Mechanics-guided 3D assembly for electronics and microsystems

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Abstract

3D micro-/nano-structures have widespread applications in a broad spectrum of cutting-edge areas, such as bio-integrated electronics, microrobots, tissue engineering, among others. Existing manufacturing approaches to form such 3D micro-/nano-structures, however, can only be used directly with a narrow range of materials and/or 3D geometries. A grand challenge in the field is in the development of schemes that allow construction of 3D structures in device-grade crystalline inorganic materials essential for high-quality electronics and microsystems. In this talk, I will introduce a mechanics-guided assembly approach that exploits controlled buckling to construct complex 3D micro/nanostructures rapidly from patterned 2D micro/nanoscale precursors. This approach applies to a broad set of materials (e.g., semiconductors, polymers, metals, and ceramics) and even their heterogeneous integration, over a wide range of length scales (e.g., from 100 nm to 10 cm). Development of a rational microlattice design allows transformation of 2D films into programmable 3D curved mesosurfaces through this assembly approach. Analytical modeling and a machine learning–based computational approach serve as the basis for shape programming and determine the heterogeneous 2D microlattice patterns required for target 3D curved surfaces. By studying fundamental aspects of adhesion and delamination in the film/substrate system, general design diagrams are developed to serve as guidelines for the selection of engineering parameters to avoid interface-related failure. A wrinkling-assisted strategy is also proposed to substantially facilitate the delamination at desired regions of the film/substrate system. The compatibility of the approach with the state-of-the-art fabrication/processing techniques available in semiconductor industries, allow transformation of diverse existing 2D microsystems into 3D configurations, providing unusual design options in the development of fundamentally new devices. I will introduce a few examples of unusual bioelectronic devices and bioinspired microrobots enabled by the mechanics-guided 3D assembly.

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