# Some critical problems of the mechanical behavior and performance of electronic and optical materials, assemblies and systems: Application of analytical (“mathematical”) modeling

**E Suhir**
Portland State University, USA

Some critical problems of the mechanical behavior and performance of electronic and optical materials, assemblies and systems are addressed and discussed. It is shown that application of analytical modeling (always confirmed by finite-element-analyses) enables to reveal and explain the underlying physics associated with such, often non-obvious, always non-trivial and sometime even paradoxical, problems and situations. Most of the problems were encountered by the first author during his tenure with Bell Labs (basic research area, Murray Hill, NJ), University-of-California at Santa Cruz, Portland State University at Portland, OR, and small business innovative research (SBIR) ERS Co., USA. The following major problems are addressed: magnitude and distribution of the interfacial thermal stresses in adhesively bonded or soldered assemblies; incentive for using low modulus bonding materials and, in some cases, materials with low yield stress; assemblies bonded at the ends; incentive for using test specimens with transverse grooves in the bonded materials for lower and more uniformly distributed interfacial stresses; thermostatic compensation in temperature-sensitive devices using conventional materials (as opposite to ceramics with negative CTE); bow-free (temperature change insensitive) assemblies; thermal and lattice mismatch stresses in semiconductor crystal grown assemblies; ability to adequately mimic drop test conditions using shock testers; demonstration that the maximum acceleration is not always the adequate criterion of the dynamic strength of an electronic product, and that a static short-term load could be more damaging than the dynamic one; combined action of tensile and bending deformations of the PCBs subjected to drop tests and ability to obtain closed-form and even exact solutions for highly nonlinear shock-excited vibrations, such as, e.g., those taking place during drop tests on the board level; role of upper harmonics during drop tests; nonlinear response of the rocket PCB (with surface-mounted devices on it) to the sudden acceleration applied to its support contour; modeling situations, when the dynamic response of a linear or a non-linear electronic system subjected to a short-time loading can be substituted with an instantaneous impulse; stress relief in solder joints of the second level of interconnections (package to PCB) owing to larger stand-off heights of the solder joints; incentive for using inhomogeneous solder joint systems for lower thermally induced stresses; thermal stress in flexible electronics; ability to predict the threshold of the added transmission losses in jacketed (single coated) optical fibers using mechanical considerations; incentive for mechanical pre-stressing of accelerated test specimens subjected to thermal loading; ability to relieve stress in thermoelectric module designs using thinner and longer legs; reducing bending stress in optical fiber interconnects by properly rotating their ends; low-temperature micro-bending of long-haul dual-coated optical fibers; two-point bending of optical fiber specimens. It is concluded that all the three basic approaches in microelectronics and photonics materials science and engineering - analytical (“mathematical”) modeling, numerical modeling (simulation) and experimental investigations - are equally important in understanding the physics of the materials behavior and in designing, on this basis, viable and reliable electronic devices and products. As to analytical modeling, it is a powerful tool that enables one to explain critical and often paradoxical situations in the behavior and performance of electronic materials and products, and to make a viable device into a reliable product.

**e**: suhire@aol.com

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