Multiphysics Simulation of Micro-LED Based on Augmented Reality

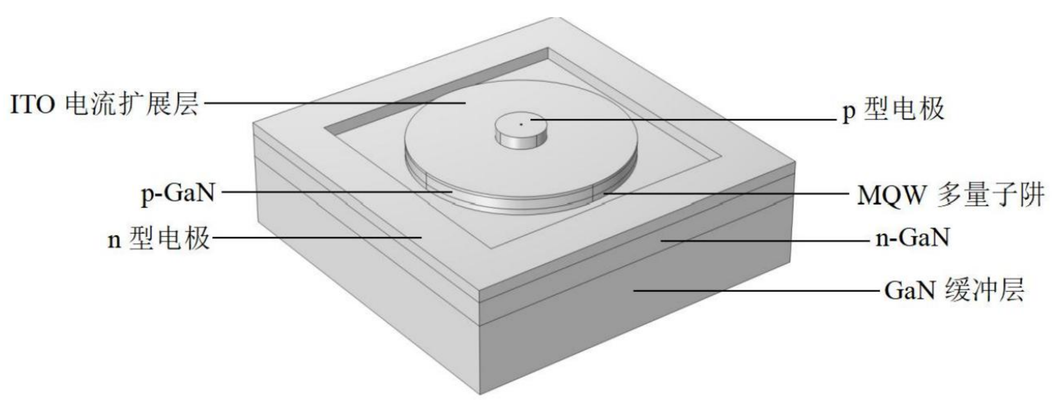
Yumeng Wei, Xiaohong Li

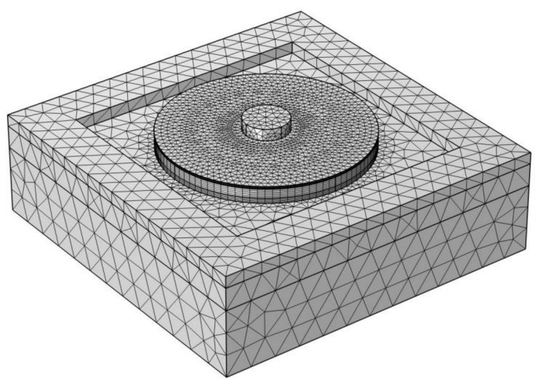
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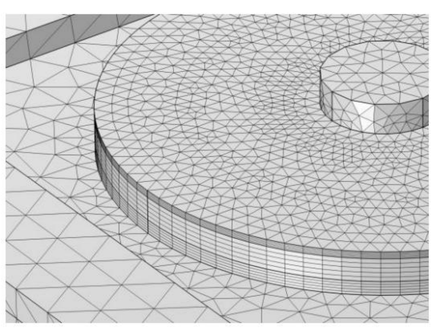
Introduction

In recent years, augmented reality (AR) display technology has advanced rapidly, finding applications in automotive, near-eye display, and industrial visualization. Micro-LED is regarded as the ideal choice for next-generation AR displays owing to its high brightness, high contrast, fast response, long lifetime, and low power consumption. However, high-density integrated Micro-LEDs generate substantial non-radiative recombination and Joule heat during operation, raising device temperature and thus reducing internal quantum efficiency, luminous efficiency, and causing wavelength shifts. Moreover, mismatched thermal expansion coefficients among materials induce thermal stress and structural deformation, affecting long-term reliability. Single-physical-field methods can no longer capture such multi-field interactions. Therefore, this work establishes 3D flip-chip Micro-LED single-pixel and 2×2 array models using COMSOL Multiphysics for thermal-mechanical coupling simulation.

