AVT-371 Research Workshop on

"Materials and technologies for electro-optical camouflage"

A transparent wavelength-selective infrared a cross-shape metamaterial for adaptive thermal camouflage

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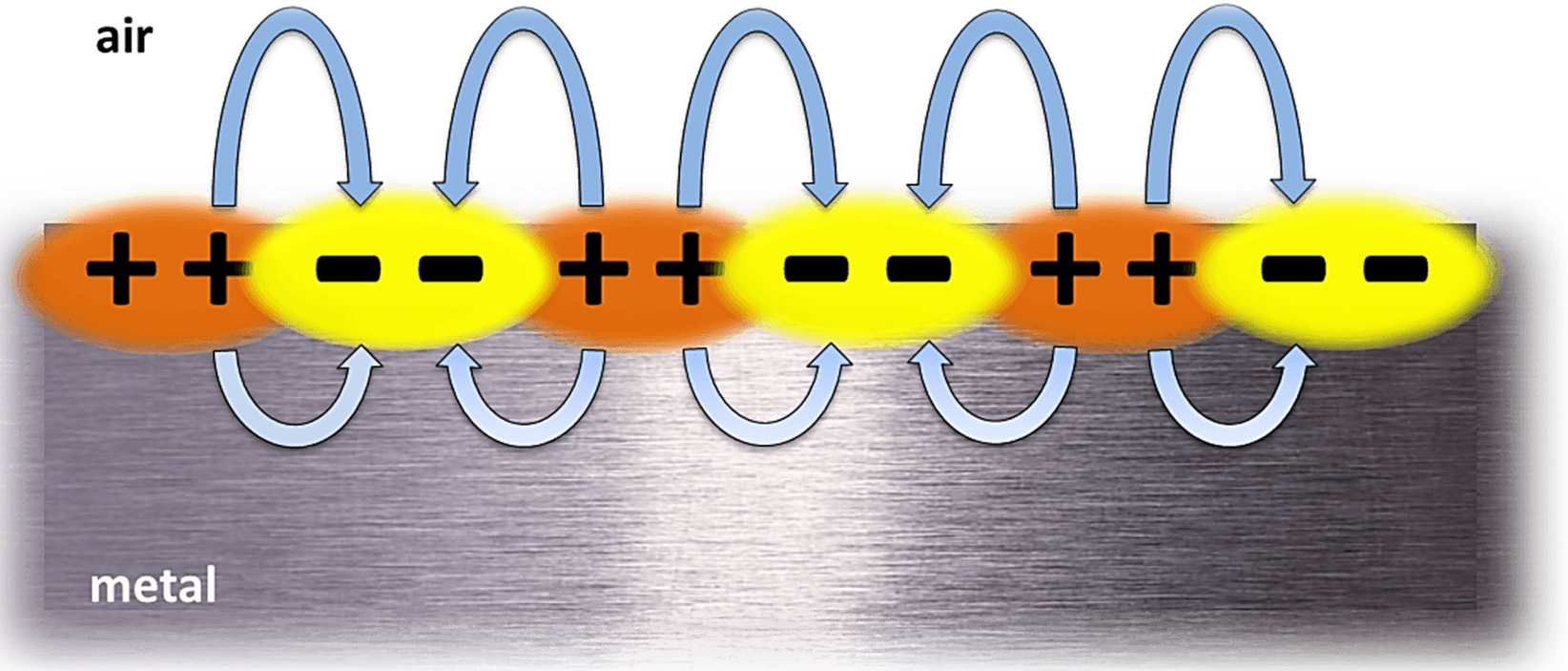
TURKISH AEROSPACE

Concept & Outline

- All-dielectric metamaterials consist of high-index, sub-wavelength arrays allow for the manipulation of electromagnetic permittivity and permeability and provide lower losses at optical frequencies compared to their metallic counterparts.
- Here, planar and cross-shape multilayer configurations consisting of dielectric interlayers are tailored to achieve thermal camouflage.
- Both computational analysis and experimental assessments were utilized to study the spectral properties of the all-dielectric metaplatform.
- This structure exhibits an immense performance for thermal applications by considering the infrared signature reduction in the long wavelength band and the reduced radiated energy dissipation along with the undetected band and the requirements for infrared camouflage.
- The possibility to obtain thermal camouflage at different background temperatures using a well-engineered all-dielectric metamaterial is investigated here.
- The results showed that the camouflage material substantially reduces the contrast between the target and the background. Beyond that, our assessments validated that the contrast in the resulting short tips is due to the differences in the reflective properties of the material and the background.

Introduction

$\lambda/2n$



Concept & Scenario

- Electronic Thermal Infrared Countermeasure System to Electro-Optic Systems
- Renders this battle tank invisible to IR threats
- Mimic to thermal texture of the IR environment
- Avoiding sky radiation and adaptive to background
- False situational awareness on the battlefield

- Air to Ground Mission to threats
- Reducing performance of the electro-optic systems

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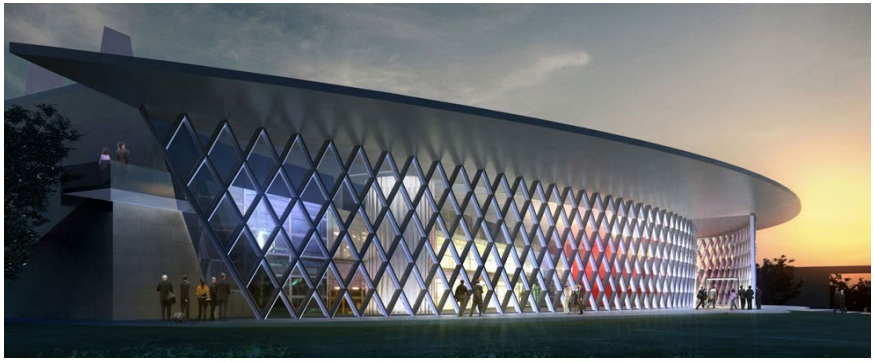
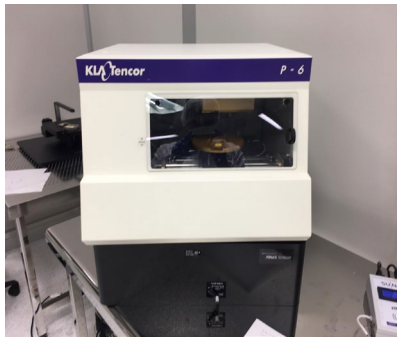
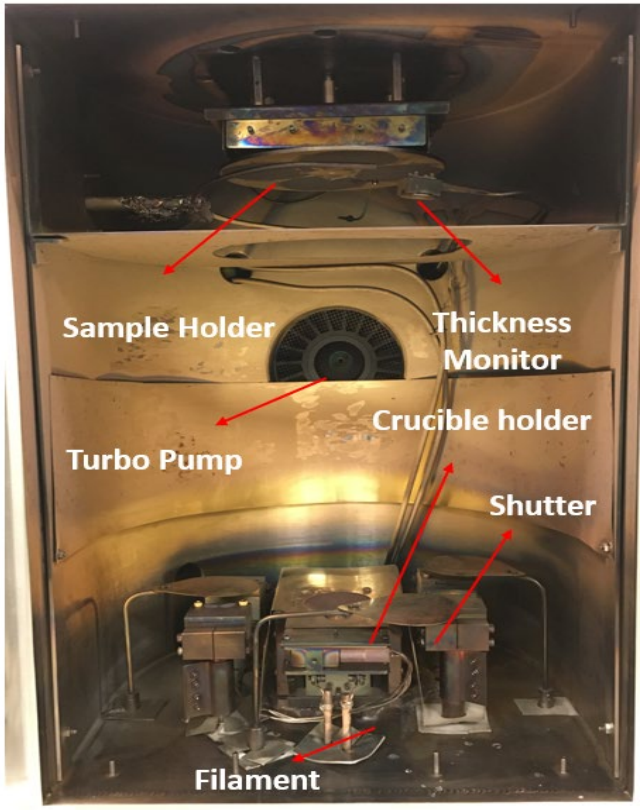
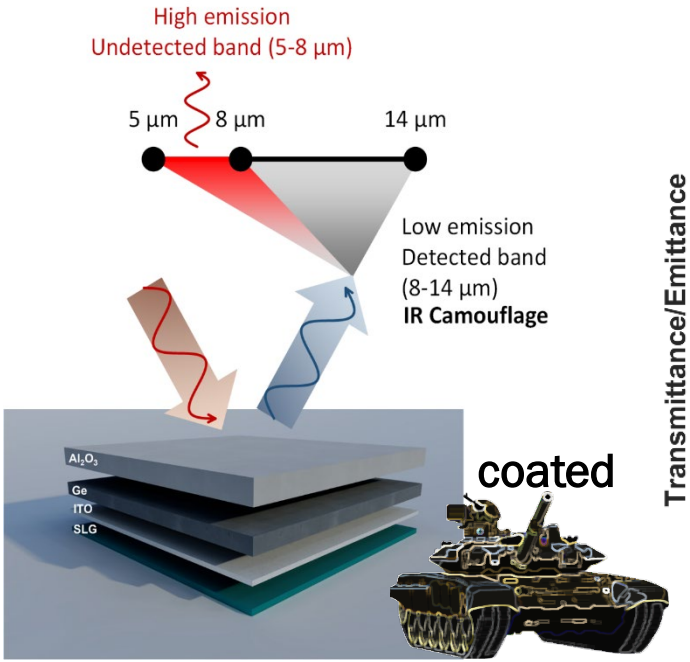


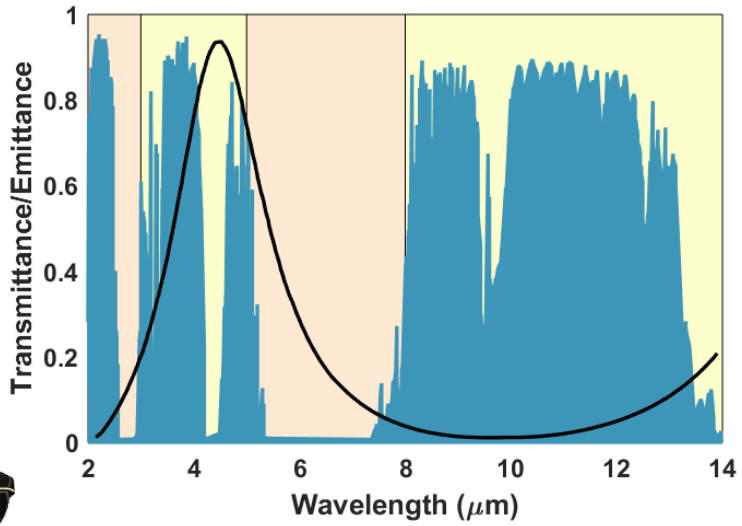
Design, fabrication, and characterization of all-dielectric multilayer bulk meta-absorbers to achieve broadband absorption of mid-infrared (MWIR) and long-infrared light (LWIR).

