

3D/4D Printing Multi-Material and Shape-Memory Devices for Wireless Electronics

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Additively manufactured electronics (AME) and 4D printing technologies are reshaping the functionalities of contemporary electronic devices. The emerging 3D/4D printing technologies facilitate the prototyping of complex electronic functions that prove challenging with conventional methods. This talk provides an insightful discussion of the evolving techniques in 3D/4D printed electronics, employing multi-materials and shape-memory materials to fabricate functional electronic devices. State-of-the-art AME (Figure 1) and 4D printed designs (Figure 2) will be introduced for 5G/6G electronics.

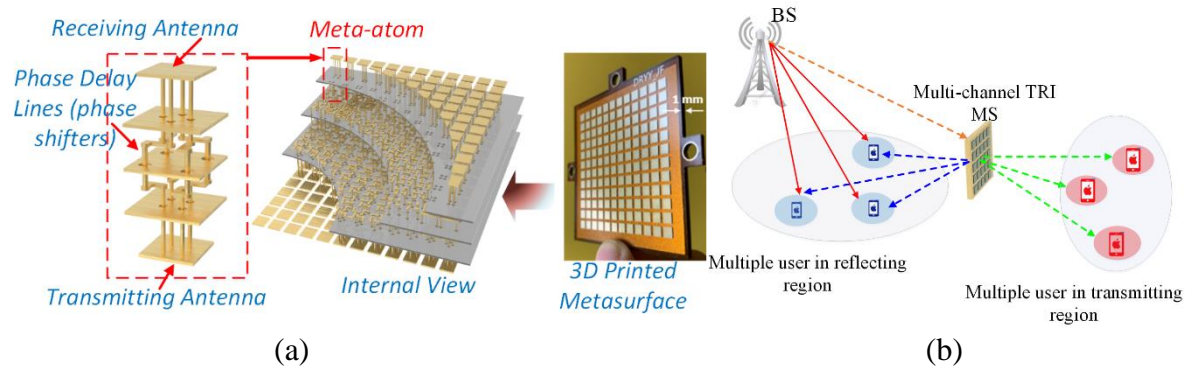


Figure 1. Multi-Material 3D printed metasurfaces with seven metal layers in a single substrate: (a) Blind vias are 3D printed for interconnecting phase delay lines among the transmitting and receiving antennas at the top and bottom surfaces [1], (b) The application of transmission-reflection-integrated metasurfaces for multiple users in wireless communication environment [2].

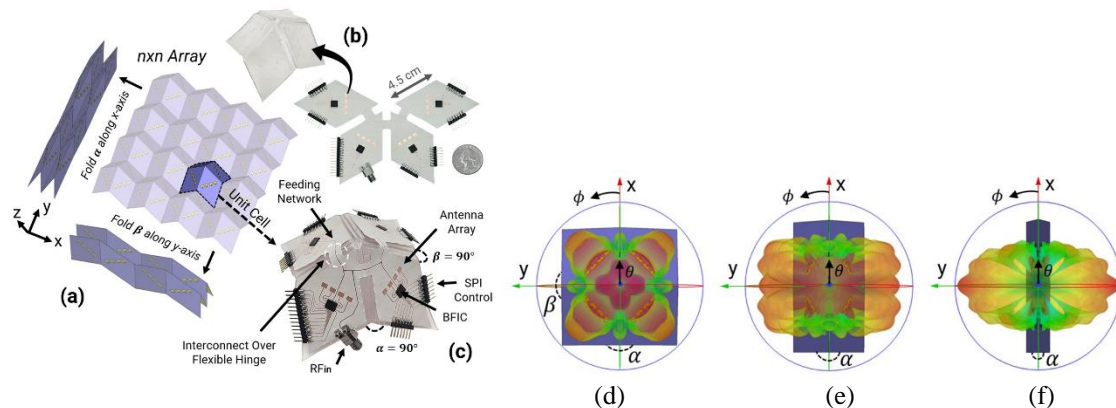


Figure 2. 4D origami-inspired, RFIC-based, and fully integrated phased array incorporating foldable “arch” interconnects. (a) Antenna array of an “eggbox” origami. (b) Fabrication process, and (c) fabricated unit cell on a flexible 3D printed substrate. (d), (e), (f) Radiation pattern reconfigurability for different folding angles [3][4].

[1] J. Zhu, Y. Yang, J. Lai, and J. Nulman, “Additively manufactured polarisation insensitive broadband transmissive metasurfaces for arbitrary polarisation conversion and wavefront shaping,” *Adv. Opt. Mater.*, vol. 10, no. 21, p. 2200928, 2022.

[2] J. Zhu and Y. Yang, “3-D printed transmission-reflection-integrated metasurface for spin-decoupled full-space quadruplex channels independent phase modulation,” *IEEE Trans. Microw. Theory Tech.*, Jan. 2024.

[3] H. Al Jamal, C. Hu, N. Wille, and M. Tentzeris, “Beyond planar: An additively manufactured, origami-inspired, and shape-changing RFIC-based phased array for near-limitless radiation pattern reconfigurability in 5G/mmWave applications,” *IEEE Antennas Wirel. Propag. Lett.*, 2024.

[4] Y. Yang, et. al. “A review of multimaterial additively manufactured electronics and 4-D printing/origami shape-memory devices: design, fabrication, and implementation”, Proceedings of the IEEE, invited paper, accepted in Sep. 2024.