

Metasurface-assisted optical transparency of a continuous metal film

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15s-Summary

Question: Transparent conductors are useful, but conventional ITO film is expensive and not sustainable.

Task: Find a new design strategy of transparent conductors based on continuous metal film.

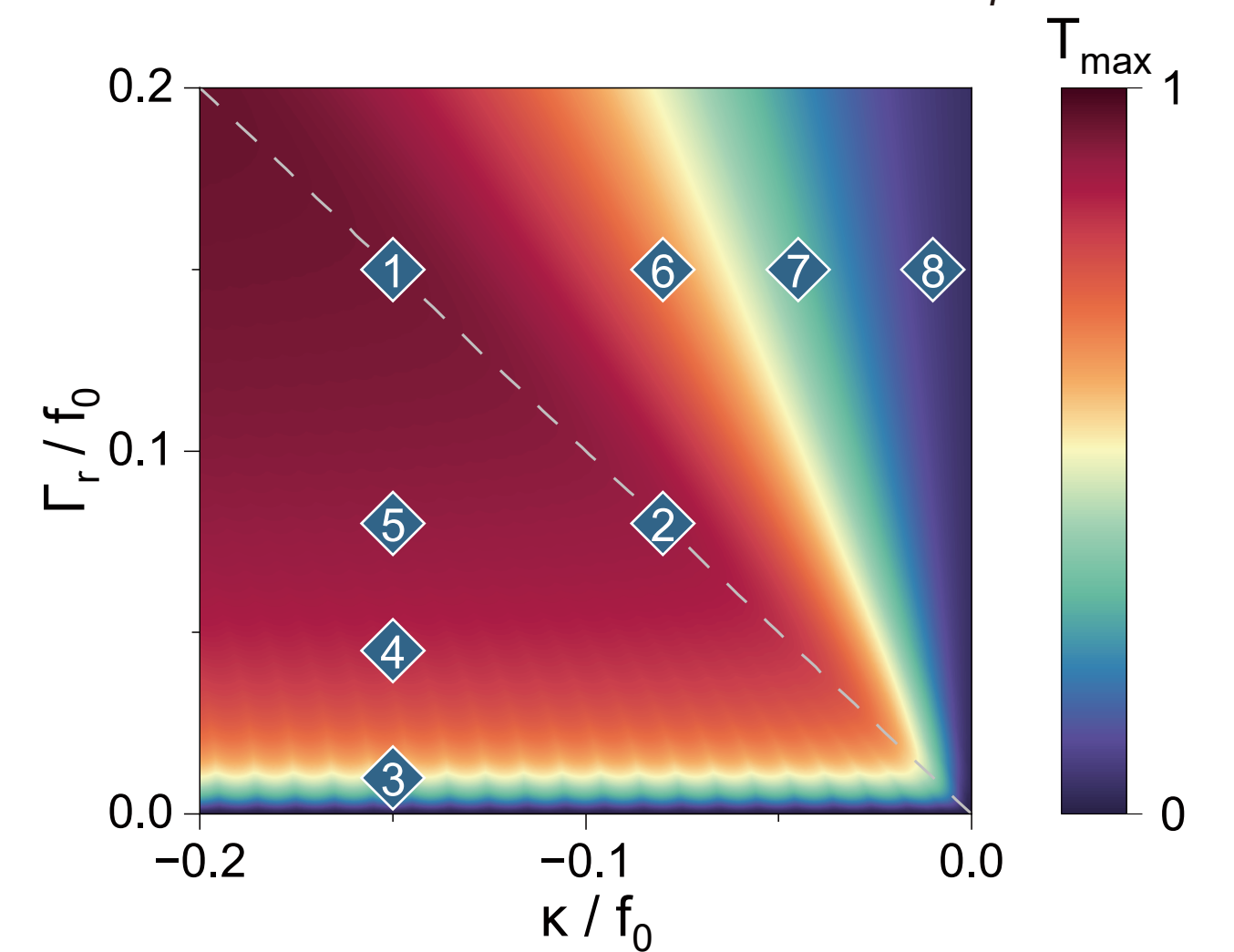
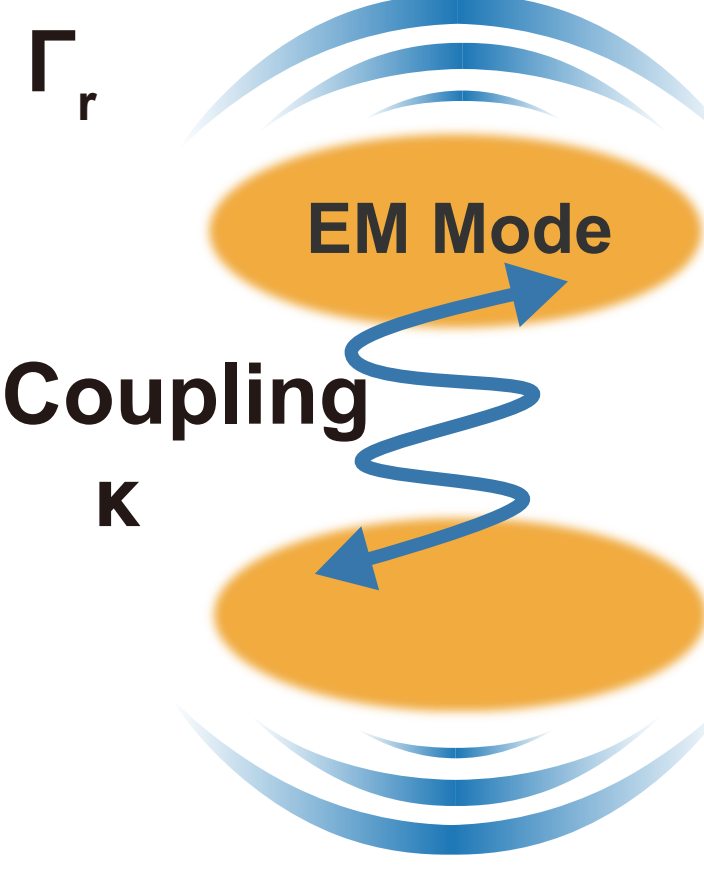
Results: A transparent metasurface/metal film/metalsurface configuration is proposed based on Coupled Mode Theory (CMT).