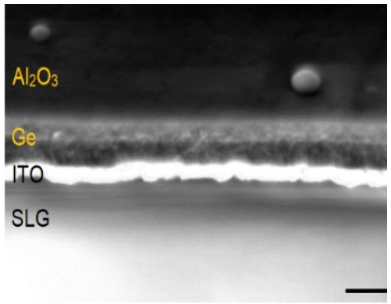


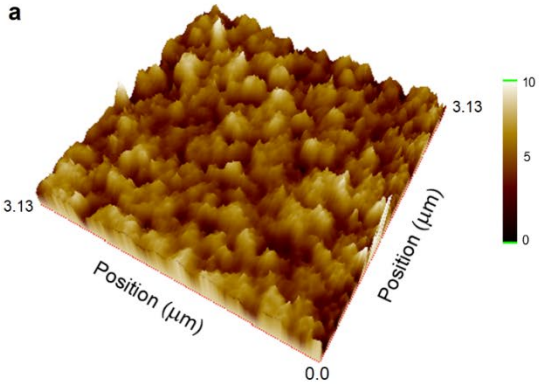


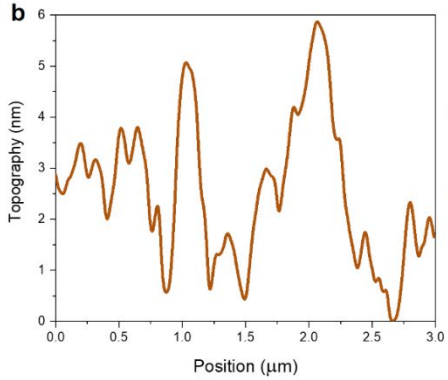
Design of the All-Dielectric Multilayer Fabry-Pérot Cavity Meta-Absorber

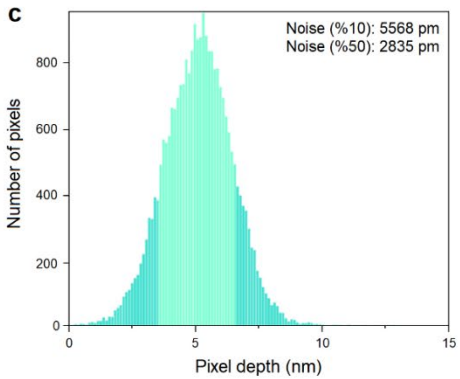


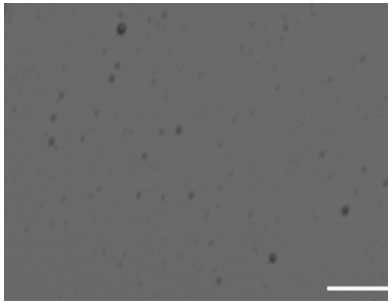




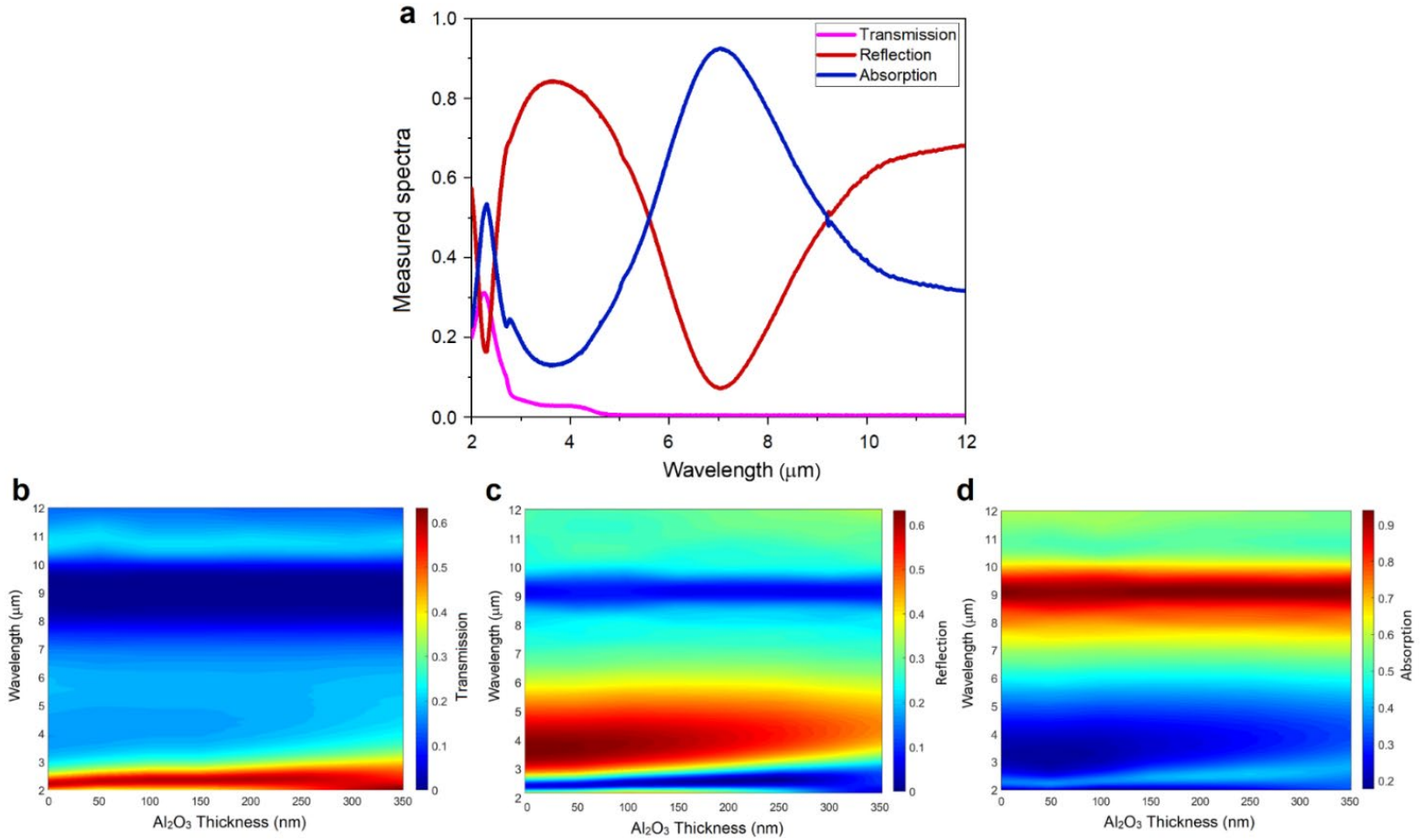




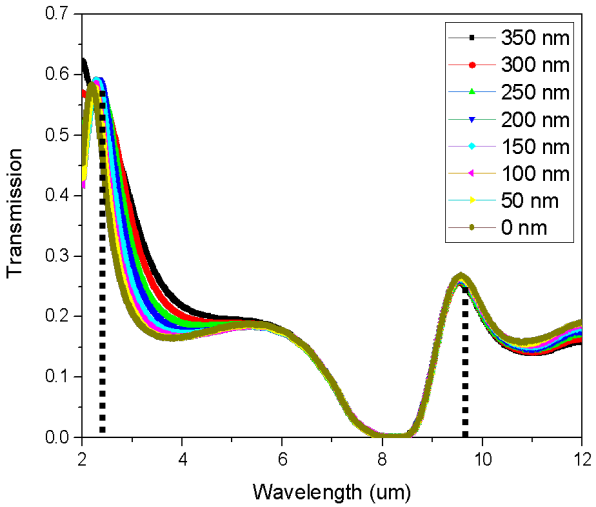


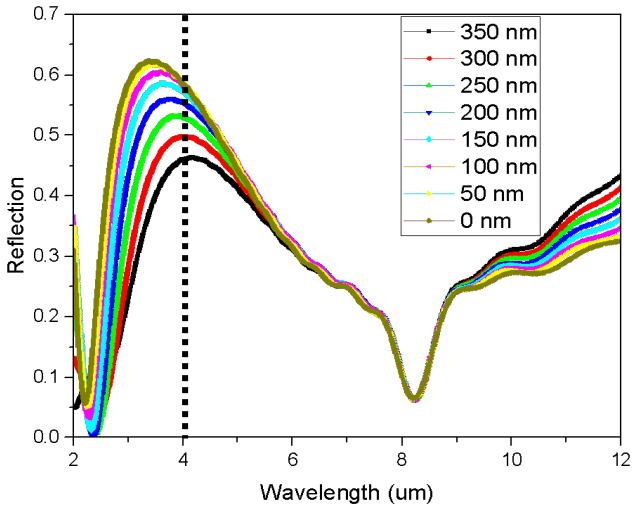


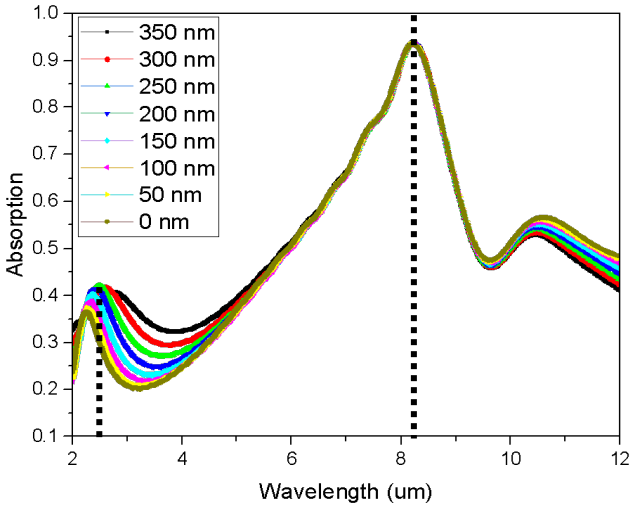
(a) Measured spectra of the multilayer all-dielectric meta-absorber. The contour plots of the (b) transmission, (c) reflection and (d) absorption spectra of the multilayer metamaterial for different values of the upper oxide layer (0 nm < t_{oxide} < 350 nm).



