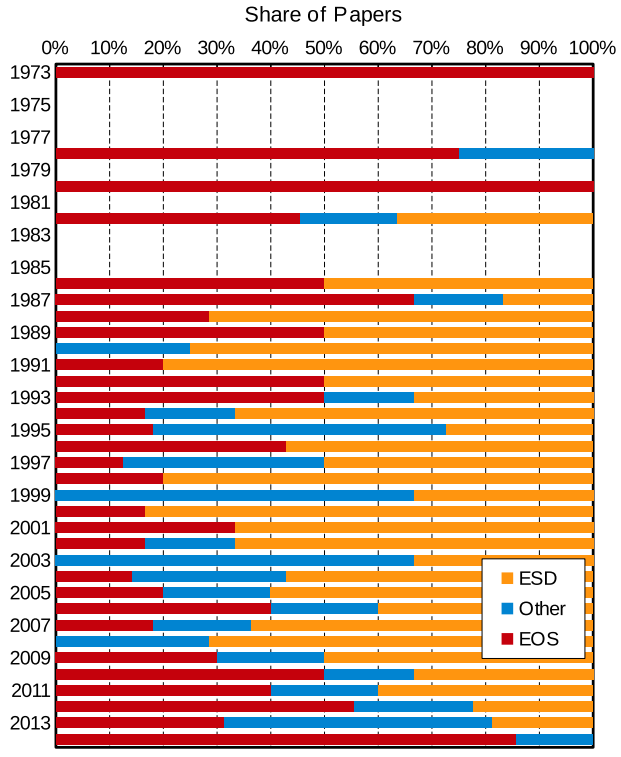

Fig. 2. Evolution of the subject of the investigated publications over 40 years. Note, as 2014 is concerned only publications published in the first half of that year are covered by this investigation. Hence, the lack of publications addressing ESD in that year is likely to be a result of the incomplete investigation of that year.

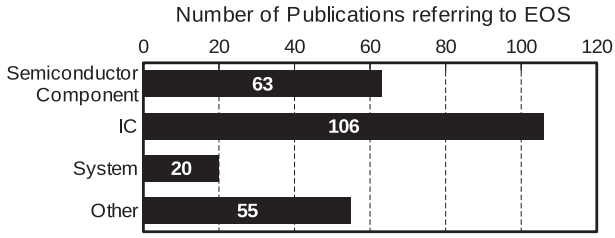

Fig. 3. Devices addressed in the investigated publications.

the term EOS, i.e. that state the exact meaning of the term EOS. The vast majority (68%) only *implies* one or multiple of the different meanings indicated by the grey bars and a significant number of publications (26%) indicated as "Undefined" even refers to the term EOS without giving any indication of its meaning. Only 12 publications representing 6% really *define* the term EOS. Among these publications, there is only one textbook but no White Paper and no standard.

The EOS definitions given in these 12 publications are:

(1) "(If) the device (is) damaged over the safe operating area (SOA); this is (an) EOS event." [9]
(2) "Electric Overstress (EOS) is the exposure of an item (an electronic component, for example) to a current or voltage beyond its maximum rating . . . ." [10]
(3) "EOS (electrical overstress) = operation beyond spec(ification) limit." [6,11]
(4) "EOS is generally any electrical stress that exceeds any of the typical failure thresholds of electrical components or systems and causes them to fail." [12,13]
(5) "EOS is any electrical stress that exceeds any of the absolute maximum ratings of a device and causes it to fail." [14]
(6) "EOS is electrical stress beyond the AMR (absolute maximum ratings) of a product." [15]
(7) "Electrical overstress (EOS) is any electrical stress that exceeds any of the absolute maximum ratings of an IC and causes it to fail, reversibly or irreversibly, immediately or delayed." [16,17]
(8) Per glossary "Electrical Overstress (is) an electrical event, of either over-voltage or over-current that leads to electrical component or electronic system damage and failure." [18]

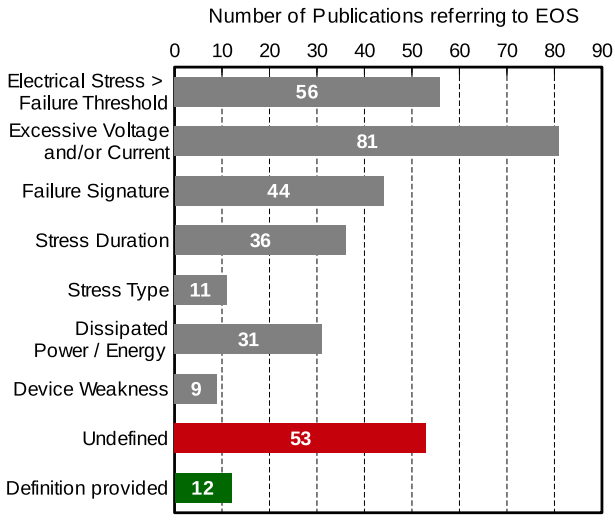

Fig. 4. Meanings of EOS.