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Editorial

# Reliability Physics of IC Products: Probabilistic Approach

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*"The only real voyage of discovery consists not in seeing new landscapes, but in having new eyes".*

*Marcel Proust (1871-1922), French novelist, critic, and essayist writer*

*"Probability theory is nothing but common sense reduced to calculation".*

*Pierre-Simon, marquis de Laplace (1749 – 1827), French mathematician and philosopher*

The reliability of the future electronics and photonics products, including the micro-electro-mechanical- systems (MEMS) and MOEMS (optical MEMS), will depend, first of all, on the performance of their materials, devices and packages [1]. The forty years old highly accelerated life testing (HALT) (see, e.g., [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] is based on 1) highly focused and highly cost-effective failure-oriented-accelerated-testing (FOAT) [5] aimed at understanding the physics of the anticipated failures and at quantifying, on the probabilistic basis, the outcome of the FOAT conducted for the most vulnerable structural element(s) of the product (such as, e.g., solder joint interconnections); 2) predictive modeling (PM) aimed at assessing, from the FOAT data, the probability of failure for the most likely operation conditions; and 3) subsequent sensitivity analyses (SA) that enable changing, if necessary, this probability to make it adequate for the given product and application. Such a 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 applications, or the future medical device engineering, is imperative. The PDfR concept proceeds from the recognition of the fact that the difference between a highly reliable and an insufficiently reliable product is "merely" the level of their never zero probability of failure. The PDfR can be used also to make sure that the product of interest is not made more robust than necessary. The operational reliability cannot be low, but does not have to be higher than necessary either: it has to be adequate for the given product and application.

Both reliability and cost-effectiveness are imperative, of course. To get the best reliability "bang for the buck" is an obvious challenge for a product designer and manufacturer. The total cost of a product, i.e. the sum of its initial (manufacturing) cost and the cost of maintenance (repair) can be minimized [4], if the product's availability (i.e., the probability that the device is available to the user when he/she needs it) is maximized. The recently suggested multi-parametric Boltzmann-Arrhenius-Zhurkov (BAZ) [6] equation could be used to predict the probability of FOAT failure and the field failure from the FOAT data. This equation can be effectively employed to analyze and design products with the predicted, quantified, assured, and, if appropriate and cost-effective, even specified probability of operational failure. These concepts and methodologies can be accepted as effective means for the evaluation of the operational reliability of electronic and photonic materials and products. The next generation of qualification testing (QT) specifications and practices for such products could be viewed and carried out as a quasi-FOAT that adequately replicates the initial non-destructive segment of the previously conducted comprehensive full-scale FOAT.

Burn-in-testing (BIT) [7], the chronologically final HALT 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) [8] by getting rid of the low reliability "freaks" prior to shipping the hopefully "healthy" products, i.e., those that survived BIT, to the customer(s).

All the above analyses were carried out using analytical ("mathematical") predictive modeling [9]. It is suggested that physically meaningful predictive modeling, preferably of the PDfR type, is always considered and conducted prior to and during the actual testing procedure and that analytical modeling always complements computer simulations.

Future work should be focused, in the author's view, on the experimental verification of the obtained findings and recommendations and should be conducted in application to particular devices, designs, manufacturing technologies, products and applications.

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