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Lateral buckling and mechanical stretchability of kirigami membranes in elastomer-supported stretchable electronics

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Abstract

Flexible/stretchable electronic technologies are of growing interest, oweing to their ability to render rigid and brittle semiconductors systems in forms that allow extremely large strain deformation. This class of technology opens up diverse engineering applications, ranging from wearable optoelectronic devices to epidermal health monitor, to sensitive robotic skins, and to eye-ball like digital camera. Many such stretchable devices utilize island-bridge design, in which active components are distributed in localized, nondeformable platform (i.e., islands), and joined by deformable interconnects. This strategy could offer considerable stretchablity (⩽ 80%), but is limited by the large heat generation and low surface filling ratio due to the narrow and long interconnects (i.e., serpentine interconnects[1] or non-coplanar interconnects[2]). An alternative type of interconnects that exploit self-similar geometries can achieve a much higher surface filling ratio[3], however, it demands highly precise planar fabrication equipment, and the problems of heat generation also remains.

Island-bridge strategy incorporated with kirigami membranes (as shown in Fig. 1) can provide large stretchability while ensuring high surface filling ratio and low heat generation[4]. In this design, membranes with precisely engineered cuts are utilized to form the bridge, and can accomodate nearly all of the deformation under stretching condition. Remarkable progresses have been made in application of stretchable kirigami membranes[5], however, the underlying mechanics that governs the postbuckling process remains unclear, due to the complex geometries and nonlinear buckling behavior.

The aim of this study is to present a systematic investigation for the postbuckling behavior of kirigami membranes, through combined analytical modeling, numerical simulations, and experimental measurements (Fig. 2). By formulating a scaling law to the localized strain, this paper established the correlations between the stretchability and various geometric parameters, providing a design guidelines for practical applications. Furthermore, we demonstrate an optimized kirigami membrane as part of a stretchable metal electrode, with high surface filling ratio and large stretchablity, thereby outperforming interconnects design reported previously.

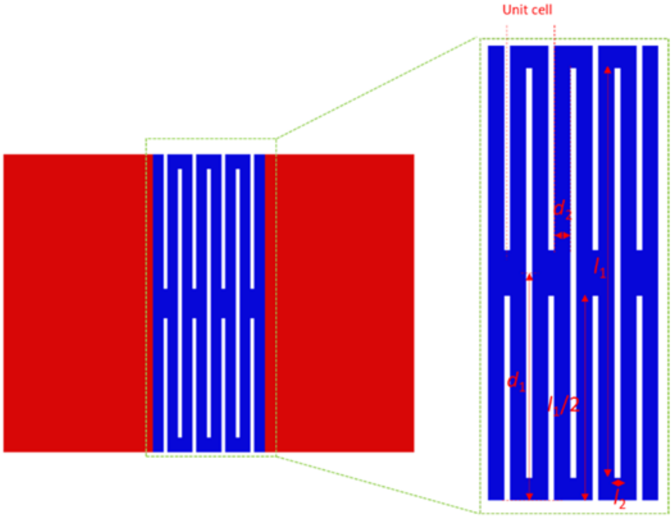

Figure 1. illustration of geometric parameters for a kirigami membrane

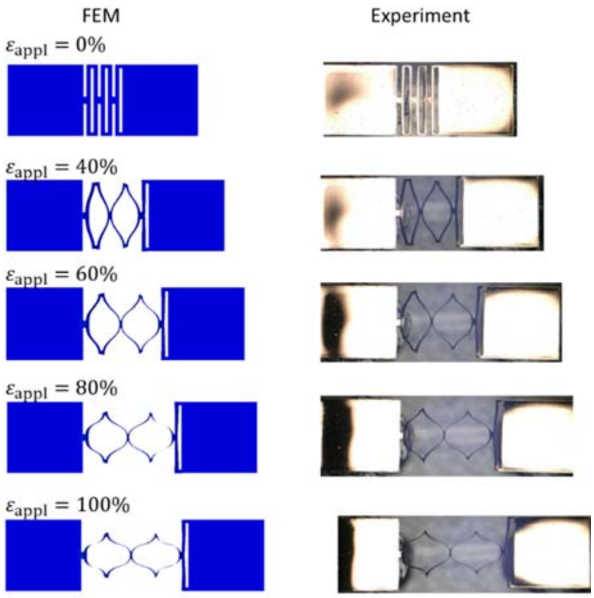

Figure 2. FEM predictions and SEM photos for the stretching process of kirigami membrane

References

[1] Kim DH, Song J, Choi WM, et al. Materials and noncoplanar mesh designs for integrated circuits with linear elastic responses to extreme mechanical deformations. Proceedings of the National Academy of Sciences of the United States of America, 1Vol. 105, No. 48, pp. 18675-18680, 2008.

[2]Graudejus O, Morrison B, Goletiani C, et al. Encapsulating Elastically Stretchable Neural Interfaces: Yield, Resolution, and Recording/Stimulation of Neural Activity. Advanced Functional Materials, Vol 22, No. 3, pp. 640-651, 2012.

[3]Xu S, Zhang Y, Cho J, et al. Stretchable batteries with self-similar serpentine interconnects and integrated wireless recharging systems. Nature communications, Vol. 4, pp. 1543, 2013.

[4]Shyu TC, Damasceno PF, Dodd PM, et al. A kirigami approach to engineering elasticity in nanocomposites through patterned defects. Nature materials, Vol 14, No. 8, pp. 785-789, 2015.

[5]Song Z, Wang X, Lv C, et al. Kirigami-based stretchable lithium-ion batteries. Science Report. Vol 5, pp. 10988, 2015.