Thin-film, wide-angle, design-tunable, selective perfect absorber from near UV to far infrared

[1]Janardan Nath, [1]Douglas Maukonen, [1]Evan Smith, [1]Pedro Figueiredo, [1]Guy Zummo, [1]Deep Panjwani, [1]Robert E. Peale, [2]Glenn Boreman, [3]Justin W. Cleary, [4]Kurt Eyink

[1]Department of Physics, University of Central Florida, Orlando FL 32816

[2]Department of Physics and Optical Science, University of North Carolina at Charlotte, Charlotte, NC 28223

[3]Air Force Research Laboratory, Sensors Directorate, Wright Patterson AFB OH 45433

[4]Air Force Research Laboratory, Materials Directorate, Wright Patterson AFB OH 45433

http://www.ucf.edu

http://physics.cos.ucf.edu

Strong selective absorbers have a wide range of applications

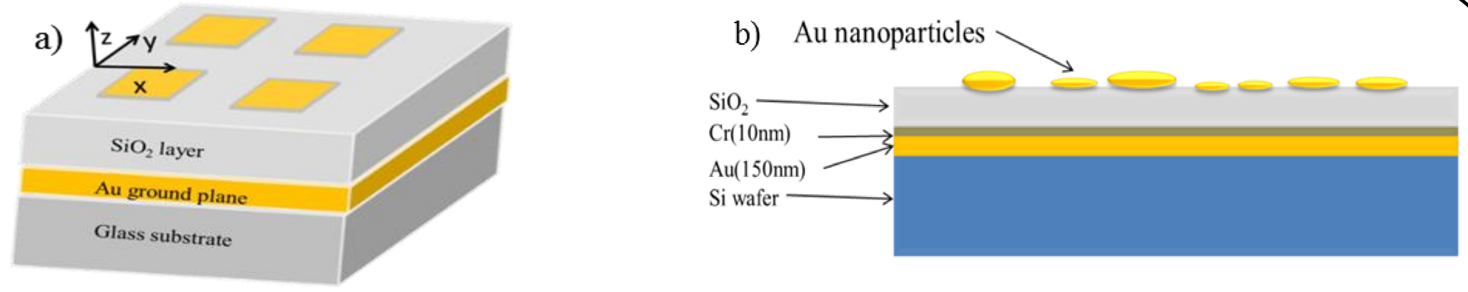
- Micro-bolometers, thermal imaging
- Coherent thermal emitters
- Solar cells
- Refractive index sensing
- Radar-absorbent material (RAM) in Stealth technology

Image:F-117 stealth attack plane, http://en.wikipedia.org/wiki/Stealth_technology

Resonant plasmonic and metamaterial structures are reported to produce perfect absorption up to 99%

- 99% absorption
- Design tunable in any range from UV- terahertz frequencies
- Ultra thin
- Wide angle of absorption

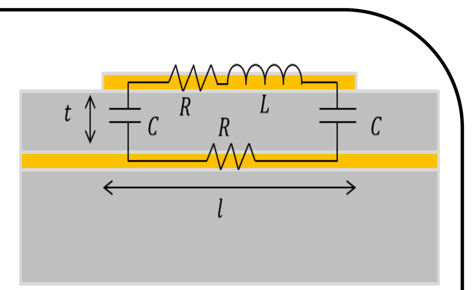
Theoretical considerations



Selective infrared absorber. (a) in mid-, far-IR region by periodic gold squares (b) broadband absorber in UV and NIR formed by gold nano-islands.