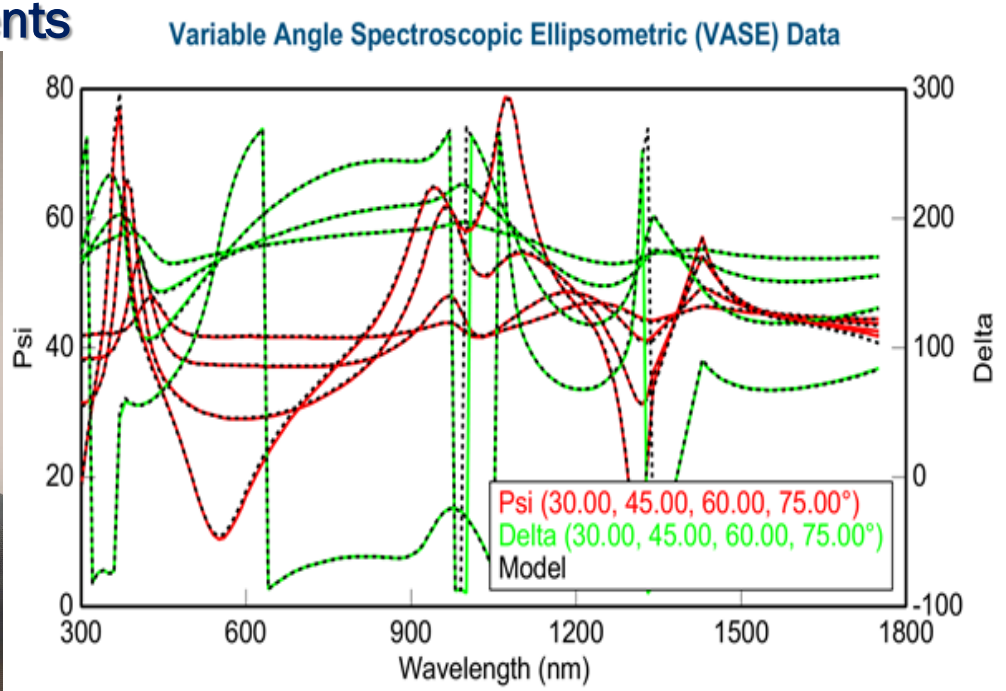
Thickness-Dependent Spectral Analysis: Numerical Analysis

