Thermal Emission Manipulation Enabled by Nano-Kirigami Structures

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INTRODUCTION

Radiative heat transfer is a fundamental physical phenomenon encountered in lighting, temperature management, energy utilization, thermal imaging, and other fields, with significant applications and research interest. Despite advances in static properties manipulation using metamaterials, dynamic control methods remain limited, often constrained by device material/structural properties.

Nano-kirigami metasurfaces, with diverse driving mechanisms and reconfigurable geometries, offer an ideal platform for dynamic radiative heat control. Leveraging focused ion beam nano-kirigami technology, a recent three-dimensional micro-nanofabrication， these surfaces enable intricate 2D pattern creation and transform flat films into complex 3D structures, overcoming traditional micro-nanofabrication limitations.

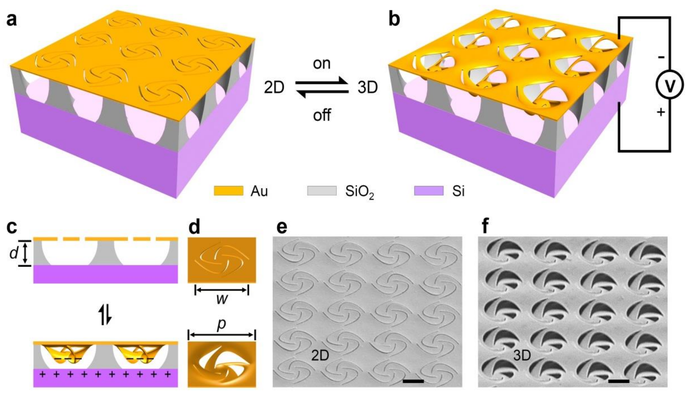

Fig.1 An example of electromechanical nano-kirigami for optical reconfiguration [Nat. Commun. 12, 1299 (2021)].

OBJECTIVES

We investigated the three-dimensional mechanical deformations of nano-kirigami structures, such as helical and pinwheel patterns, under the influence of electrostatic forces, mechanical stress fields, and other factors. Additionally, we observed their dynamic spectral response characteristics in the mid-infrared wavelength range.

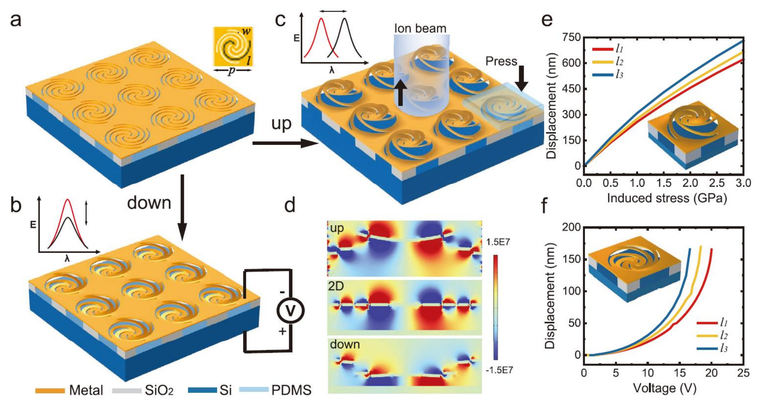

Fig.2 Schematic of the designed nano-kirigami structures and the dynamic driving methods.

RESULTS

- **The three-dimensional deformation of nano-kirigami structures can not only induce changes in the intensity of infrared resonance absorption/emission but also lead to variations in the wavelengths of resonance absorption and emission.**