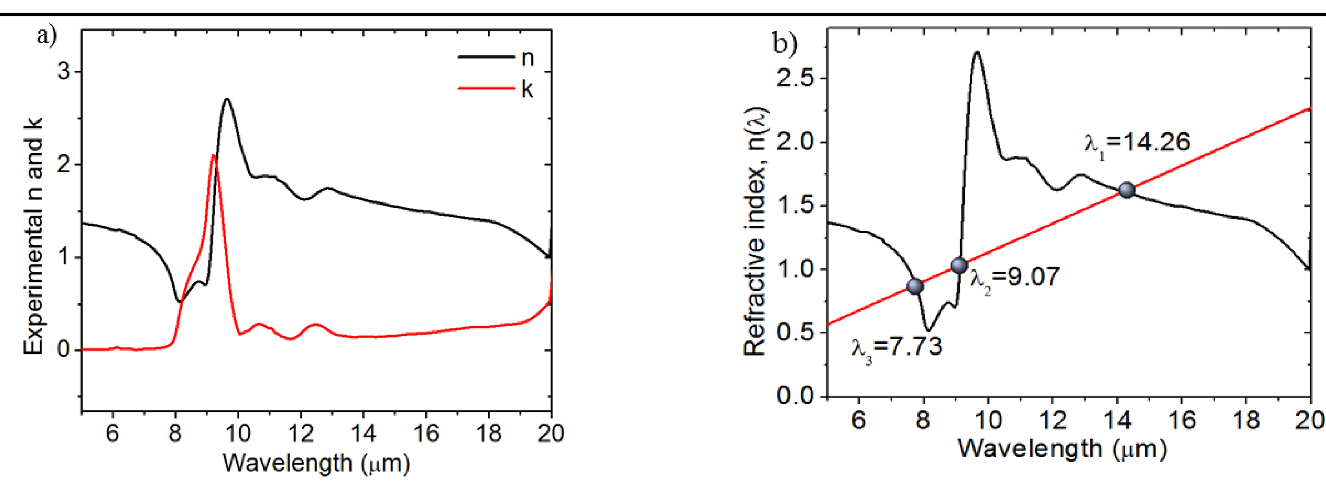
- Electric dipole is excited on the top gold square
- An image dipole is excited on the gold ground plane
- Resonance absorption can be explain by simple LCR circuit model
- LCR resonance frequency= $f = \frac{\sqrt{2}}{2\pi\sqrt{LC}}$
- Capacitance and mutual inductance=

$$C = \varepsilon_0 \varepsilon_r l^2 / 2t \qquad L = \mu_0 \mu_r t$$



$$\lambda = \pi l \, n(\lambda)$$

Resonance wavelength

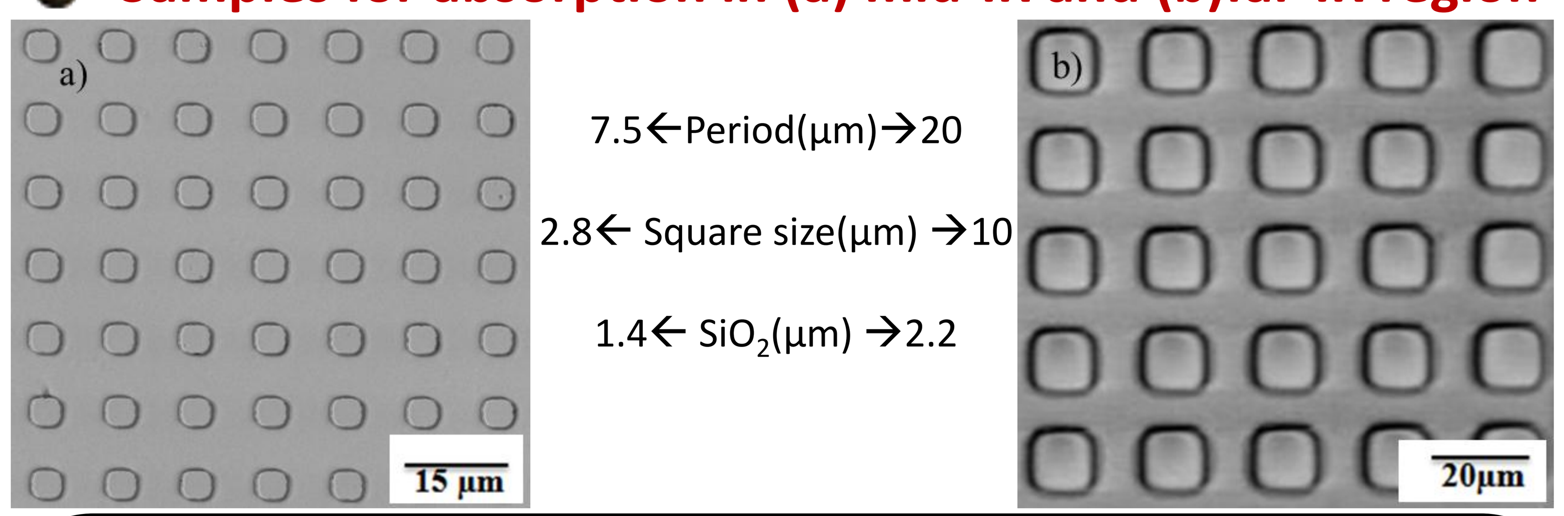


(a)Experimental refractive index n and absorption coefficient k of e-beam evaporated SiO_2 (b) Graphical solution of resonance condition