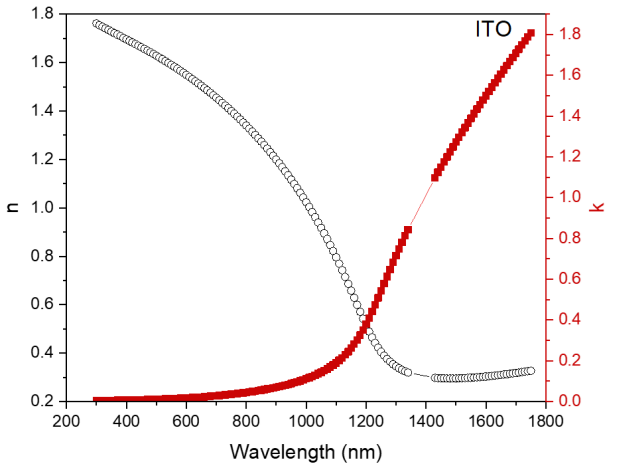


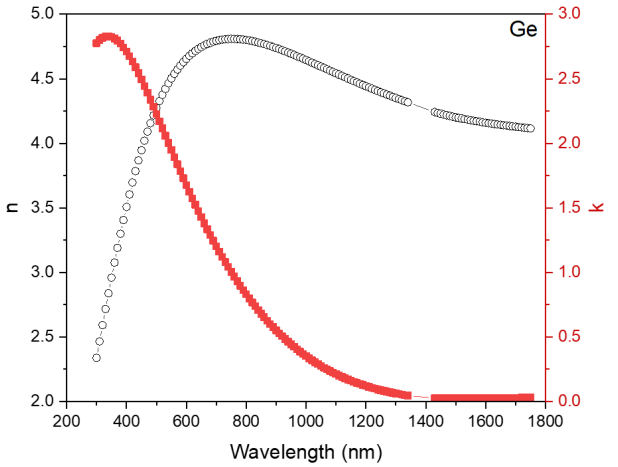


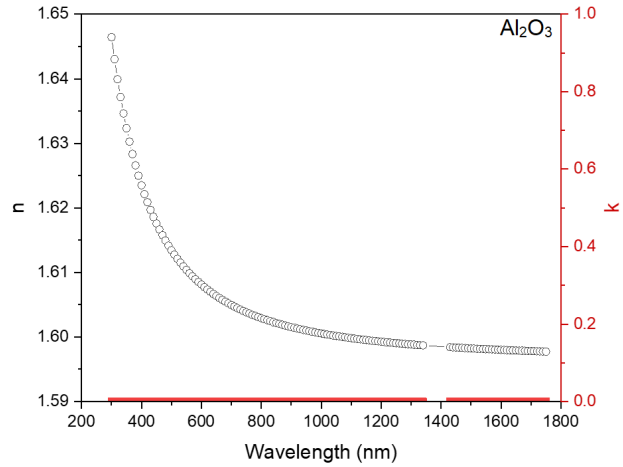


Spectroscopic Ellipsometry Measurements



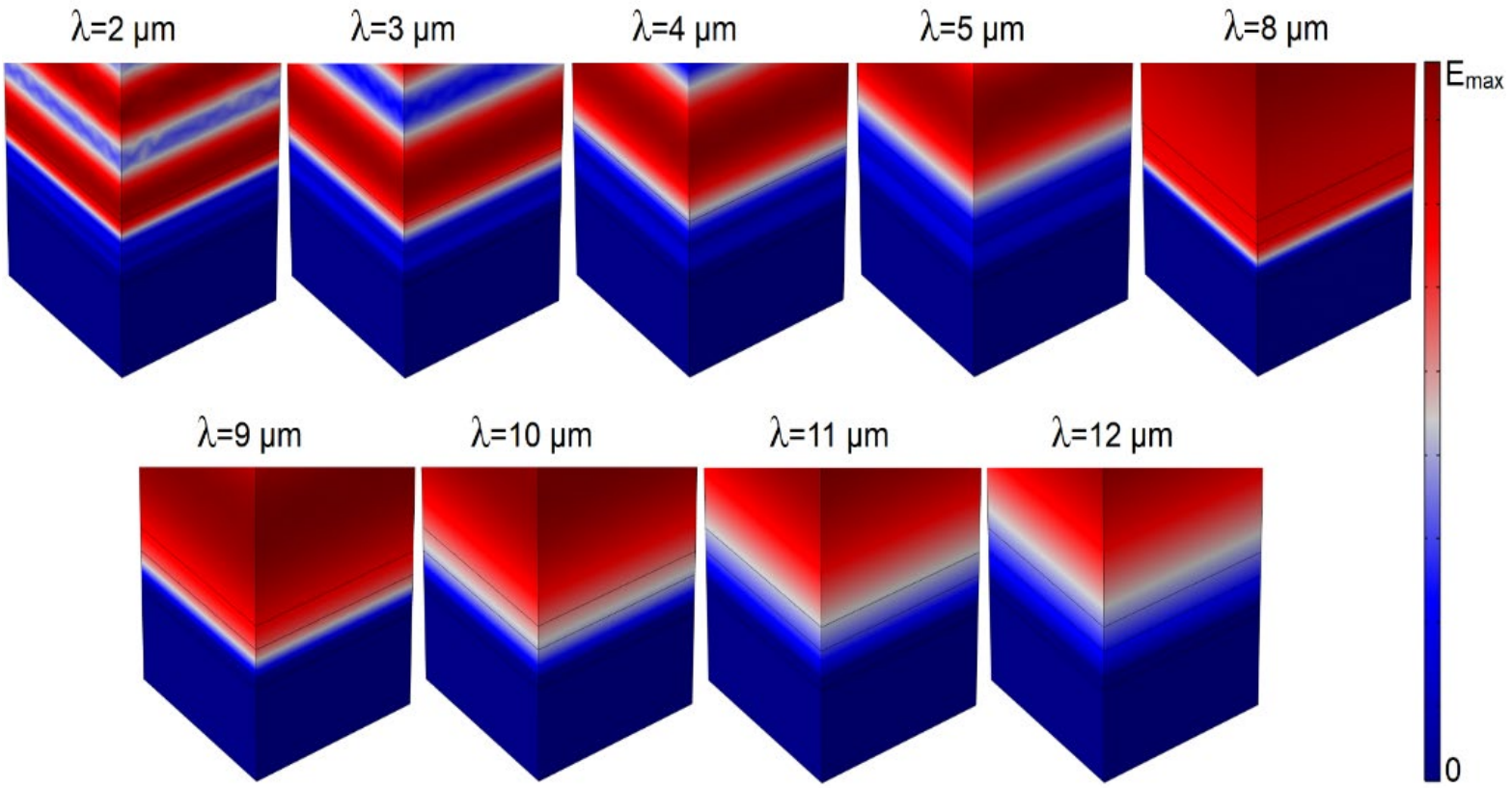




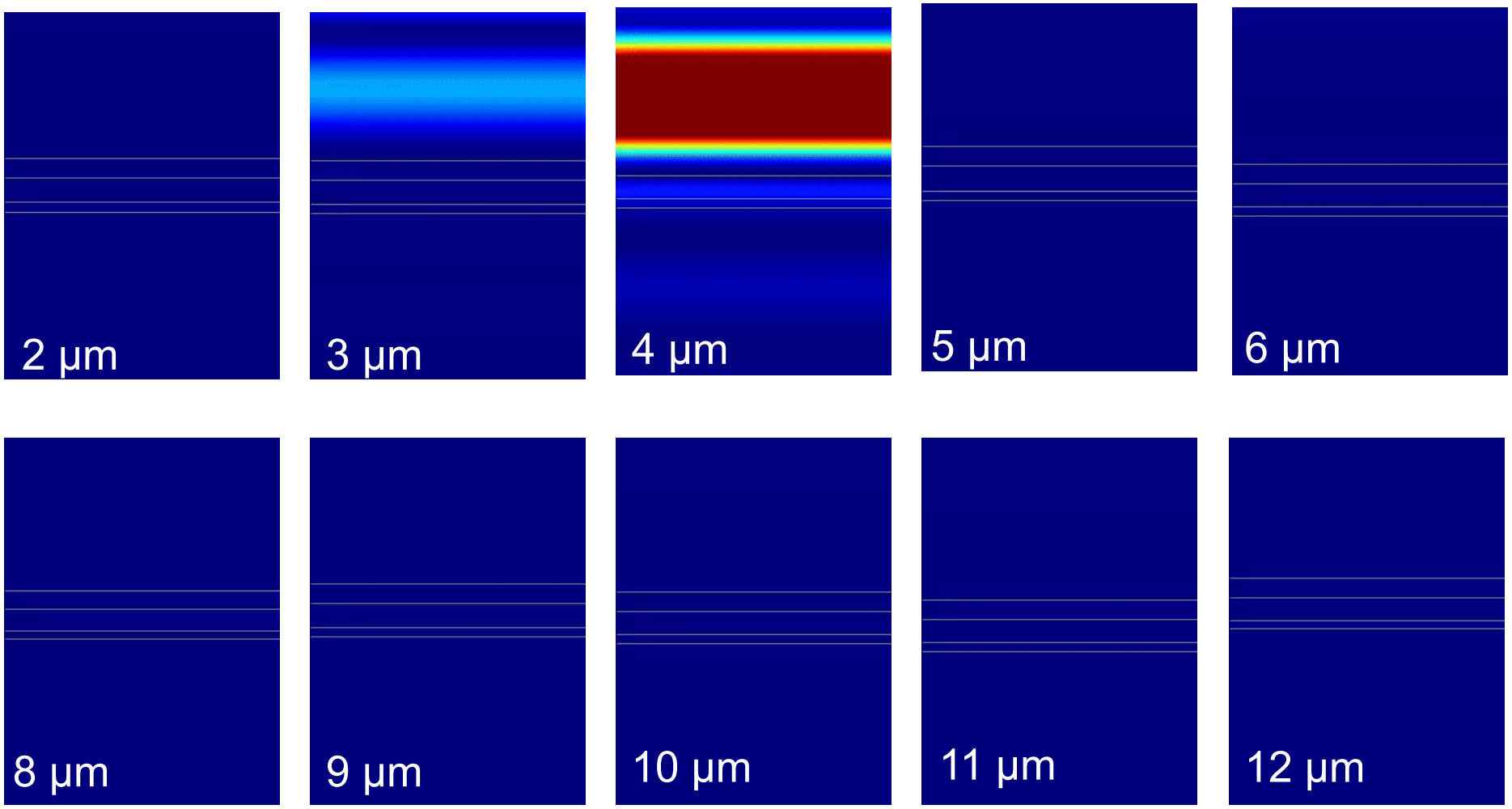


Electric Field Distribution of the Multilayer Meta-Absorber

Numerically obtained 3D demonstration of the electric-field distribution throughout the multilayer meta-absorber at different wavelength with the upper Al_2O_3 layer (t_{oxide}= 250 nm)

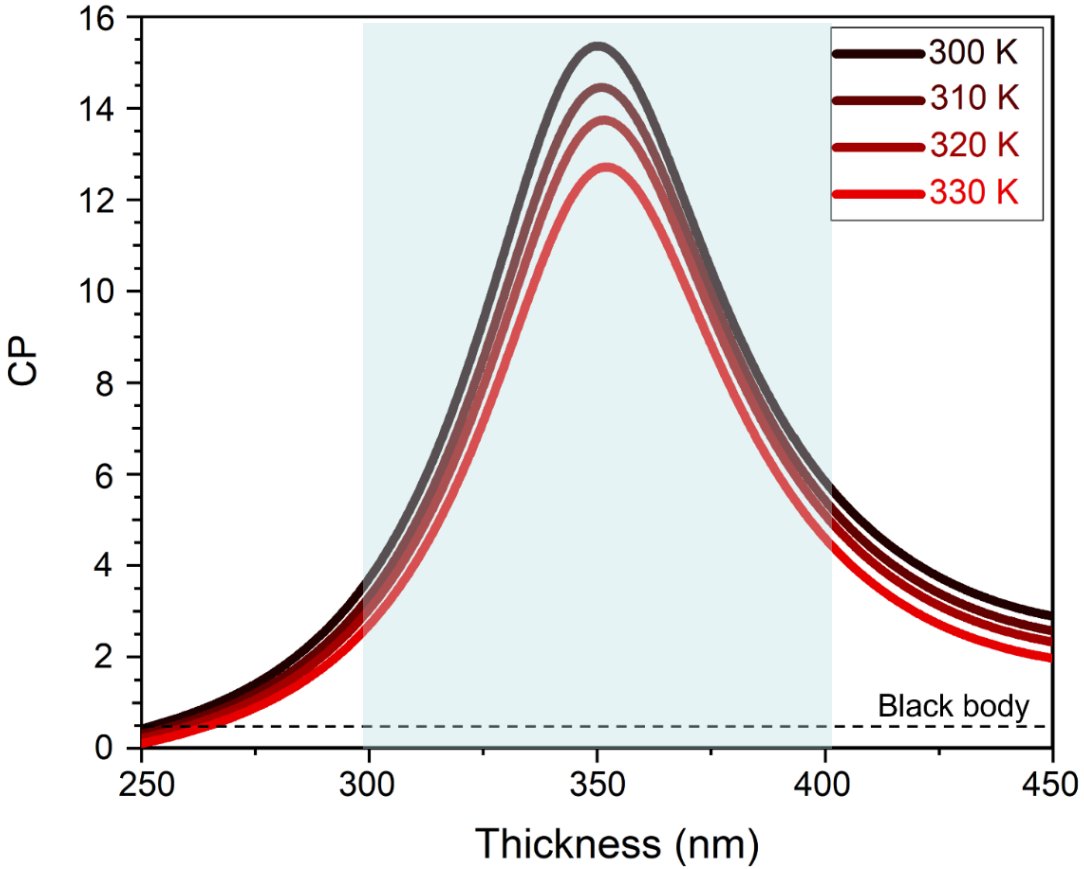


Electric Field Distribution of the Multilayer Meta-Absorber



Radiation/Surface Temperature for Thermal Camouflage Application

Thermal camouflage aims to minimize the chance of being detected or otherwise reduce the range at which a camouflaged object.



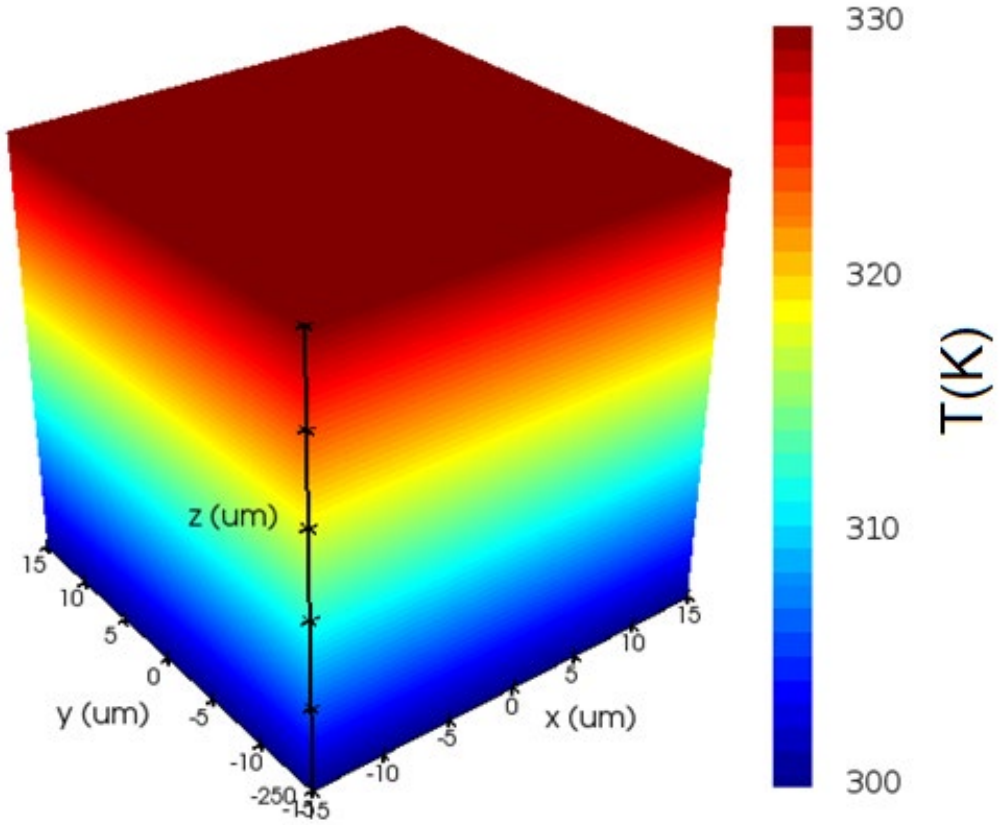
Camouflage performance of single band (CP)