Free-standing samples were fabricated by the transmitted e-beam lithography technique. $T_{\max} \approx 55\%$ is obtained for a 28nm thick Ag film.

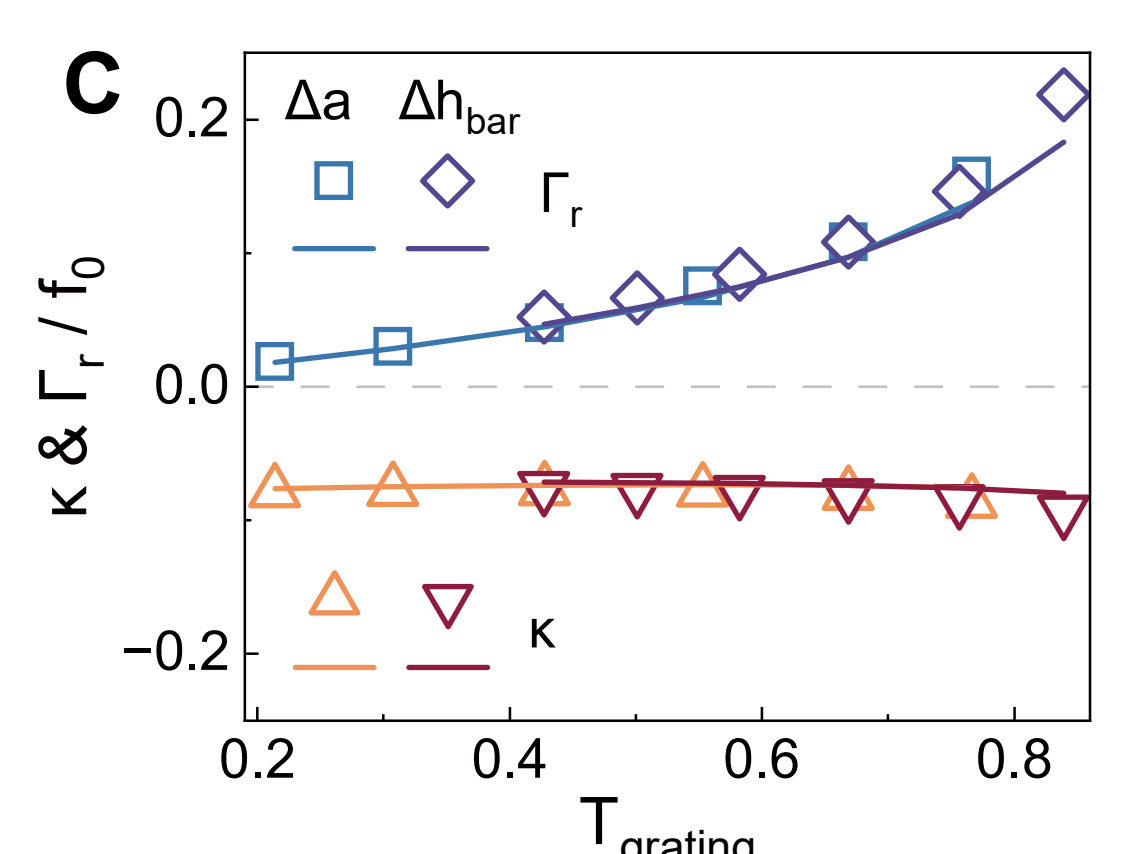
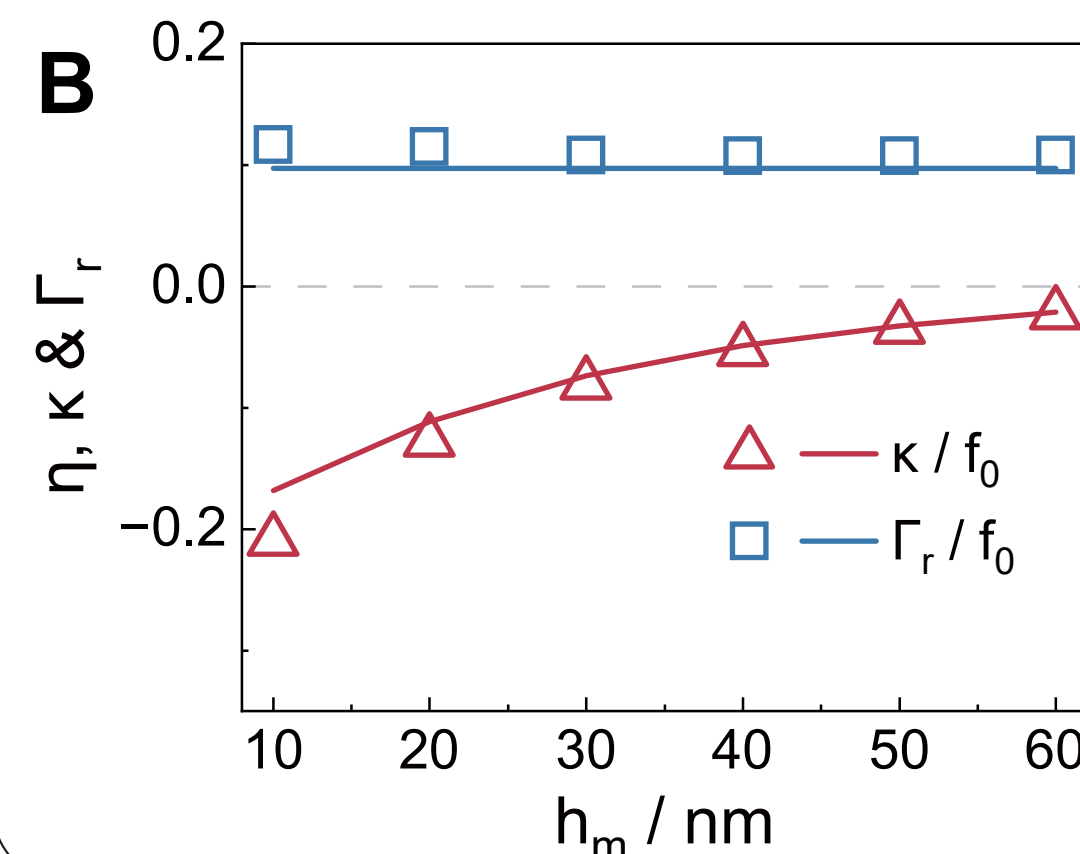
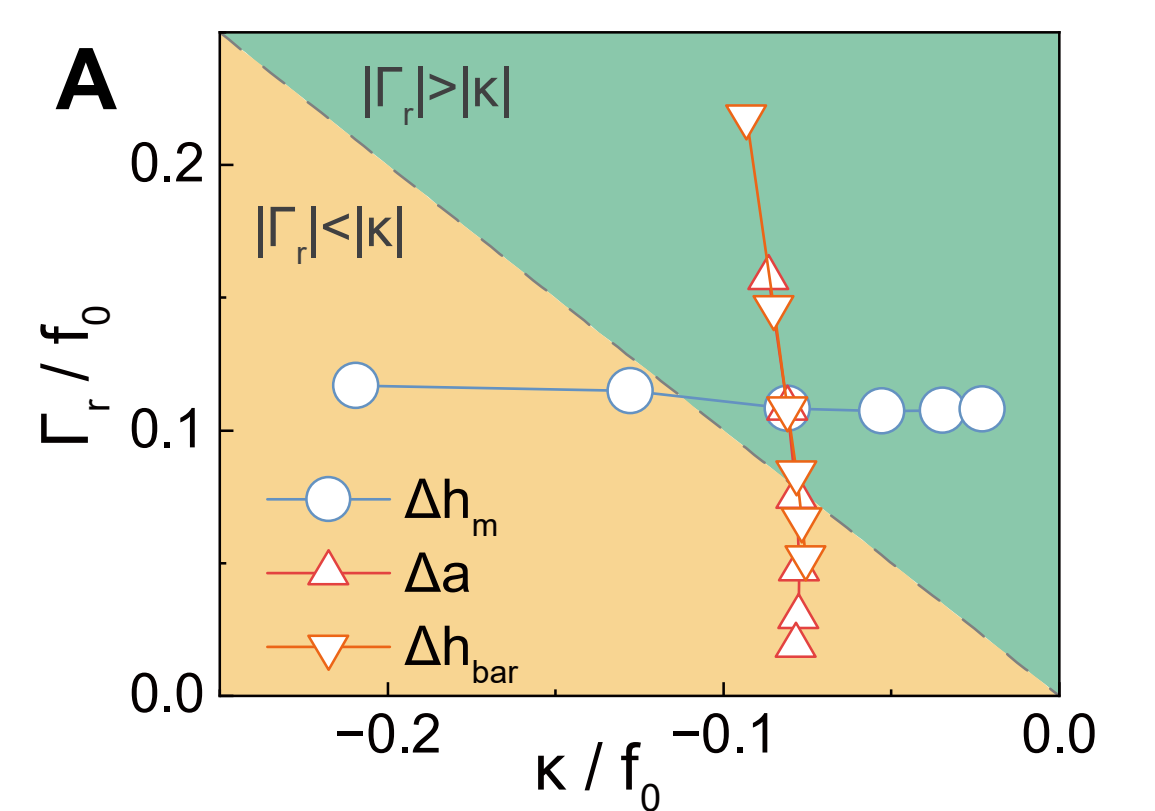
Theory

