外国語要旨

Mechanical response of kirigami sheet materials
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”Kirigami” is originally a Japanese art technique using paper and scissors (”Kiri” means cutting, ”gami” means paper in Japanese), and can be regarded as a variation of ”Origami” in scientific fields. These kinds of technique can add sheet materials mechanical and functional properties with macroscopic patterning [1]. The basic kirigami structure with parallel patterned slits makes sheet materials highly stretchable. This property has been applied to varieties of materials [2, 3]. However, any simple relations between the mechanical response and arrangements of cuts have not been explored, although such relations could be useful for engineering applications [4, 5].

In this study, we develop a simple theoretical model, while we perform experiments to provide physical understanding. We conduct tensile tests at a constant low pulling speed. Our samples are one-column kirigami sheets made of Kent paper for various parameters characterizing kirigami patterning. On the other hand, we estimate the deformation energy of the simplified kirigami model regarding the structure as a series of slightly bent beams. We further present our experimental results and demonstrate the agreement between theory and experiment.

The main results are summarized as follows. (I) Kirigami’s high extensibility is a result of a transition of the deformation modes from the in-plane to out-of-plane deformation. This transition occures at the point at which terminates the initial regime of the mechanical response of kirigami structure. (II) We clarify the physical origins of the transition and mechanical regimes, which are revealed to be governed by simple scaling laws. We confirm that the results could be useful for controlling and designing the mechanical response of sheet materials. (III) The transition in the force-elongation curve is discontinuous in our experimental results for Kent paper. Analyzing our simple model further, we show the discontinuous transition qualitatively, obtaining the ratio of the forces before and after transition. We also find that an analytical expression for the ratio well accounts for the experimental results. (IV) We perform experiments with rubber kirigami, which shows a continuous transition in the initial regime. To reproduce this continuity theoretically, we modify our previous model. We demonstrate an analogy between the present theory and Landau’s theory of continuous thermodynamic transitions, by regarding a rotation angle and elongation of kirigami as the order parameter and the inverse temperature, respectively. We compare this modified model with the original model and discuss in what situation each model is relevant for

describing experiment.

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