KY Infrastructure for Convergent/Divergent Research on Voxel-Based Multi-material/multi-architecture Structure and Assembly

Summary

The goal of this proposal is to establish the infrastructure for convergent/divergent research on voxel-based multi-material/multi-architecture structure and assembly, which is integrated by the design for performance and functionality (DFPF). This proposed infrastructure will make KY more competitive in high-impact research by addressing multiple areas identified by National Science Foundation (NSF) including "Mid-scale Research Infrastructure" and "Growing Convergent Research at NSF". This proposed infrastructure strengthens statewide research collaborations among major KY academic research players (University of Louisville, University of Kentucky, Western Kentucky University). The newly established infrastructure will stimulate convergent research collaborations in the broad areas of advanced manufacturing processes and design for advanced manufacturing, with specific focus on the physical, mechanical and chemical interactions of material voxels (liquid droplets, slurries, suspensions, aerosols, hydrogel, aerogel) with each other and with 3D substrates/structures. Further, this infrastructure will empower a range of divergent research in application areas including energy &environment, biomedicine, pharmacy & healthcare, agriculture & food, as well as electronics and space exploration, which are empowered by close integration with smart data analysis and algorithms. These research topics not only align with the science and innovation strategy of KY but also foster synergies between academia and industry for sustainable societal and economical development of the state. A schematic of the research theme is shown in Figure 1, which illustrates the short-term and long-term research areas (divergence), as well as the anticipated impacts. It also clearly shows the high level of synergies/correlations among individual subject areas.