- Two SiN_x cavities support two F-P electromagnetic modes.
- Max transmittance is mainly controlled by Radiation Loss Γ_r and Nearfield Coupling κ , with optimal condition $\kappa = \Gamma_r$.

Radiation



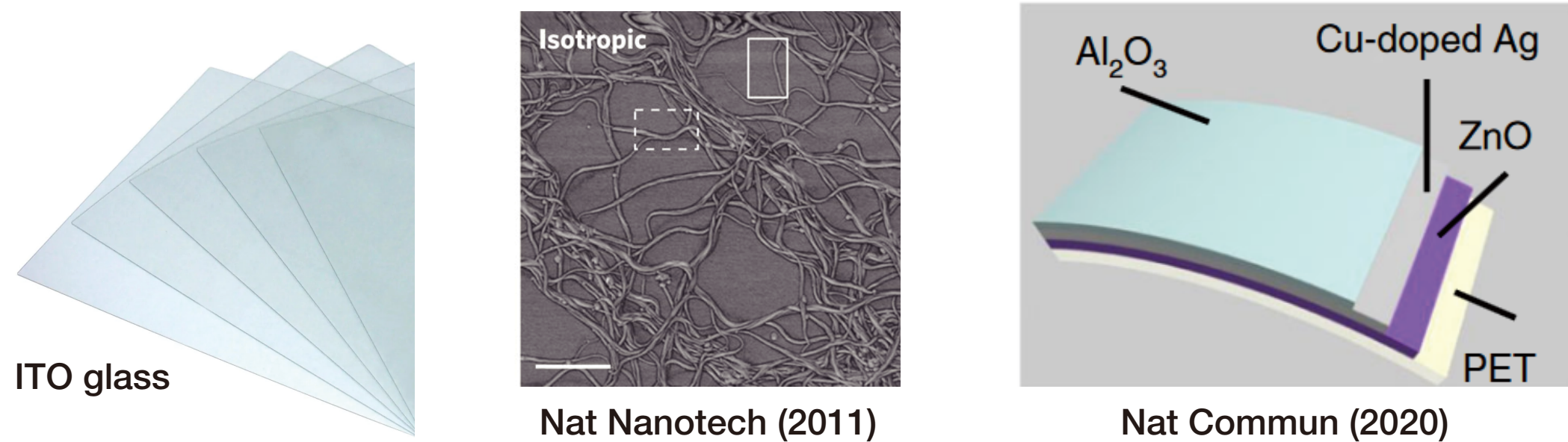
- **A:** κ and Γ_r are controlled by the geometry.
- $h_m \rightarrow \kappa$; $a, h_{\text{bar}} \rightarrow T_{\text{grating}} \rightarrow \Gamma_r$.
- **B, C:** κ, Γ_r from theory (line, by Tight Binding Method and energy flow analysis) and simulation (scatter) agree well.