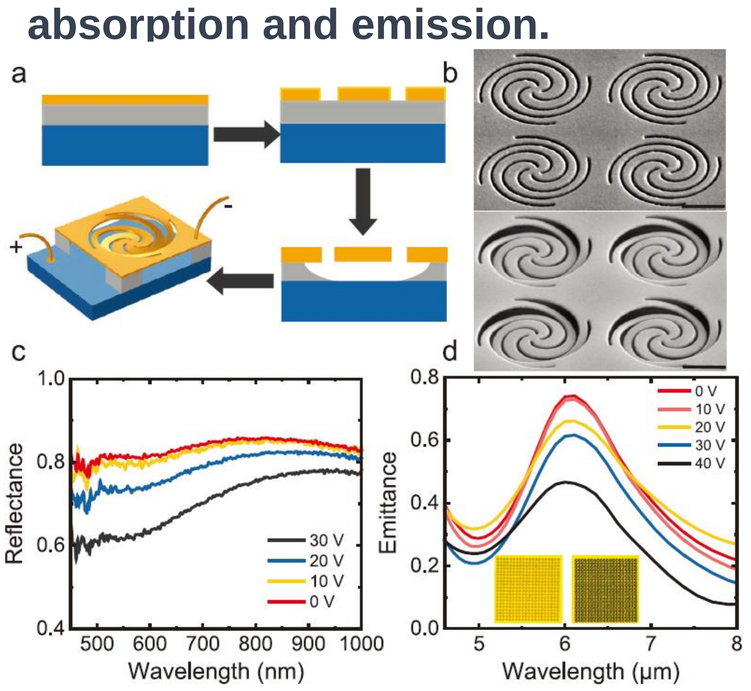

Fig.3 Implementation of a Spiral-Shaped Dynamic Radiative Heat Control Metasurface Device.

- **Nano-kirigami thermal radiation devices can also dynamically control the wavelength range of thermal radiation and the transmission/absorption of visible light, thereby achieving efficient thermal management.**

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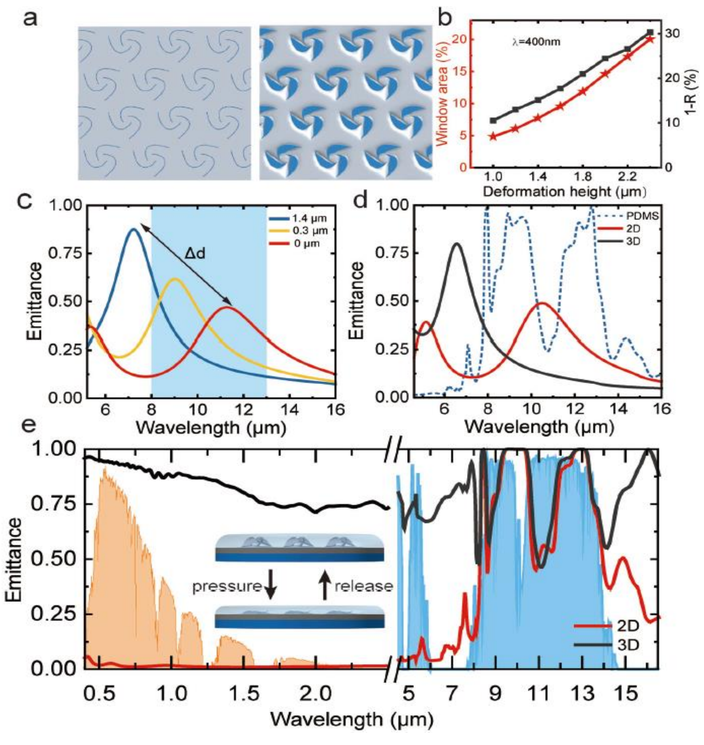

Fig.4 Implementation of a Pinwheel-Shaped Dynamic Thermal Management Device.

CONCLUSIONS

- **The infrared response of nano-kirigami structures can be dynamically controlled through electrostatic forces or mechanical stress.**
- **The nano-kirigami thermal radiation control system can independently adjust radiative intensity and radiative peak wavelength over a wide range.**

Based on nano-kirigami structures, metasurfaces for thermal radiation control offer flexible spectral tuning capabilities and unique dynamic control methods. They serve as an ideal platform for reconfigurable thermal radiation control and hold the potential to play a significant role in areas such as energy conversion and thermal camouflage.