Metamaterials - Camouflage

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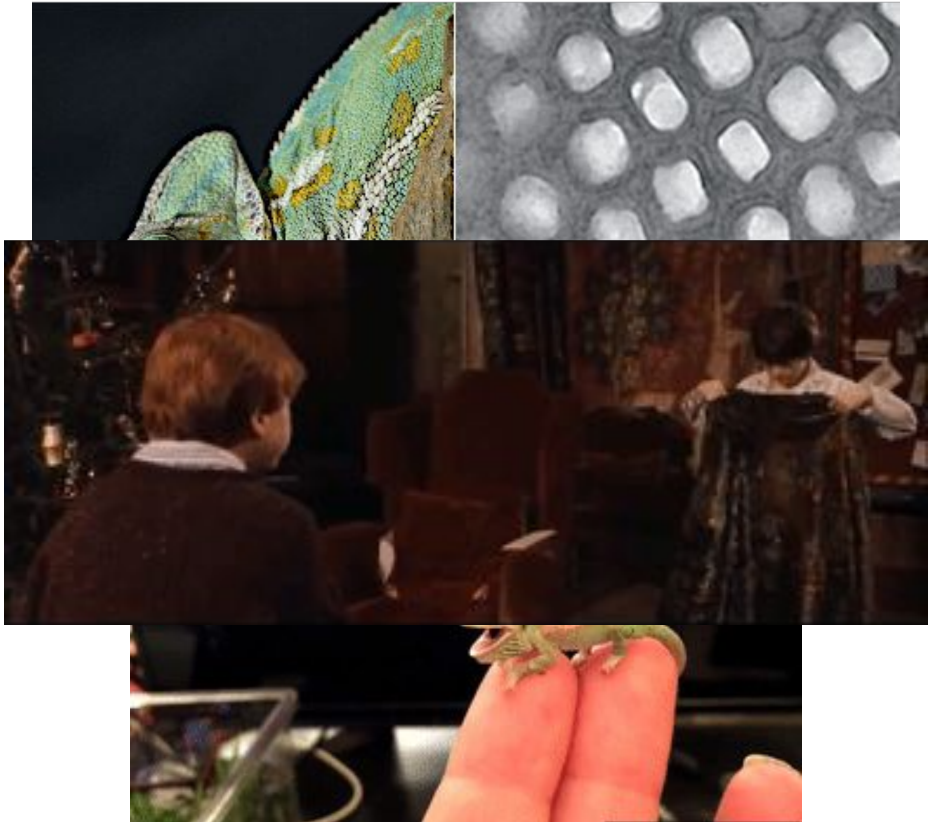
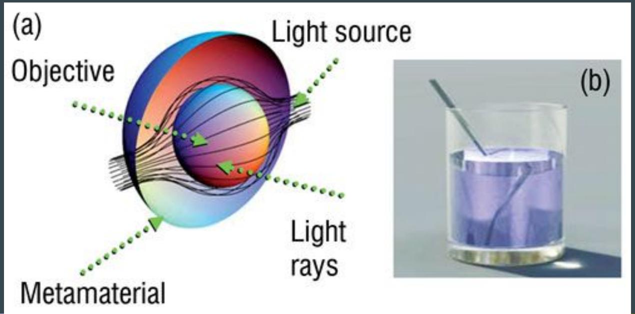
Introduction

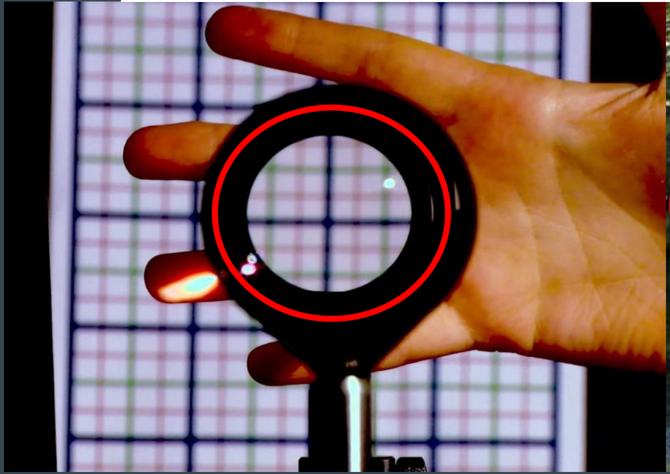
What are Metamaterials?