$$\emptyset_{undetected\ band} / \emptyset_{detected\ band}$$

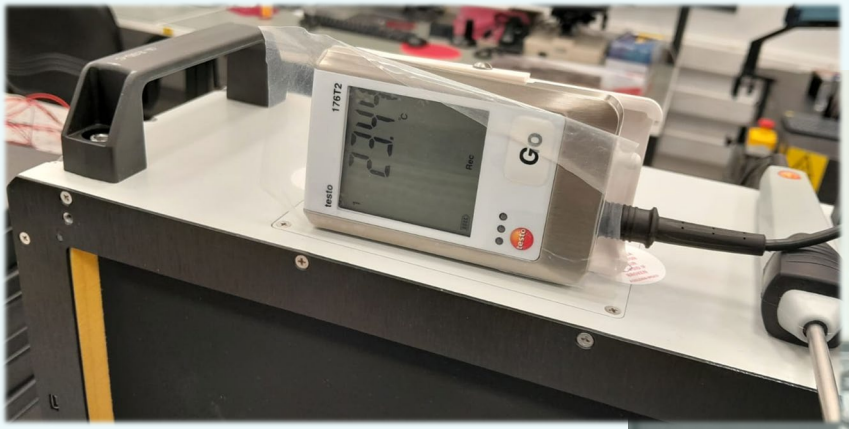
Total camouflage performance (TCP)

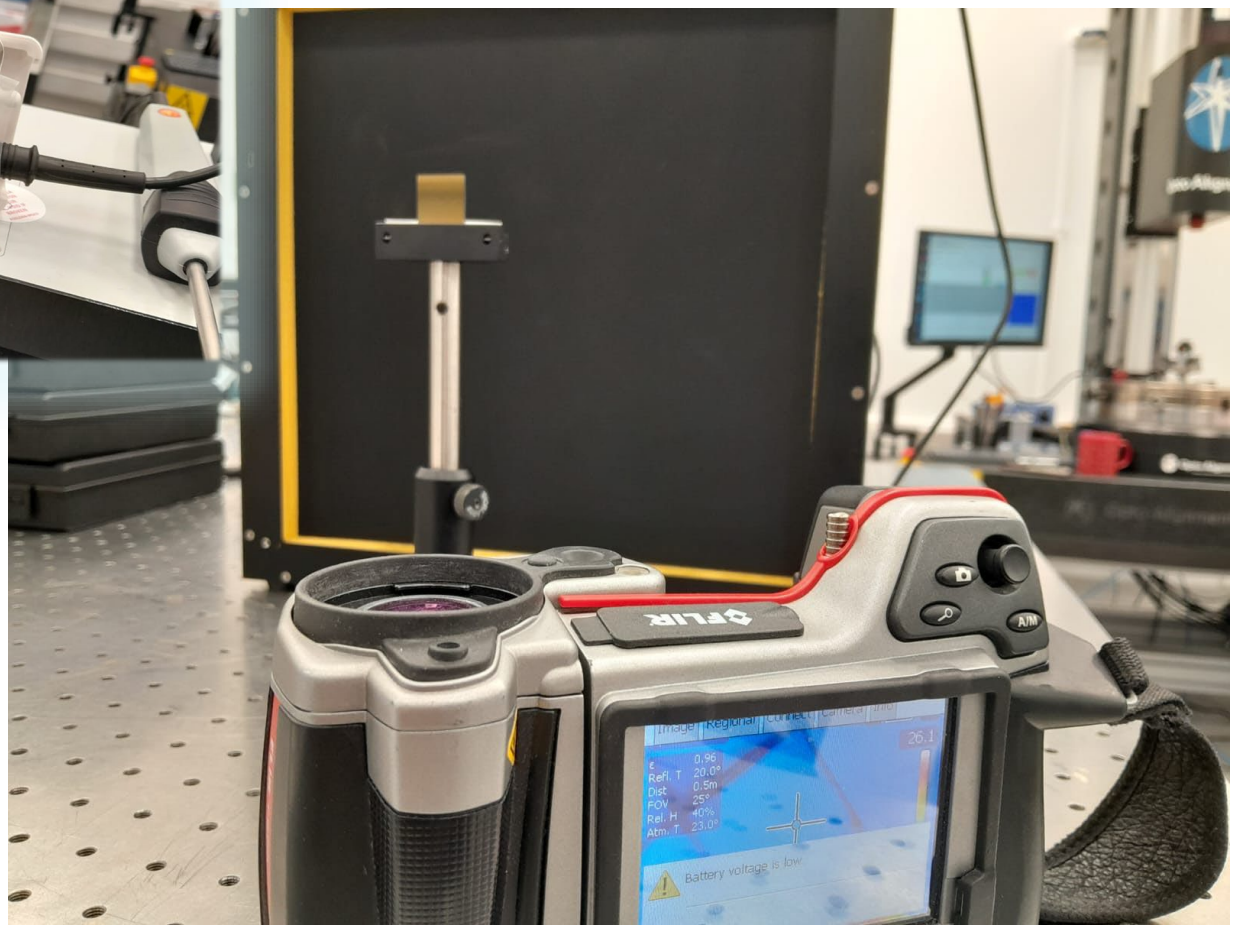
$$CP\ (\lambda_1 - \lambda_2).CP(\lambda_3 - \lambda_4)$$

Radiation/Surface Temperature Simulations for Thermal Camouflage Application

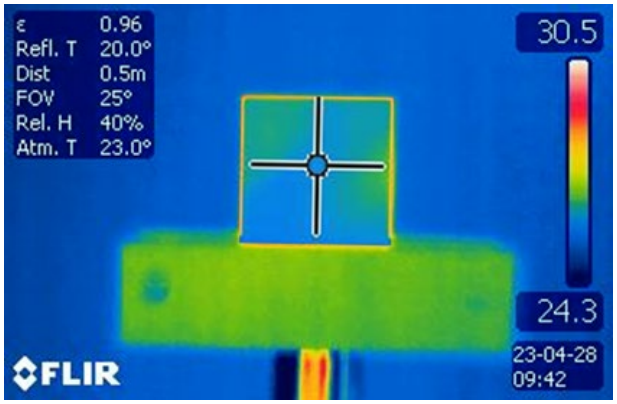


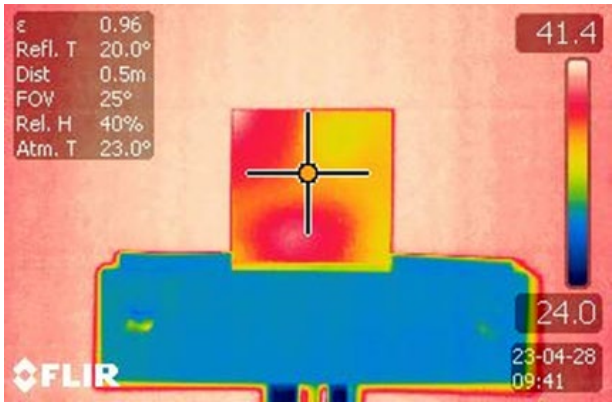
Radiation/Surface Temperature Measurements for Thermal Camouflage Application

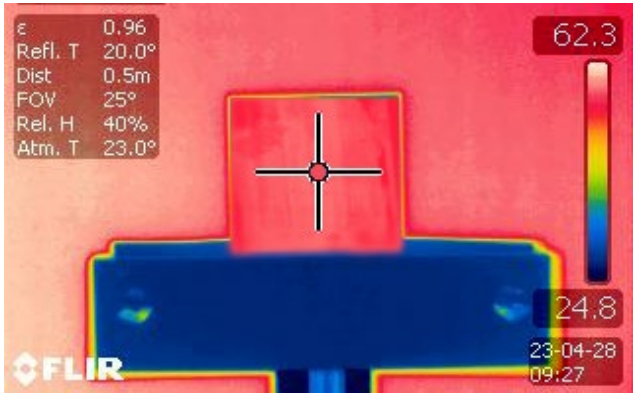




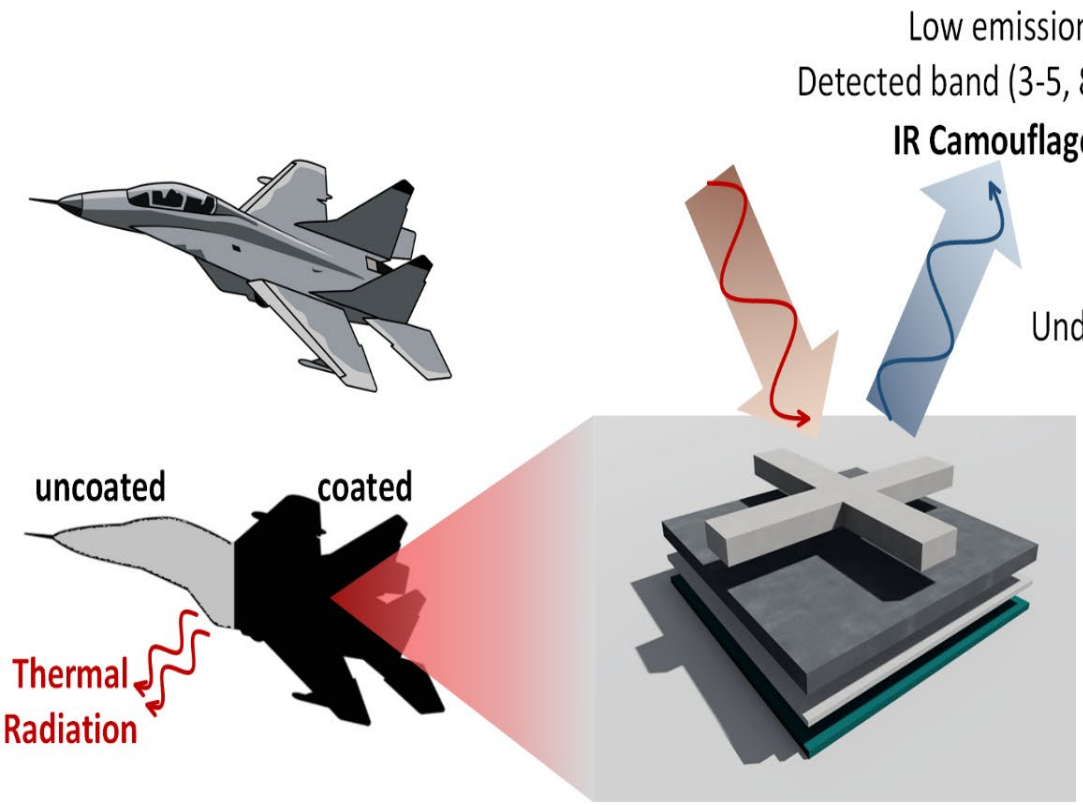
Radiation/Surface Temperature Measurements for Thermal Camouflage Application