Introduction

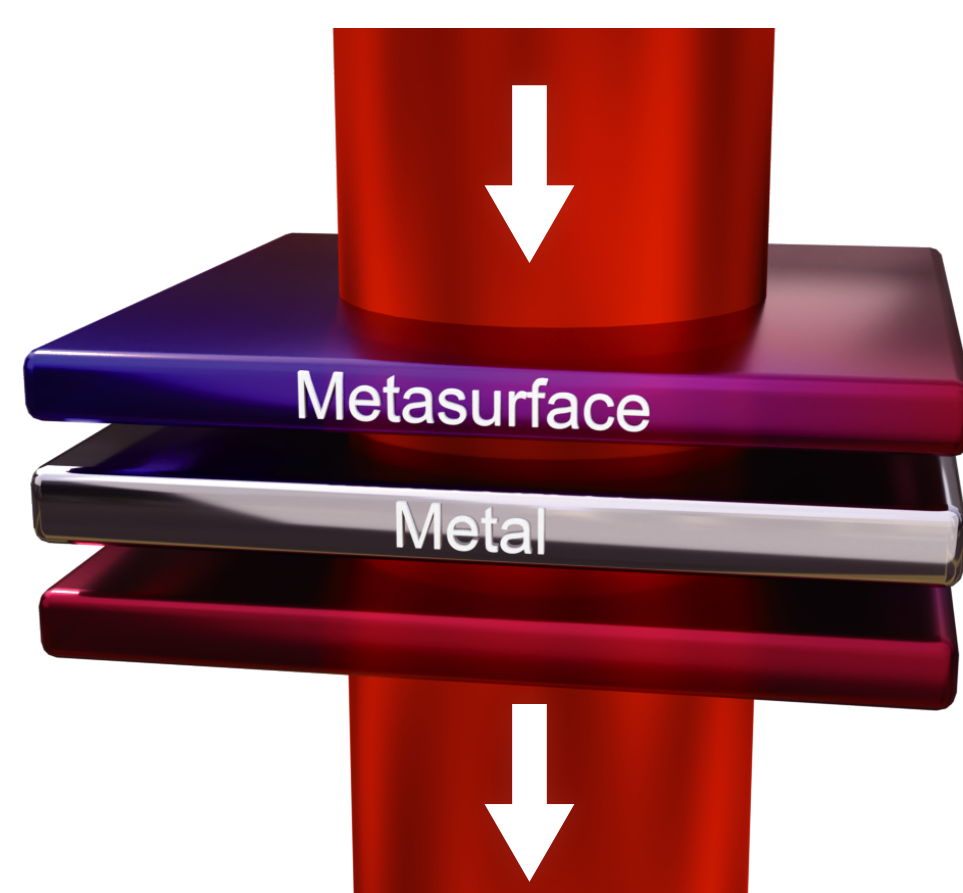
Former realizations of transparent conductors

- Indium Tin Oxide (ITO): widely used, but expensive due to the scarcity of indium.
- Nanostructures (carbon nanotube, Ag nanowire/mesh etc.): low conductivity and high optical haze.
- Continuous metal film: good conductance, but hard to be made transparent.