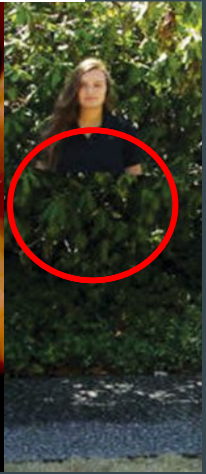


Objective for Camouflage based Metamaterials

- Stealth applications
  - Applied as a camouflage cloak to hide objects from viewer’s eyesight
- Object can be hidden by layering synthetic nanostructures to bend the electromagnetic radiation
- <u>**Issue:**</u> The layered nanostructures are limited to a narrow region of the visible or infrared spectrum & the angle of refraction to conceal object







Current State Of The Art - Camouflage

Research studies are looking to improve the range of light absorbed and angles of refraction by ***layering different materials*** to ***achieve higher ranges*** for multispectral camouflage.

Hierarchical Metamaterials (HMM)[1]: achieved through layering different materials with specific properties to reflect or absorb ranges of light desired to hide object from electromagnetic waves.

Analytical Techniques:

1) **Scanning Electron Microscopy (SEM)**
2) **Fourier-transform infrared spectroscopy (FTIR)**
3) **Raman Spectroscopy (Raman)**

Synthesis of Hierarchical Metamaterials

The metamaterial involved will be layers of different materials stacked on top of each other.

- Si and Quartz wafers for intermediate layer
- 200 nm of Au and ZnS deposited on dielectric layers

Photolithography was used to produce the unit structure of the Au disk

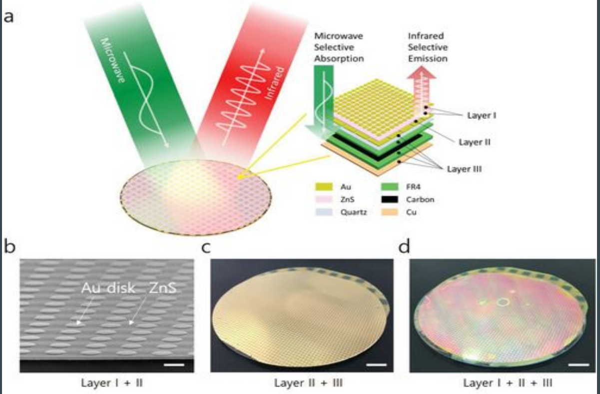
Bottom of the composite is a Copper disk used for a ground layer and a flame retardant-4 (FR4) layer.

Composed of three layers

Layer 1- Au layer, ZnS wafer

Layer 2- Au disk with etched patterns

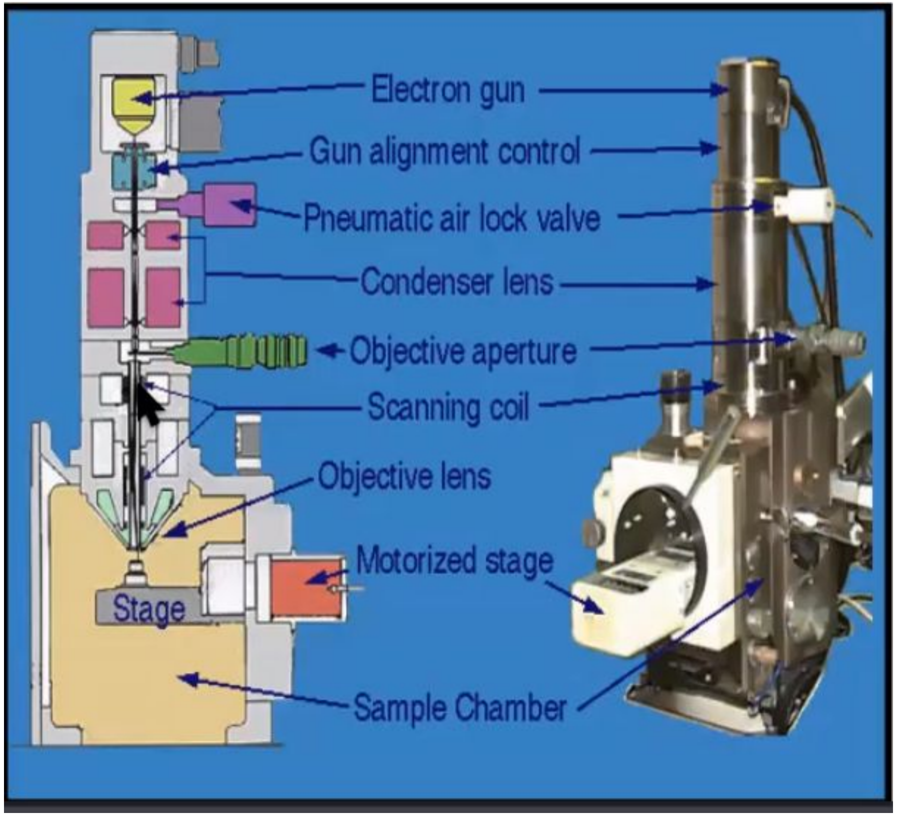
Layer 3- Quartz wafer, FR4, Carbon, FR4, Copper ground metal