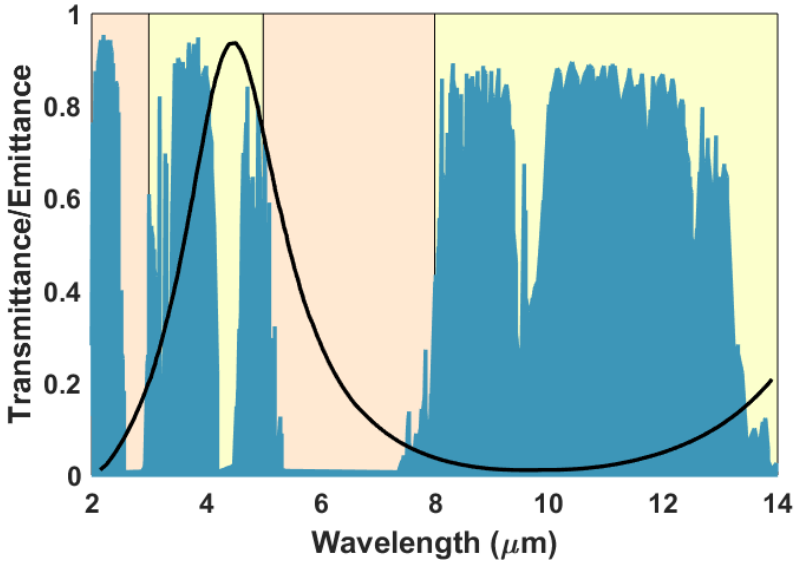




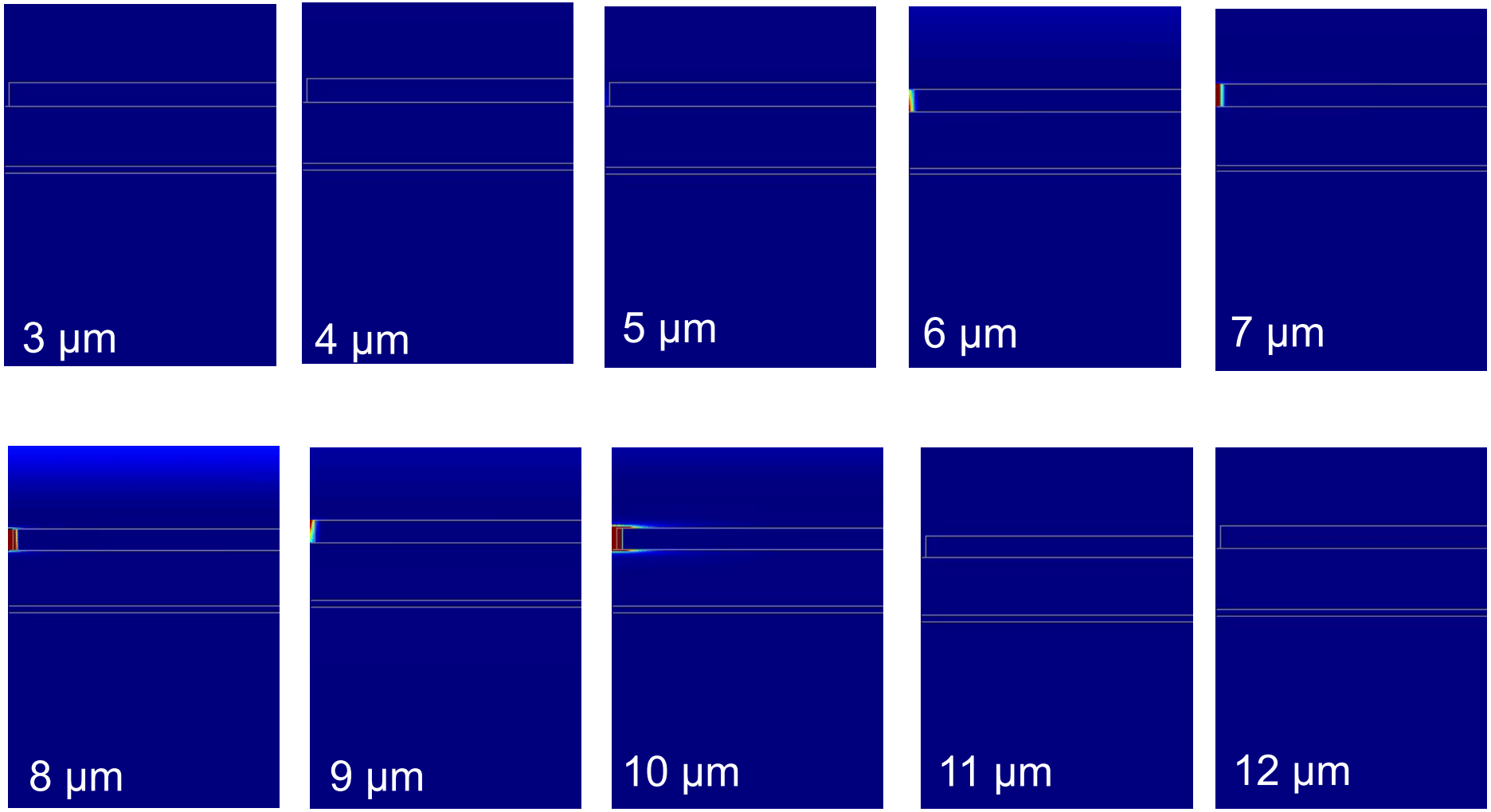


All-Dielectric Cross-Shape Metasurface for Thermal Camouflage

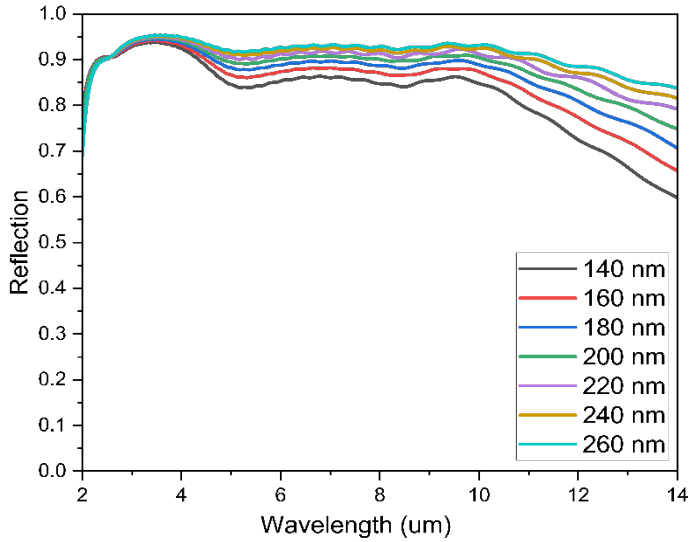


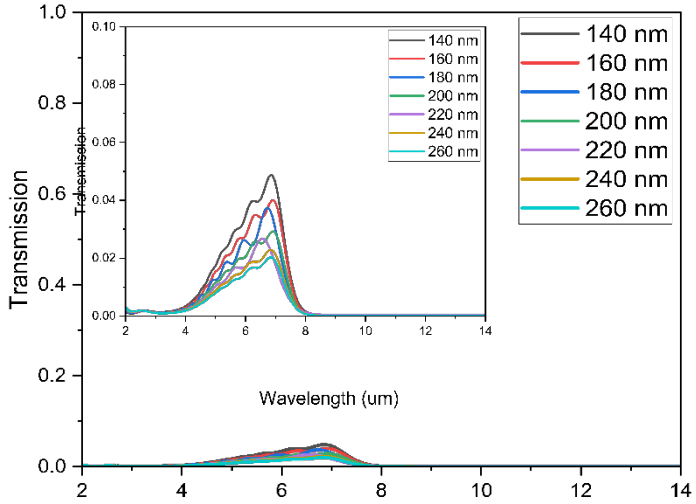


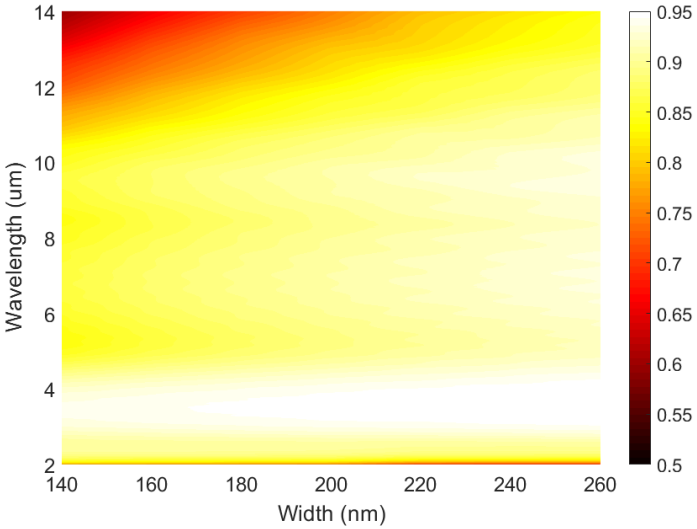
Electric Field Distribution of the Cross-Shape Material