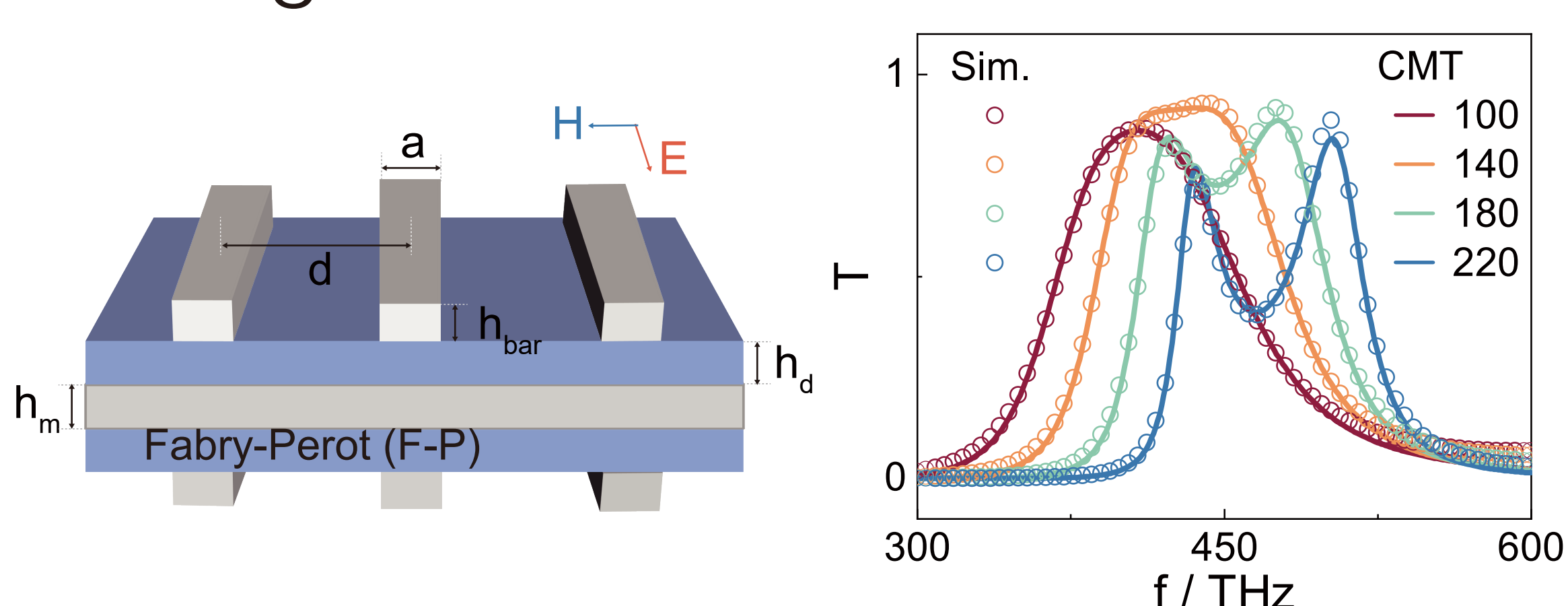


Our results

- Metasurface-assisted transparency of a continuous metal film with numerical and experimental verifications.
- Transparency is interpreted by CMT.
- Optoelectronic performance comparable to ITO.