SEM Introduction

- Creates an image through an electron beam that scans the sample

- Allows analysis of biomaterials structure that already have camouflage properties



SEM Research[2]

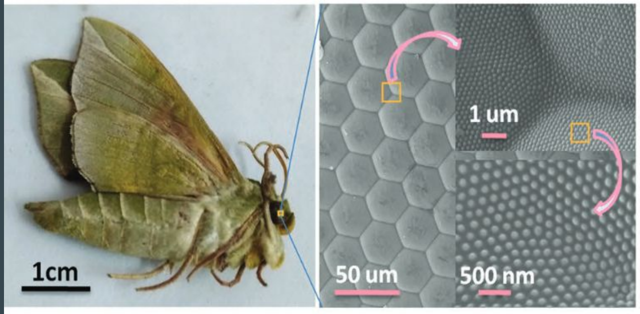
The microstructure of a Moth eye was studied

- Able to suppress reflection of light
- Hydrophobic

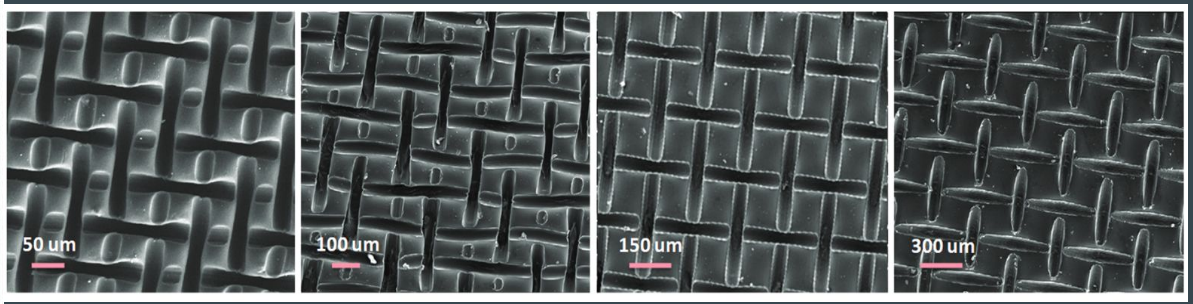
Results:

- MM camouflage to red, blue and purple light
- Anti visible light reflection
- Self-cleaning