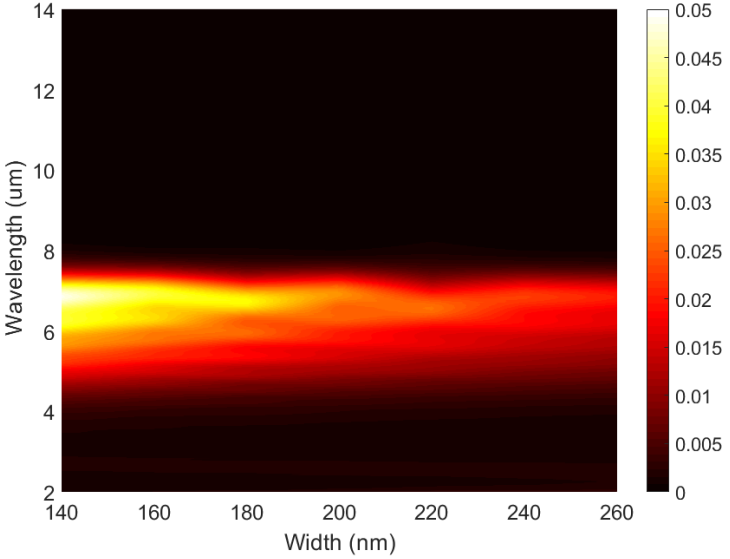


Cross Width

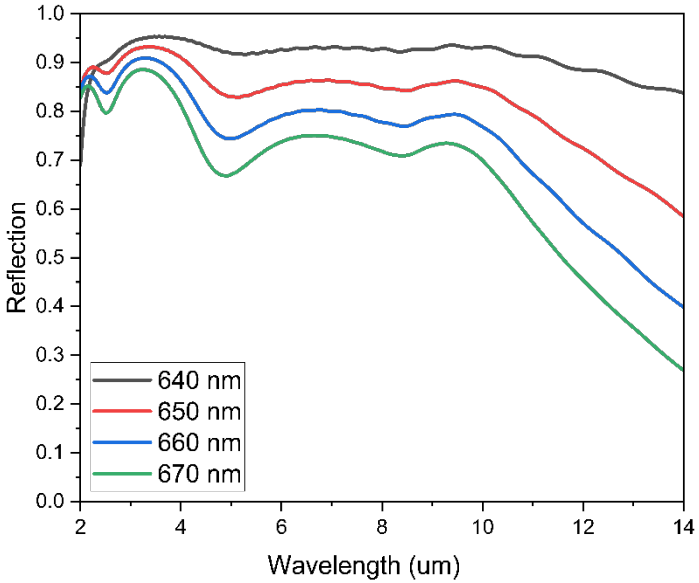

Reflection
Wavelength (um)
140 nm
160 nm
180 nm
200 nm
220 nm
240 nm
260 nm

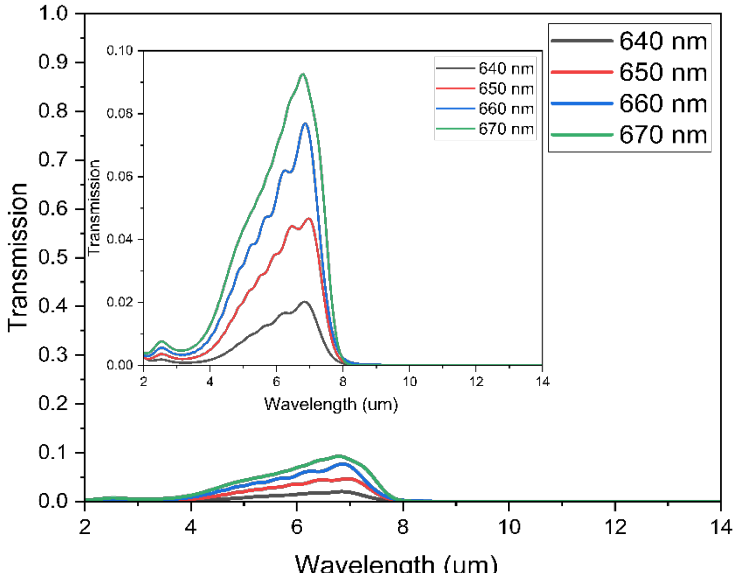

Transmission
Wavelength (um)
140 nm
160 nm
180 nm
200 nm
220 nm
240 nm
260 nm

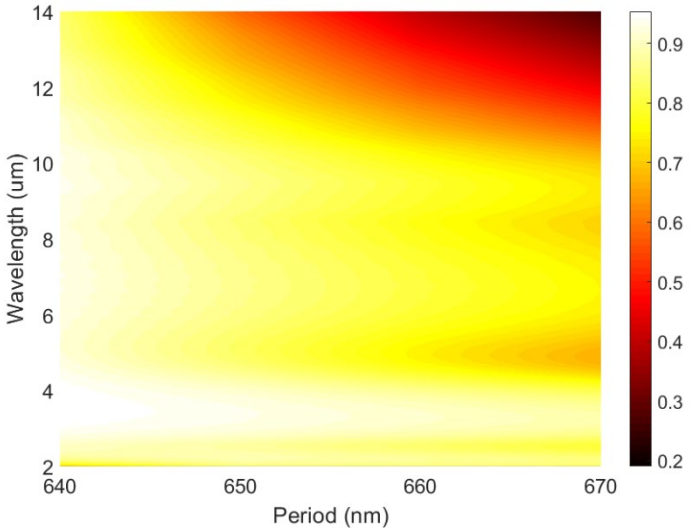

Wavelength (um)
Width (nm)

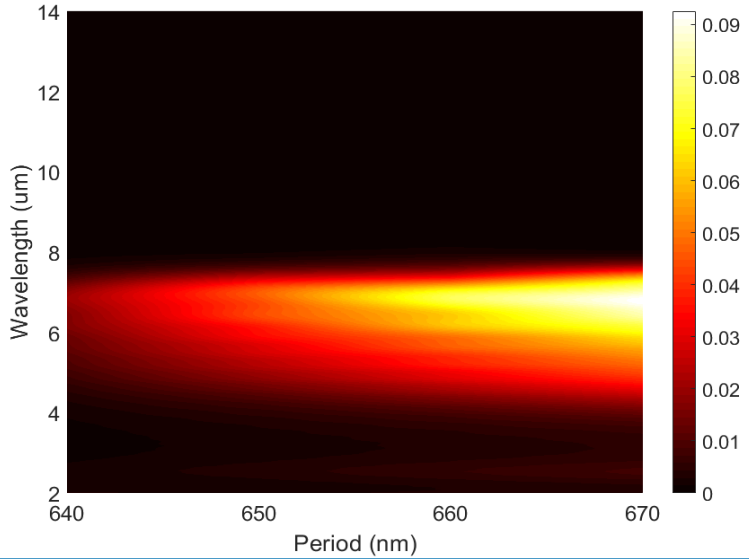

Wavelength (um)
Width (nm)

Period

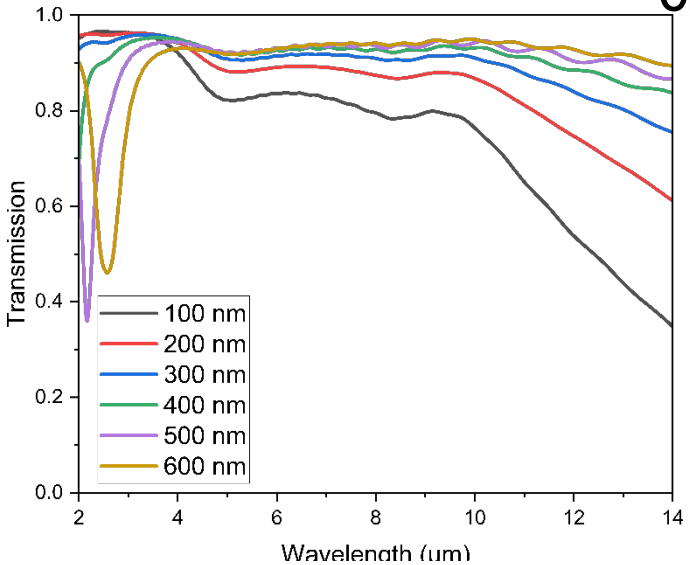

Reflection
Wavelength (um)
640 nm
650 nm
660 nm
670 nm

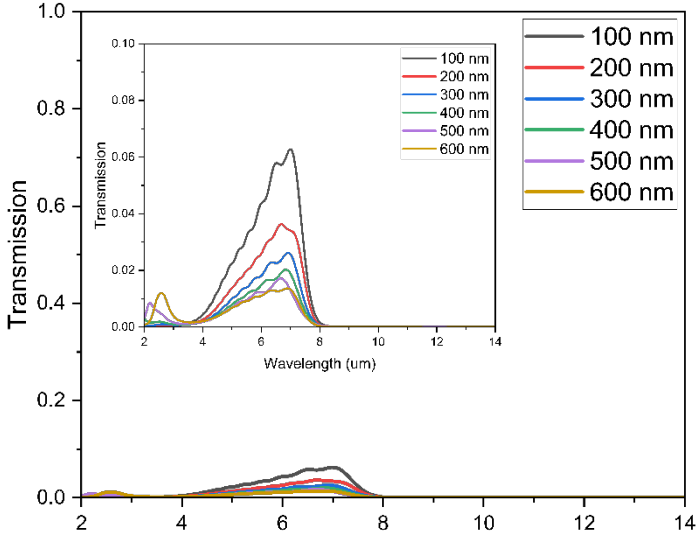

Transmission
Wavelength (um)
640 nm
650 nm
660 nm
670 nm

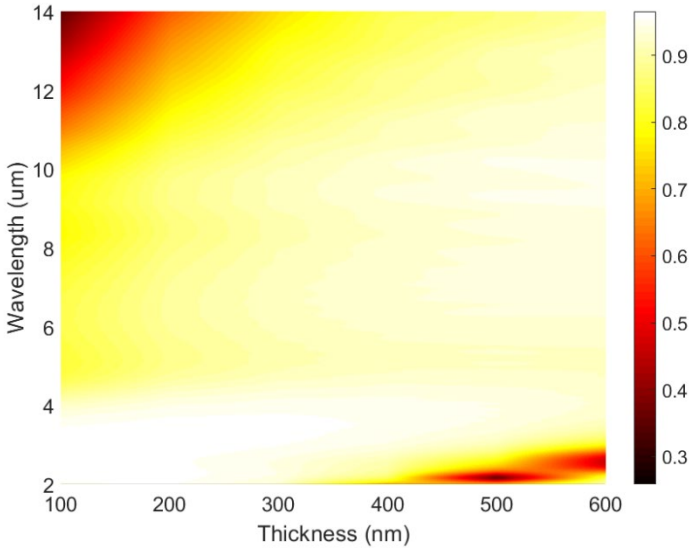

Wavelength (um)
Period (nm)