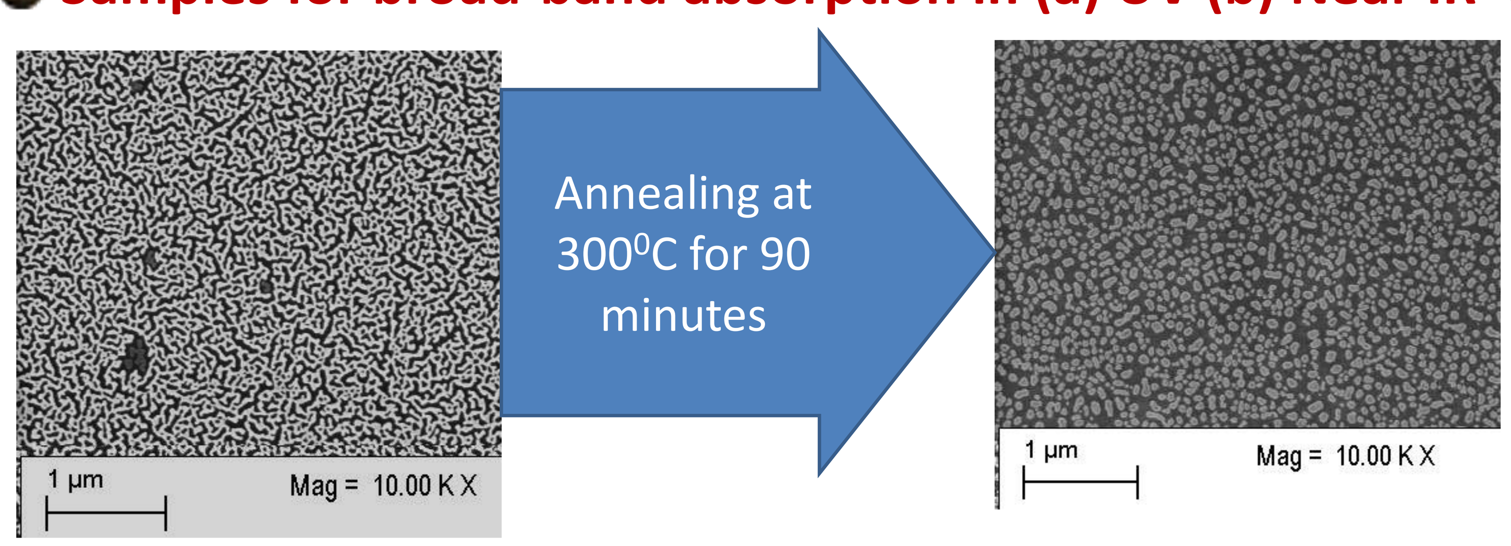
Materials and methods

- ✓ Sequencial e-beam evaporation on Si wafer
  1. 10nm -Cr
  2. 150nm -Au
  3. 10nm -Cr
  4. SiO_2
- ✓ Photolithography
- ✓ Au deposition by DC sputtering
- ✓ Metal lift off by acetone for periodic squares/ Annealing optically thin films to form gold nano-islands

