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Editorial

Probabilistic-design-for-reliability Concept in Reliability Physics of Electronics and Photonics Systems

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"Probability theory is nothing but common sense reduced to calculation" Pierre-Simon, marquis de Laplace (1749-1827), French mathematician, astronomer, and physicist.

The reliability of the electronics and photonics products, including micro-electro-mechanical-systems (MEMS) and MOEMS (optical MEMS), depends, first of all, on the performance of the materials, devices and packages, and this situation will not change in the future [1]. The popular today forty-years-old highly-accelerated-life-testing (HALT) [2] has many merits, but is unable to predict the probability-of-failure of the product in the field. The recently suggested probabilistic-design-for-reliability (PDfR) concept [3,4] makes a difference in the state-of-the-art of reliability physics of electronic and photonic systems by putting the reliability prediction and assurance in these areas of engineering on a quantifiable and "reliable" ground. The concept is based on 1) highly focused and highly cost-effective failure-oriented-accelerated-testing (FOAT) that is expected to be conducted at the design stage and is aimed at understanding the physics of the anticipated failures, as well as at quantifying, on the probabilistic basis, the outcome of the FOAT conducted for the most vulnerable materials and structural element(s) of the product of interest (such as, e.g., solder joint interconnections that might experience inelastic strains and, as a result, suffer from low cycle fatigue conditions); 2) predictive modeling (PM), both computer simulations and analytical ("mathematical"), aimed at evaluating from the FOAT data, also on the probabilistic basis, the useful lifetime of the design of interest in actual operation conditions; and 3) subsequent sensitivity analyses (SA) that enables, if necessary, modifying, using the developed predictive models, the obtained information, so that the adequate probability of failure is established and assured. The PDfR concept proceeds from the recognition of the fact that the difference between a highly reliable and an insufficiently reliable product is "merely" in the levels of the never-zero probabilities of their failure. The approach can be used also to make sure that the product of interest is not more robust than necessary for the accepted low-enough level of the probability of failure. This probability cannot be high, of course, but does not have to be lower than necessary either: it has to be adequate for the given product and application. To get the best reliability "bang for the buck" is an obvious challenge for a product designer and manufacturer. It has been determined that the total product's cost computed as the sum of its initial (manufacturing) cost and the cost of maintenance (repair) can be minimized, if the product's availability (determined as the probability that the product is available to the user when the user needs it) is maximized. The design-stage FOAT is intended to be carried out when developing a new design or a new manufacturing technology and when high operational reliability, like the one required, e.g., for aerospace, military, or long-haul communication industries, or some medical devices is imperative. The recently suggested constitutive multi-parametric Boltzmann-Arrhenius-Zhurkov (BAZ) [5] constitutive equation could be used to predict the probability of FOAT failure, as well as the product's field failure, from the FOAT data. The BAZ equation can be effectively employed to analyze and design products with the predicted, quantified, assured, and, if appropriate and cost-effective, even with the specified probability of the operational failure. The next generation of (hopefully, failure-free) qualification tests (QT) for products designed and manufactured using PDfR, FOAT and multi-parametric BAZ could be viewed and conducted as a sort of a quasi-FOAT that adequately and consistently replicates the initial non-destructive segment of the previous full-scale FOAT. Burn-in-testing (BIT) [6] the chronologically final reliability test that is routinely conducted at the manufacturing stage of almost every IC product is also of a FOAT type: it is aimed at eliminating the infant mortality portion (IMP) of the bathtub curve (BTC) by getting rid of the low reliability "freaks" prior to shipping the “healthy” products, i.e., those that survived BIT, to the customer(s). It is noteworthy that some of the product development tests (PDT), such as, e.g., shear-off tests, are also failure-oriented, and contain many features of the FOAT conducted at the design and manufacturing stages. All the analyses of this perspective were carried out using analytical ("mathematical") predictive modeling. It is concluded that physically meaningful predictive modeling, preferably of the PDfR type, should always be considered and conducted prior to and during the actual testing procedure and that analytical modeling always complement computer simulations. Future work should be focused mostly on the experimental verification of the obtained findings and recommen-

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