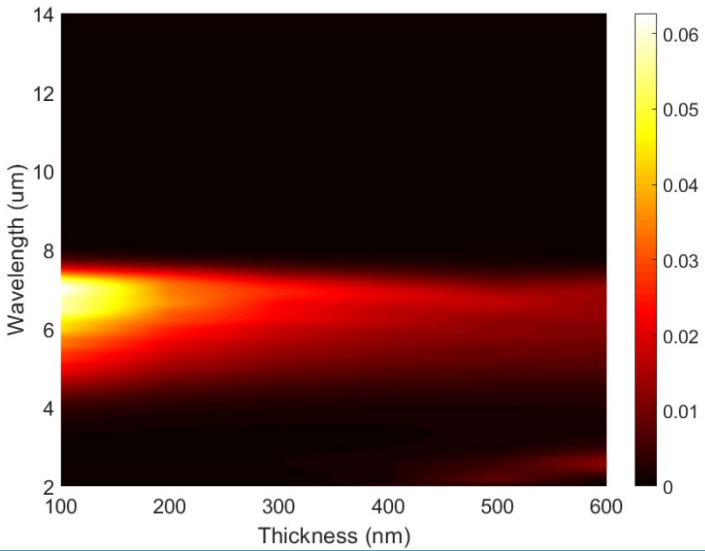

Wavelength (um)
Period (nm)

Cross Thickness

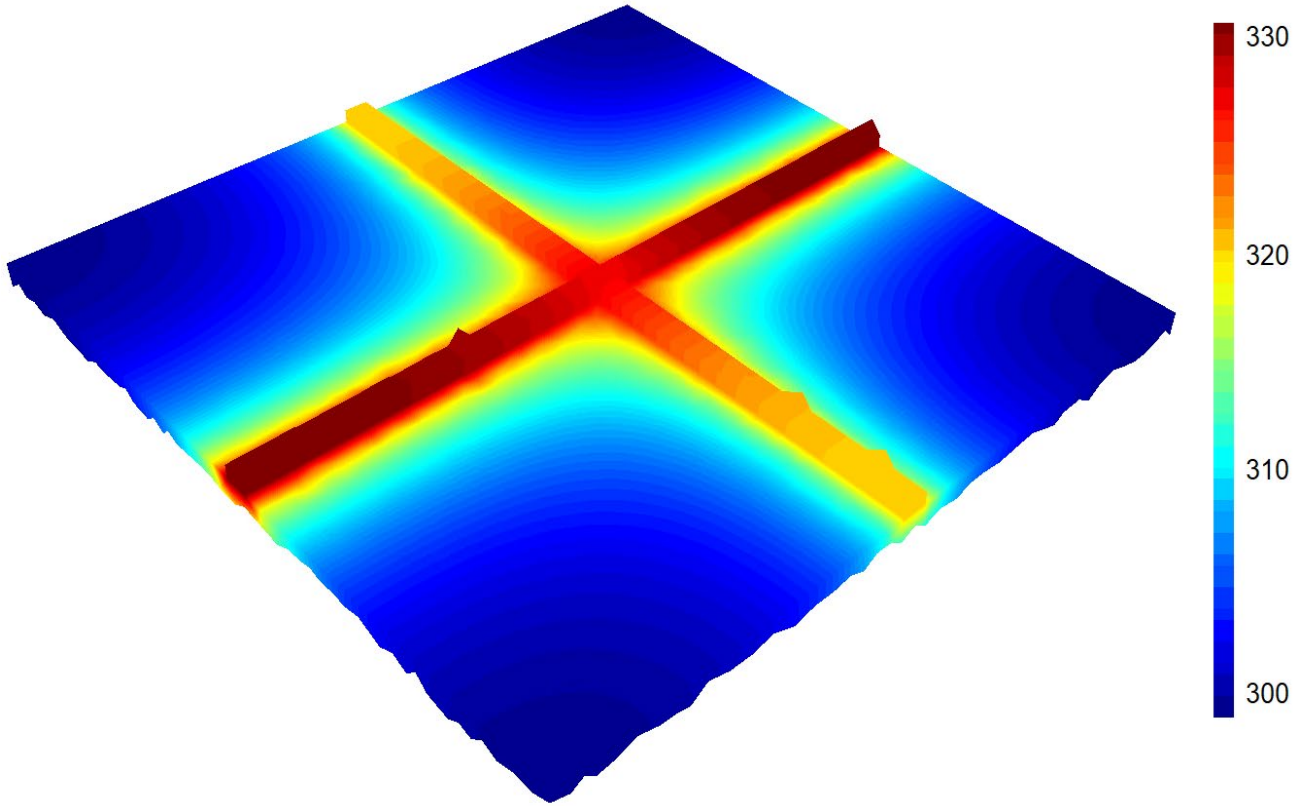








Radiation/Surface Temperature Simulations for Thermal Camouflage Application



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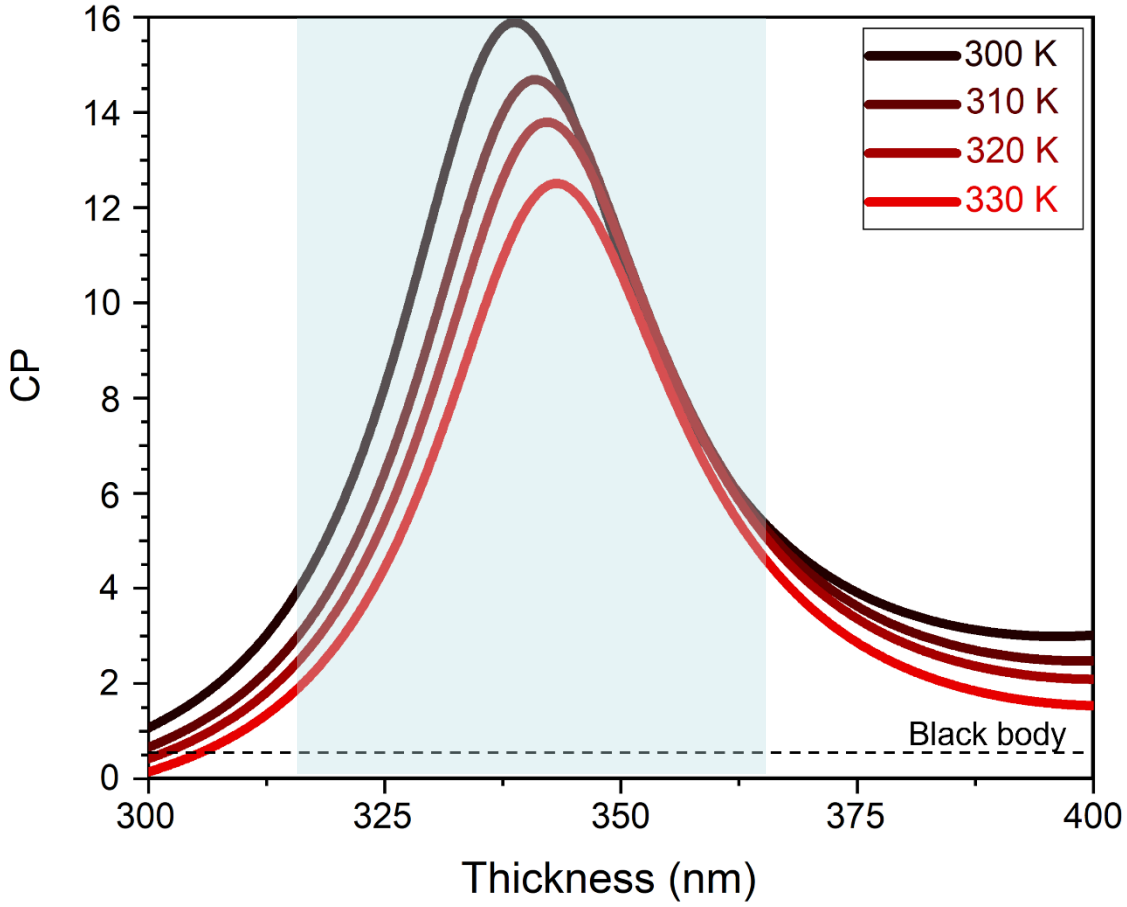

Conclusions

- Developed and analyzed the spectral properties of a metamaterial
  - based on stacking layers of dielectric compounds
- Conducted extensive electromagnetic computations and experimental assessments
  - To investigate the exceptional characteristics of the metastructure in the broadband absorption of IR wavelengths
  - To understand the operating principle of the meta-surface mechanistically and comprehensively.
- Heat transfer simulation at COMSOL Multiphysics
  - Heat transfer and surface-to-surface radiation modules
- The new adjustable metamaterial structure
  - To control the radiant heat to match the background
- Future Work
  - Design and optimize multi-layered patterned structures that offer both visible, RF and IR camouflage simultaneously align with the platform

Thank you for your interest and attention

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