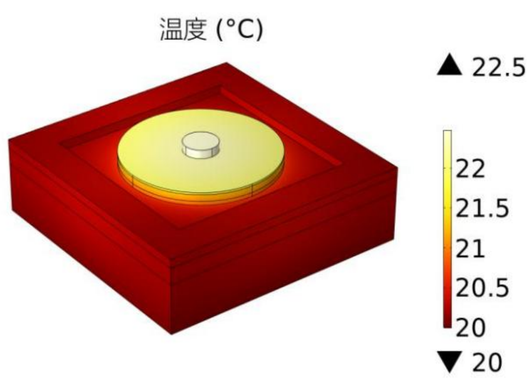
Modeling

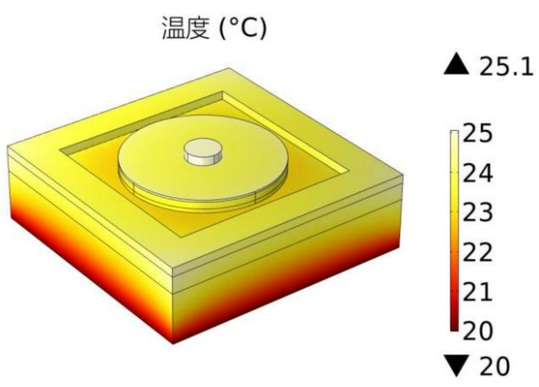


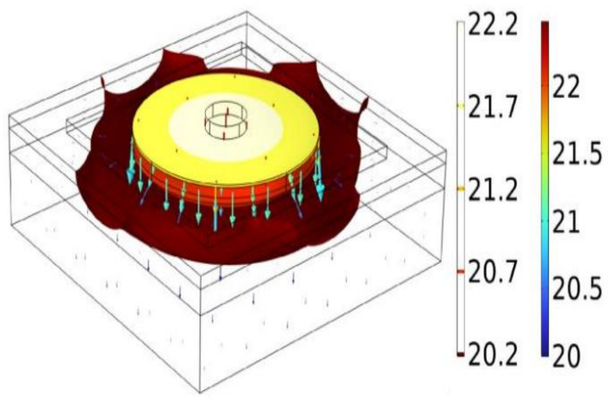


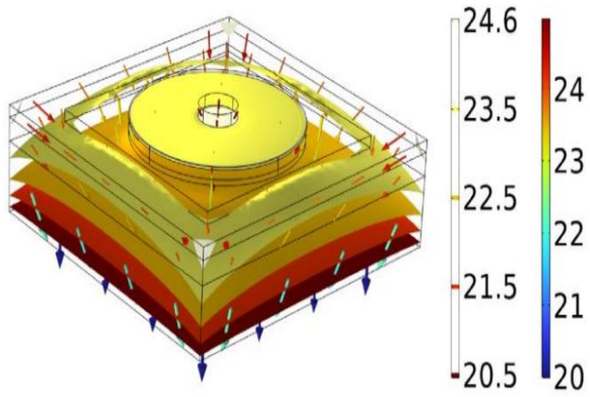


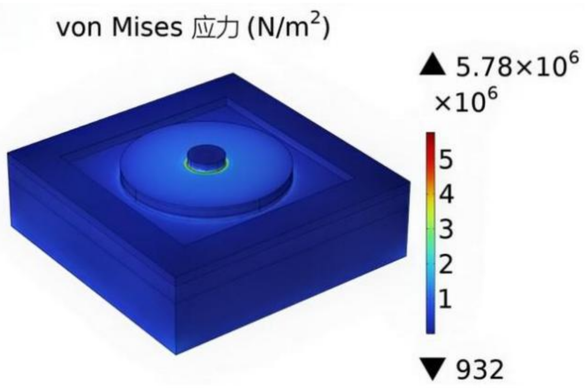
Results

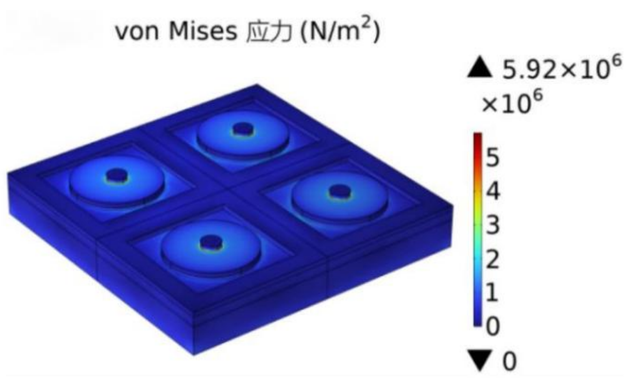


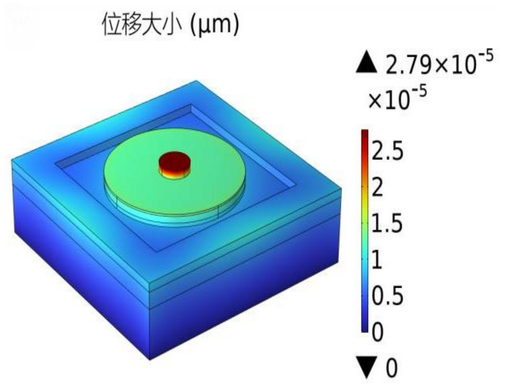


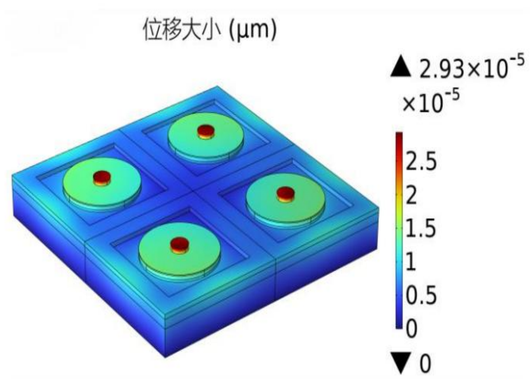












Conclusion

This work addresses the demand for high-brightness, highly integrated Micro-LEDs in AR displays. To tackle thermal stress failure and heat dissipation issues in high-density integrated devices, 3D flip-chip Micro-LED single-pixel and array models were built in COMSOL Multiphysics for systematic multi-physics coupling simulation and thermal management solutions. Key findings: (1) Heat is mainly concentrated in the multiple quantum well active region and electrode contacts; solar radiation loading significantly affects temperature rise, with full-boundary loading causing far greater heating than local loading. ITO acts as the main vertical thermal resistance due to its low thermal conductivity, while Au electrodes and GaN epilayers are critical for lateral uniformity and vertical conduction. (2) Under thermal-mechanical coupling, maximum von Mises stress occurs at p-electrode corners and electrode/epilayer interfaces due to mismatched thermal expansion and geometric discontinuities; arraying amplifies this stress. Thermal deformation manifests as upward bulging of top electrodes and the active region, decaying from center to edge and from top to bottom.

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