A Generic Soft Encapsulation Strategy for Stretchable Electronics

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Abstract

Recent progress in stretchable forms of inorganic electronic systems has established a route to new classes of devices, with particularly unique capabilities in functional bio-interfaces, because of their mechanical and geometrical compatibility with human tissues and organs.[1] A reliable approach to physically and chemically protect the electronic components and interconnects is indispensable for practical applications, since a direct exposure to the environment could lead to failure or damage of fragile elements.[2] Although recent reports describe various options in soft, solid encapsulation, the development of approaches that do not significantly reduce the stretchability remains an area of continued focus.[3] Here, we reported a generic, soft encapsulation strategy that is applicable to a wide range of stretchable interconnect designs, including those based on two-dimensional (2D) serpentine configurations, 2D fractal-inspired patterns, and 3D helical configurations. This strategy forms the encapsulation while the system is in a pre-strained state, in contrast to the traditional approach that involves the strain-free configuration, followed by release of the pre-strain to complete the process. Combined theoretical modeling and experimental measurements highlight the deformation mechanisms of the interconnects encapsulated using both the proposed and the traditional strategy. A systematic comparison reveals that substantial enhancements (e.g., ~ 6.0 times for 2D serpentine, ~ 4.0 times for 2D fractal and ~ 2.6 times for 3D helical) in the stretchability can be achieved through use of the proposed strategy. Demonstrated applications in highly-stretchable light-emitting diodes (LEDs) systems that can be mounted onto complex curvilinear surfaces illustrate the general capabilities in functional device systems.

Key words: encapsulation method; two-stage encapsulation; soft elastomers; stretchable electronics; buckling

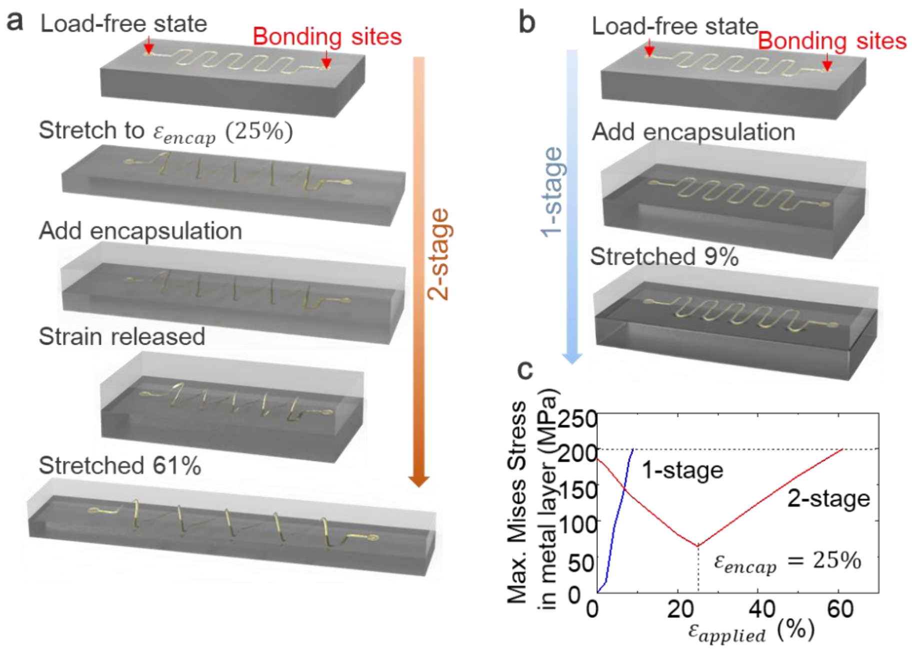

Figure 1. Schematic illustration of the proposed 2-stage encapsulation strategy and conventional 1-stage encapsulation strategy for 2D serpentine interconnects. (a,b) Process of the (a) 2-stage and (b) 1-stage soft encapsulation strategy for 2D serpentine interconnects. For 2-stage encapsulation strategy, the soft elastomer encapsulation is added while the substrate, on which the 2D serpentine interconnects are selectively bonded, is stretched to an encapsulating strain (ε_{encap}). Meanwhile for 1-stage encapsulation strategy, the encapsulant is added at load-free state. (c) Maximum Mises stress in the metal layer of the 2D serpentine interconnect as a function of the applied strain ($\varepsilon_{applied}$).

References

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