SEM image of moth eye

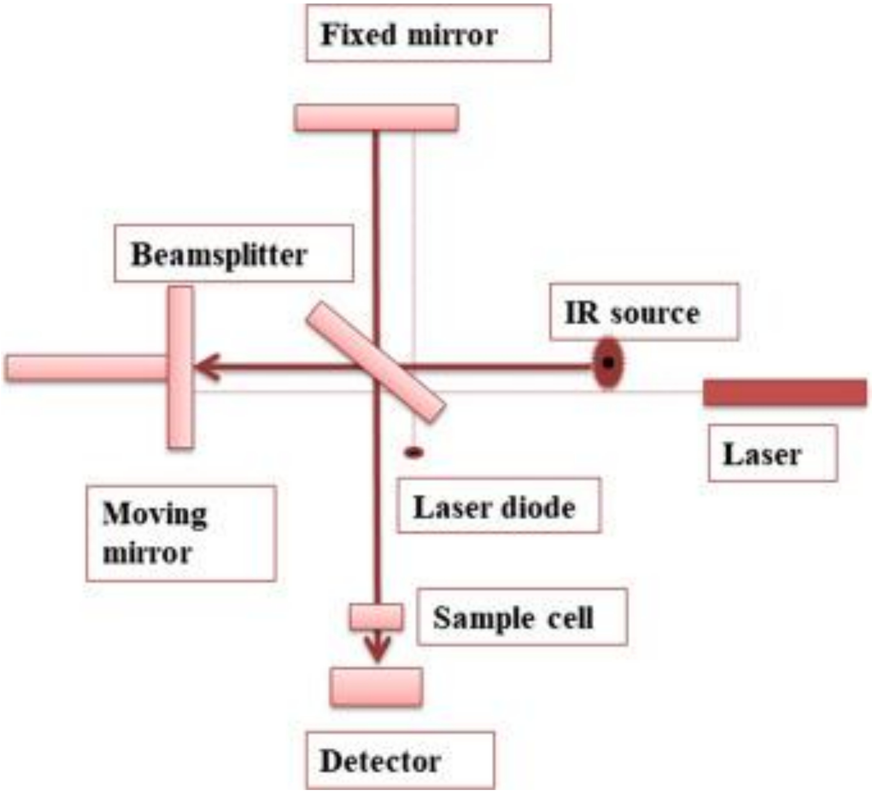


SEM image of a metamaterial



FTIR Introduction

- Uses infrared radiation to determine the structures of molecules with the molecules' characteristic absorption
- Measures how much light a sample can absorb at each wavelength
- Can obtain an infrared spectrum of absorption or emission of a solid, liquid or gas



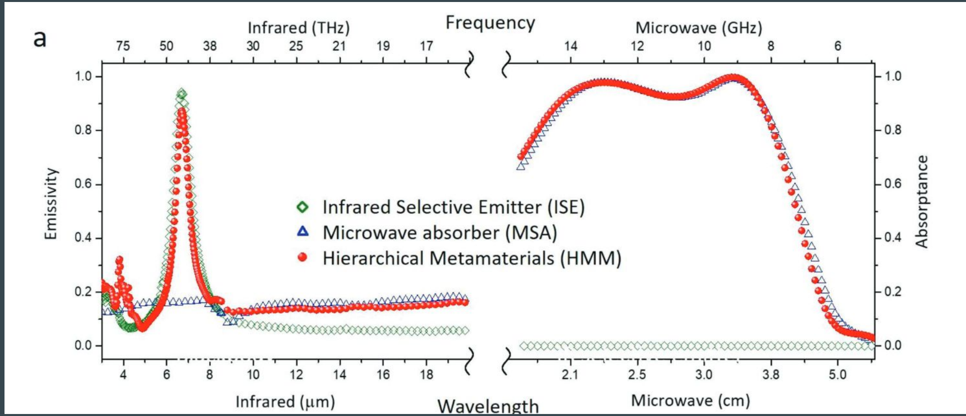
FTIR Research[3]

Spectral emissivity and reflectance were measured using FTIR

Simultaneously multispectral camouflage against infrared wave and microwave

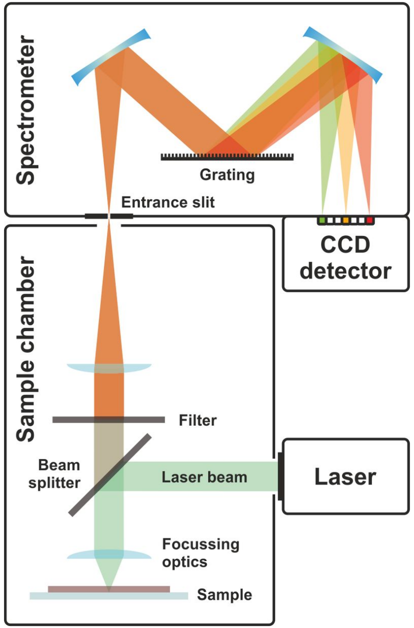
Results:

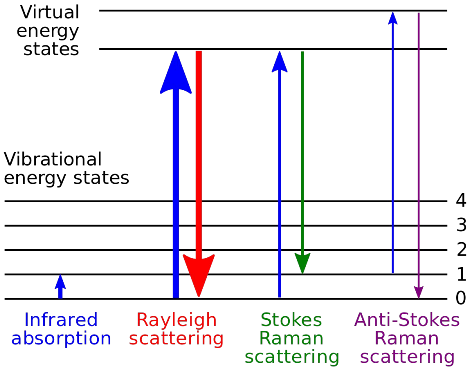
- Contrast radiant intensity (CR)I is up to 95% reduced
- Radar cross section (RCS) is up to 99% reduced
- Reduce thermal instability with higher emissive power



Raman Introduction

- Raman Scattering- scattering of photons by a matter
- A laser hits the sample and interacts with the chemicals of the material
- Inelastic scattering causes the energy level of the photon to be at a lower or higher state
- Determine the chemical structure and impurities of the material