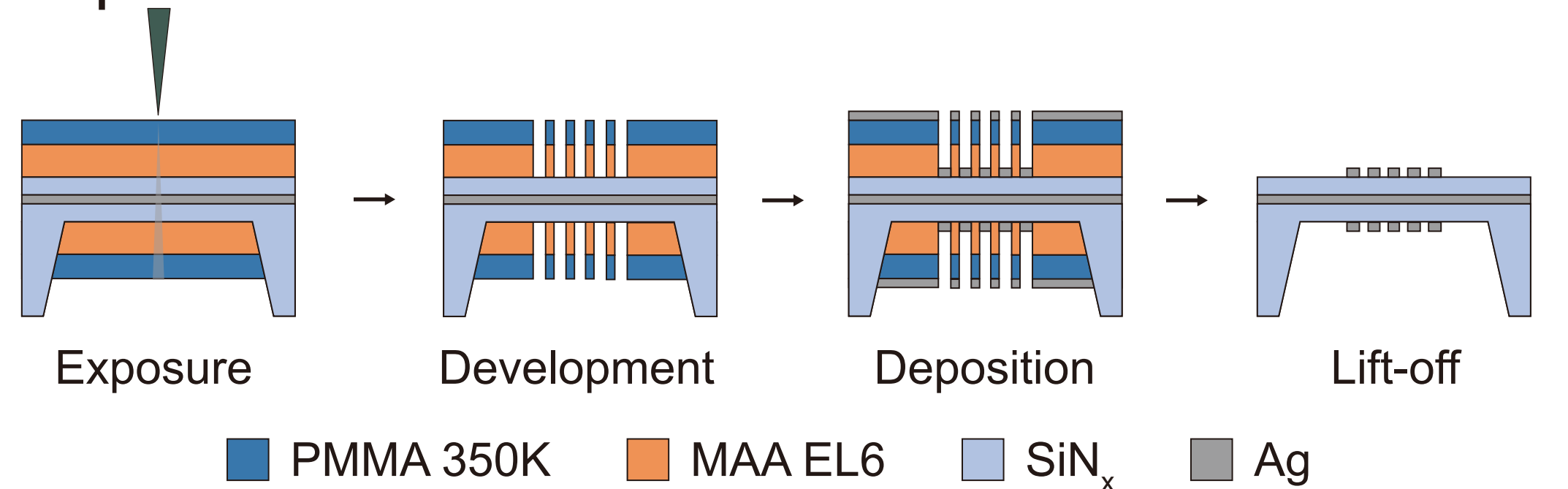


Design

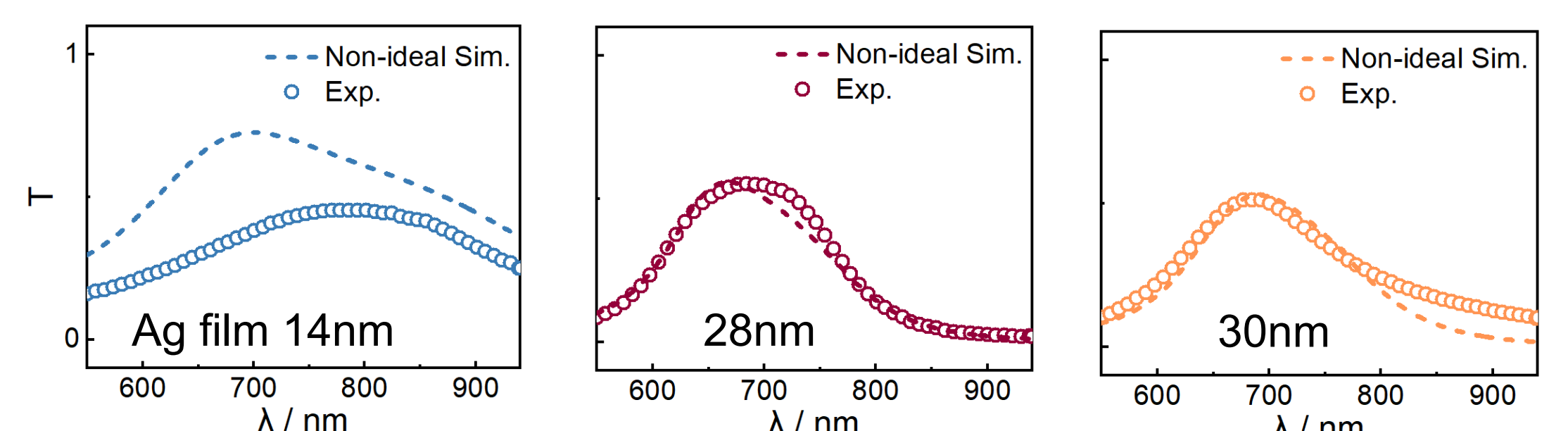


- 5-layer demo: Ag grating/ SiN_x /Ag film/ SiN_x /Ag grating.
- Transmittance simulated and fitted by two-port two-mode CMT with different a (nm)

Experiment



- Transmitted e-beam lithography was applied to fabricate free-standing samples



- Figure of Merit (FoM) ≈ 397 for our 28nm sample, comparable to ITO (FoM ≈ 350)

References

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- [3] X. Zheng et al., Photonix 4, 3 (2023).