Function/Performance Oriented Design and Manufacturing

Longqiu Li[1,2,#], Junmin Liu[1,2], Rencheng Zhuang[1,2], Dekai Zhou[1,2] and Xiaocong Chang[1,2]

1 State Key Laboratory of Robotics and System, Harbin Institute of Technology, Harbin, 150001, China
2 Key Laboratory of Micro-systems and Micro-structures Manufacturing, Harbin, 150001, China
Corresponding Author / Email: longqiuli@hit.edu.cn, TEL: +86-451-86403564, FAX: +6-451-86403564

KEYWORDS: Micro/nano functional devices, Micro/Nanorobots, Design, Manufacturing

Micro/nano functional devices (MNFDs) are highly integrated devices capable of performing multiple functions at the micro- and nanoscale. Their design and manufacturing have evolved from single-material, single-function and simple structures to multi-material, multi-function and complex structures. This evolution aims to enhance their application in cutting-edge fields such as biomedical engineering, microelectromechanical systems, and communications. The conventional design and manufacturing paradigm for MNFDs is serial and orientated towards assembly and dimensional accuracy. However, the isolated nature of material selection, structural design and process control inevitably leads to a trial-and-error process, introducing uncertainty in the functionality and performance of MNFDs. Consequently, this paradigm is no longer suitable for the development of multifunctional and high-performance MNFDs. The function/performance-oriented design and man ufacturing paradigm for material-interface-structure integration (FPD&M-MSI) is parallel. It emphasizes the functio n and performance of MNFDs, and considers the design and manufacturing of MNFDs in an integrated manner fr om multiple perspectives, including material properties, interface effects, structural layout and manufacturing proces ses. Compared with traditional design and manufacturing, FPD&M-MSI provides an alternative approach that no l onger blindly pursues assembly and dimensional accuracy. Instead, it directly targets the functionality and perform ance of MNFDs, thereby avoiding the tedious trial-and-error process. The FPD&M-MSI methods offer the opportunity to design and manufacture MNFDs with multi-materials and complex structures under multi-factor coupling, thus paving the way for the development of multifunctional/high performance MNFDs. This paper explores the FPD&M-MSI approach within the context of micro/nanorobots. We highlight three methodological ideas for FPD&M-MSI — "material-led design: selection and layout", "energy-field-led manufacturing: material distribution control" and "function-led testing: black-box testing" — all of which are function- and performance-oriented. Finally, the limitations of the current investigation are discussed, and our envisioned future directions for FPD&M-MSI improvements are shared. Our objective with this review is to propose a new paradigm for function/performance oriented design and manufacturing, providing a reference template for the design and manufacturing of micro/nanorobots and other MNFDs. This will assist researchers to develop MNFDs with richer functionality and higher performance.