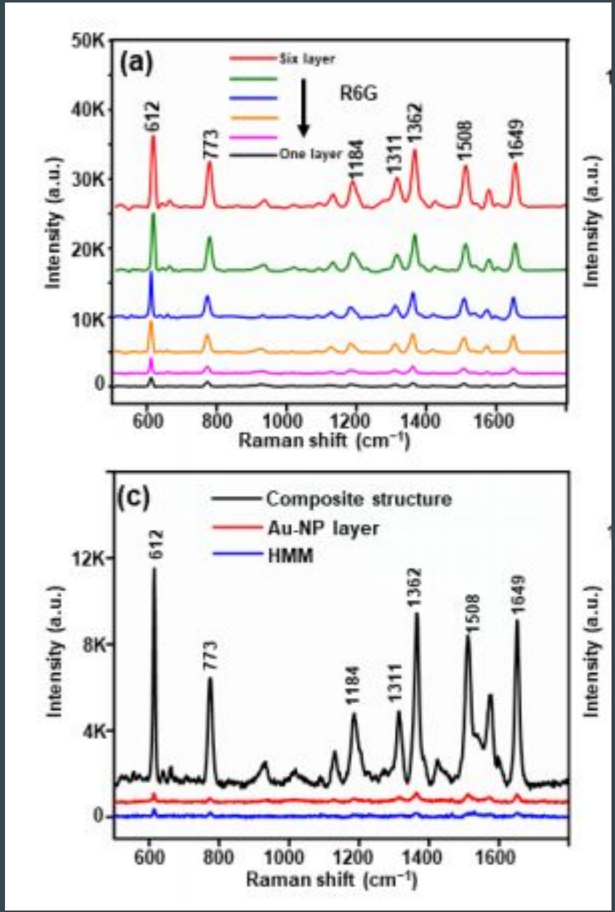
Raman Research[4]

Raman Scattering used on a hyperbolic metamaterial and gold-nanoparticle layer

Figure a shows drop in intensity between two peaks

Figure b shows large peaks due to the number of Au/Al2O3 bilayers of the sample

For the hierarchical metamaterial camouflage synthesize, Raman spectroscopy would show the uniformity of the material as well as intensity of light be refracted



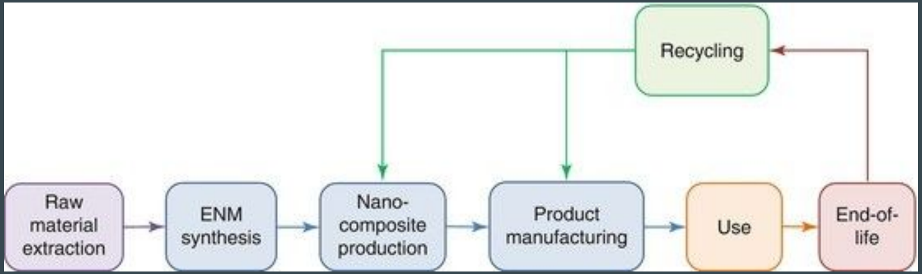
Environmental Impact*

Nanomaterials:

- Synthesized by “top-down” or “bottom-up” methods and are restricted to laboratory scales not suitable from industry yet
- Processing occurs in closed reactors or open conditions of labs and is considered unlikely to release in the environment
    - After processing, nanomaterials are embedded into a mixture/matrix and both recovery and waste treatments become easier

Disposal:

- At the end of metamaterial life expectancy, the product can be discarded or recycled
    - Metamaterials Camouflage contain Gold (Au) and Silicon (Si) nanostructures which would be extracted and recovered to recycle



*Metamaterials as a whole are a fairly new research topic and are unique based on their application. In the case of their environmental impact, we will look at how Hierarchical Metamaterials are fabricated and base the environmental assumptions off Slide 4 “Synthesis in Hierarchical Metamaterials”

Future Work

- Camouflage spray
  - Rapid and efficient.
  - Military Purposes
- Solar Panel Camouflage
  - Light absorption
  - Reduce loss of bird death

Conclusion

Through layering of metamaterials, camouflage will be achievable at higher ranges.

Metamaterials are better at refracting light.

Photolithographic processes allows the formation of meta material patterns in a nano scale.

Applying metamaterial camouflage on solar panels will be environmentally beneficial by reducing the amount of bird death.

Reference

[1] Lee, S., Kang, B., Keum, H. et al. "Heterogeneously Assembled Metamaterials and Metadevices via 3D Modular Transfer Printing". *Sci Rep* 6, 27621 (2016). https://doi.org/10.1038/srep27621

[2] Huang, Lingxi, et al. "Bioinspired Metamaterials: Multibands Electromagnetic Wave Adaptability and Hydrophobic Characteristics". *Small* 15(40), 2019. doi:10.1002/smll.201902730

[3] Kim, T., Bae, J.-Y., Lee, N., Cho, H. H. "Hierarchical Metamaterials for Multispectral Camouflage of Infrared and Microwaves". *Advanced Functional Materials* **29**(10), 2019. https://doi.org/10.1002/adfm.201807319

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