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Editorial

Understanding the Reliability Physics of Electronic and Photonic Products: Roles of Failure-Oriented-Accelerated-Tests (FOATS)

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The reliability bottleneck of electronic, photonic, MEMS or MOEMS (optical MEMS) systems is, as is known, the physical performance of their materials and structures [1] and not its functional (electrical or optical) performance. It is well known also that it is the device packaging that is the most critical undertaking, when making a viable, properly protected and effectively-interconnected device and package into a reliable product. Accelerated life testing (ALT) [2,3] conducted at different stages of an IC package design and manufacturing is the major means for achieving that. Burn-in-testing (BIT) [4], the chronologically final ALT, aimed at eliminating the infant mortality portion of the bathtub curve prior to shipping to the customer(s) the "healthy" products, i.e. those that survived BIT, is particularly important: BIT is an accepted practice for detecting and eliminating possible early failures in the just fabricated products. Originally BIT used continuously powering the manufactured products by applying elevated temperature to accelerate their aging, but today various stressors, other-than-elevated-temperature, or a physically meaningful combination of several of them, are employed in this capacity. BIT, as far as "freaks" are concerned, is and always was, of course, a failure-oriented-accelerated-testing (FOAT) type of testing. The recent analyses improved our understanding of the role and significance of several important factors that affected BIT's testing time and stress level: the random failure rate of the mass-produced components that the product of interest is comprised of; the way to assess, from the highly focused and highly cost effective FOAT, the activation energy of the "freak" population; the role of the applied stressor(s); and, most importantly, - the probabilities of the "freak" population failures depending on the duration and level of the BIT's effort. These factors should be considered when there is an intent to quantify and, eventually, to optimize the BIT's procedure. But there is also another, so far less well-known and not always conducted today, FOAT [5-8] that has been recently suggested in connection with the novel probabilistic design for reliability (PDfR) concept [9-12]. Such a FOAT is supposed to be conducted at the design stage as a highly focused and highly cost effective undertaking and is the experimental foundation of the PDfR concept. Unlike BIT, which is always a must, the design stage FOAT should be conducted, when developing a new technology or considering a new design, and when there is an intent to better understand the physics of failure and, for many demanding applications, such as, e.g., aerospace, military, or long-haul communications, to quantify the lifetime and the corresponding, in effect, never-zero probability of failure of the product in the field. Such a design-stage FOAT could be viewed as a quantified and reliability-physics-oriented forty years old highly-accelerated-life-testing (HALT) [13,14], and should be particularly recommended for new technologies and new designs, whose physics of failure is yet unclear and when neither a suitable HALT, nor more or less well established "best practices" exist. When FOAT at the design stage and BIT at the manufacturing stage are conducted, a suitable and physically meaningful constitutive equation, such as, e.g., the kinetic multi-parametric Boltzmann-Arrhenius-Zhurkov (BAZ) model [15-21], could be employed to predict, from the test data, the probability of failure and the corresponding useful lifetime of the product. It is noteworthy that the flexible and physically meaningful BAZ model can be used also to predict the lifetime not only of IC packages, but the lifetime and the corresponding probability of failure of electronic devices as well [22]. The referenced reliability physics oriented analyses use, as a rule, analytical ("mathematical") predictive modeling [23,24]. In the author's opinion and experience, such modeling should always complement computer simulations: these two major modeling tools are based on different assumptions and use different computation techniques, and if the calculated data obtained using these tools are in agreement, then there is a good reason to believe that the obtained data are accurate and trustworthy.

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