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Digital Twin-based hybrid PHM framework for monitoring package-level degradation

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Digital Twin can be broadly described as a continuously updated virtual representation of an object, system, or process which replicates all phases in the lifecycle of its physical counterpart. Originally conceptualized in 2003 [1], the term 'Digital Twin' came into existence after it first appeared in NASA's roadmap in 2010 [2]. The concept initially evolved within the framework of aerospace and manufacturing applications and has picked up a lot of traction in the past five years. Digital Twin is now commonly used in the context of products, processes, businesses, etc., and it has been embraced by many other industries such as healthcare and electronics.

The adoption of electronic devices and components in various applications has shown steep growth in last ten years, where some of the applications require them to withstand harsh environments. Thus, prognostics and health management (PHM) of microelectronics has gained importance more than ever. So far, the concept of Digital Twin has been implemented by contextualizing it for the respective use-case; and thus, it does not have a single fit-for-all definition or a standardized workflow. Therefore, it is crucial to clearly define a framework to implement a Digital Twin system for PHM of microelectronics. This presentation introduces such a framework adapted from a five-dimensional model [3] of Digital Twin.

First, physics-based and data-driven approaches of modelling and lifetime-prognosis are described, and their limitations on an individual basis are discussed. Then, a hybrid approach, which utilizes both of the aforementioned approaches as building blocks, is introduced along with its additional requirements such as the 'physics-of-degradation' models. Fundamental differences between a model and a Digital Twin of a product have been addressed, and three different complexity-levels (weak, cloud, and edge) of connections to the physical entity are discussed. The conflict of using edge and cloud-based computing for data-driven models, as well as the advantages of utilizing both of them together is also briefly touched upon. Lastly, an example of implementing the hybrid approach for monitoring temperature and humidity induced package-level degradation is presented.

Keywords: Digital Twin, prognostics and health management (PHM), electronic packaging, in-situ monitoring, physics of degradation.

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