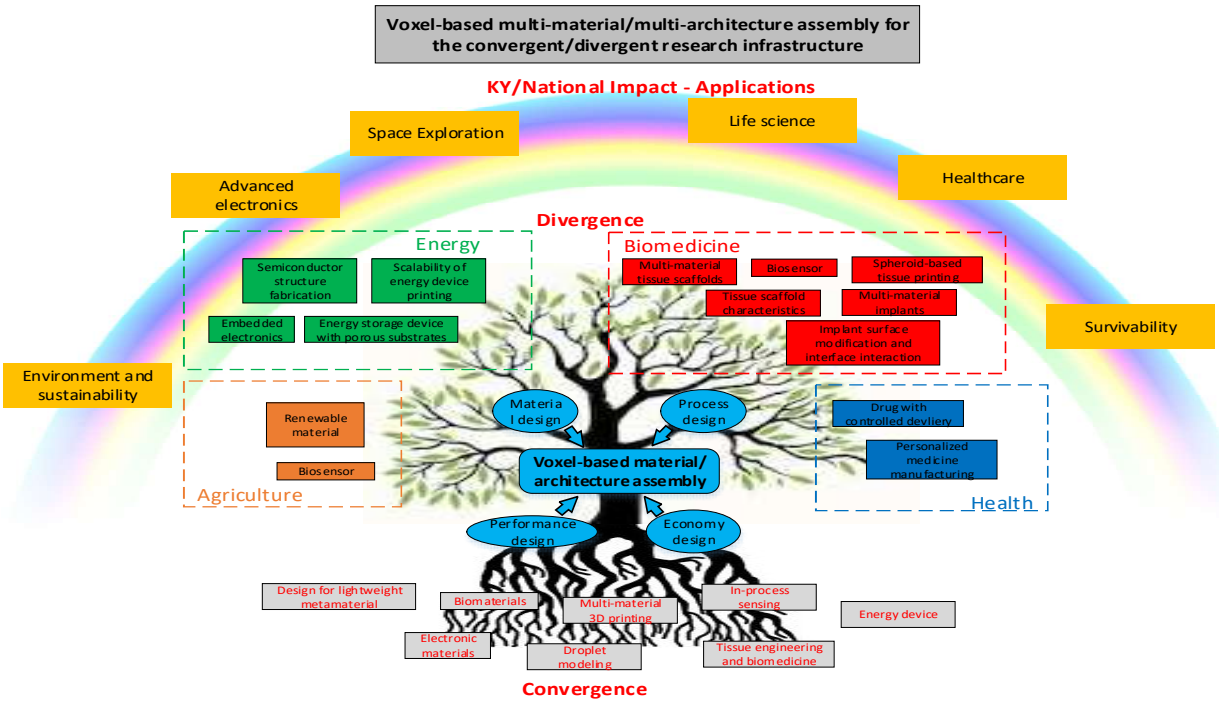


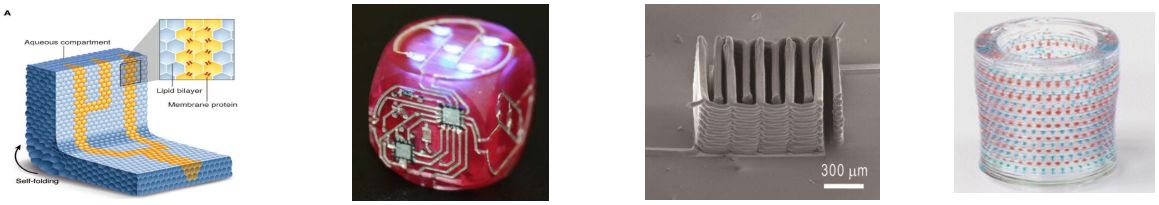
Fig.1 Research theme

Research focuses

The concept of "voxelized" fabrication opens the possibility of realizing "smart" material voxel assemblies. As in the case of direct write (DW) technologies, materials are delivered in forms of individual droplets, which are deposited on the substrate with spatial location control to form complex 3D architectures as shown in Fig. 2. Significantly enhanced performance and multi-functionality could be potentially achieved via the manipulation of **material designs** (e.g. doping, functionalizing, surface treatment, etc.) and the

manipulation of **structural designs** (e.g. metmaterial design, cellular/porous structures, agglomerate profiles, etc.), which require accurate **process control** of both the multi-material/multi-architecture structure formation and in-depth understanding of the behaviors of material voxels in highly complex environments (in-process and in-application). The fundamental research works in this area consist of multiple **fundamental aspects**:

1. The spatiotemporal characteristics of the material voxels during the fabrication processes;
2. The design and optimization of material voxels for both the functionality and the manufacturability;
3. The spatiotemporal interactions between the material voxels and the surrounding environments;
4. The design of architectures (structure + material) for the optimization of functionality and integrity;
5. Advanced processing technologies to enable fully-informed fabrication of multi-material/multi-architecture structures with high efficiency.



a. A printed droplet network for tissues

b. 3D electronic circuit on substrate

c. Micro Li-ion battery

d. Capsules for controlled drug release

Fig.2 Advanced multi-material/multi-architecture designs

Convergence/Divergence: The proposed research infrastructure will be established from multiple research areas that are highly synergistic. The convergence research efforts will focus on the generalization (synthesis) of knowledge from specific research topics, which are categorized into material design, process design, architecture/ performance design, and economic design. In supporting the establishment of fully-informed DFPF, process/material characterization technologies and process qualification methodologies (e.g. in-process sensing and control optimization) will be established, which is assisted by big data analysis algorithms, as it is expected that large amount of data (in-process, characterization, testing) will be generated. The fundamental knowledge will then be applied to the analysis and optimization of structures and materials in each specific areas and applications (derivation).

Mid-Scale Infrastructure: The research team is comprised of the multiple major research universities at KY (UofL, UK and WKU), with faculty members from diverse academic background across multiple principles (mechanical engineering, materials science, chemical engineering, biomedical engineering, biomedicine, manufacturing engineering, chemistry and biology). The team members represent faculty with a range of academic ranking, which allows the tenure-track faculty to collaborate with senior faculty on high-impact research areas. In addition, it is anticipated that with the proposed infrastructure other faculty from the member institutes and other KY institutes will interact with the team members on various research activities both during the project period and beyond. There also exist extensive research and education infrastructures in each of the institutes that will be utilized to establish the proposed infrastructure.

Broader Impacts

This project will spark significant synergistic collaborations with the existing research infrastructures in KY, and enable more extensive research collaborations between the team members and various federal grant agencies by creating fundamental knowledge creation and application. It is also a pivot platform to continue introducing frontier and promising technological concepts into application areas, realize the exploration and breakthrough of the critical component of the advanced manufacturing and promote a diversified emergence of innovative technologies and their supportive new scientific knowledge. The broad impact of this research will also actively interconnect the upstream education and the downstream technological and business development. It functions as a bridge to remove barriers of development in each individual areas, satisfying, inspiring and stimulating demands and developments.