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Analytical ("mathematical") modeling enables explaining some critical paradoxical situations in electronic and photonic materials behaviors

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Merits, attributes and challenges associated with the application of analytical predictive modeling in electronics and photonics materials science are addressed, based mostly on the author's research during his tenure with Bell Labs, UC-Santa Cruz, Portland State University, and small business innovative research (SBIR) ERS Co., USA. The emphasis is on practically important, yet paradoxical, i.e., intuitively non-obvious, material behaviors. The addressed problems include, but are not limited to the answers to the following questions: 1) why do the interfacial thermal stresses concentrate at the assembly ends and, for large size and/or stiff assemblies, do not increase with the further increase in the assembly size? 2) Could thermostatic compensation in temperature sensitive optical devices be achieved by employing regular materials? 3) Is it possible to design, fabricate and operate a bow-free electronic assembly? 4) What are the relative levels of thermal and lattice mismatch stresses in semiconductor crystal grown assemblies, and could one grow dislocation free lattice-mismatch assemblies? 5) Could shock tests adequately mimic drop test conditions? 6) Is the maximum acceleration an adequate criterion of the dynamic strength of an electronic product? 7) Could a static load be more damaging than a dynamic one? 8) Could a closed-form solution be obtained for highly nonlinear vibrations? 9) How significant is the role of higher modes of the shock induced PCB vibrations? 10) Could inelastic strains in solder joint interconnections be avoided? 11) Stretchable electronics: does one really need good thermal expansion (contraction) match between the die and the carrier? 12) Could the threshold of the added transmission losses be predicted based on mechanical considerations? 13) Is there an incentive for pre-stressing accelerated test specimens? 14) Could thinner and longer legs in a thermoelectric module design relieve stress? It is concluded that analytical modeling should always complement computer simulation in every materials science undertaking of importance. These two major modeling tools are based on different assumptions and use different calculation techniques, and if the computed data obtained using these tools are in agreement, and then there is a good reason to believe that these data are accurate and trustworthy.

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