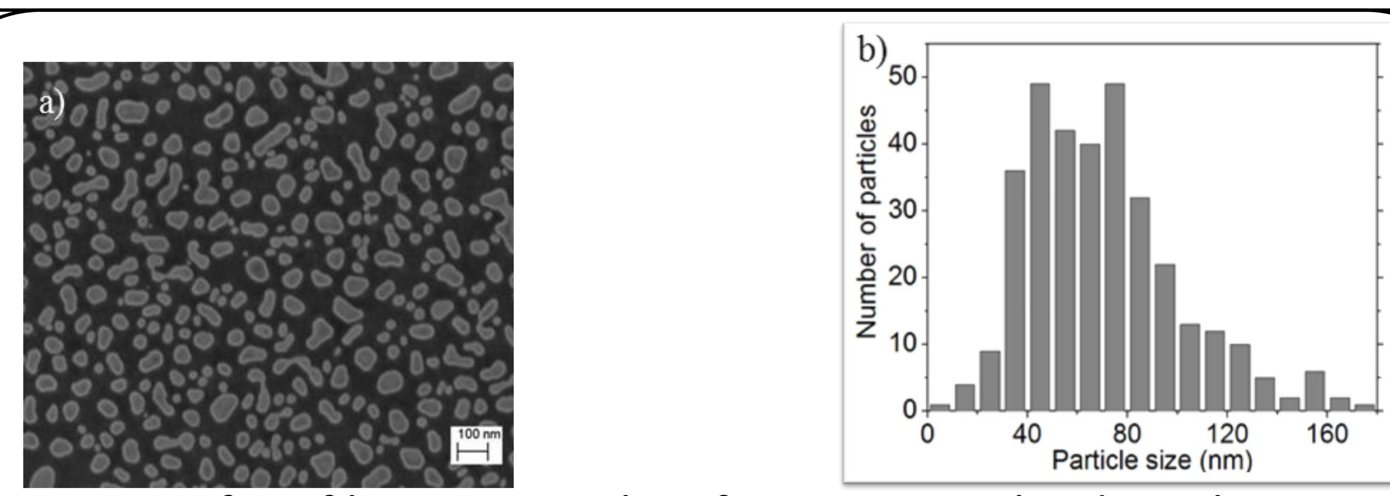
Samples for absorption in (a) mid-IR and (b)far-IR region



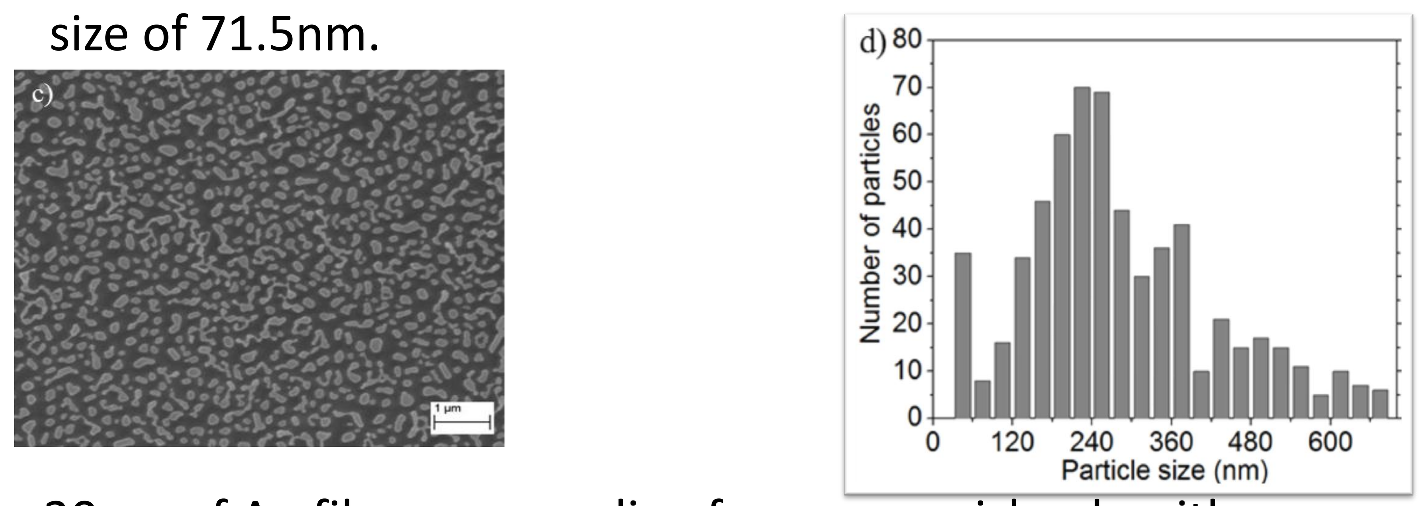
Samples for broad-band absorption in (a) UV (b) Near IR



DC sputtered optically thin gold films are annealed to form gold nano-islands

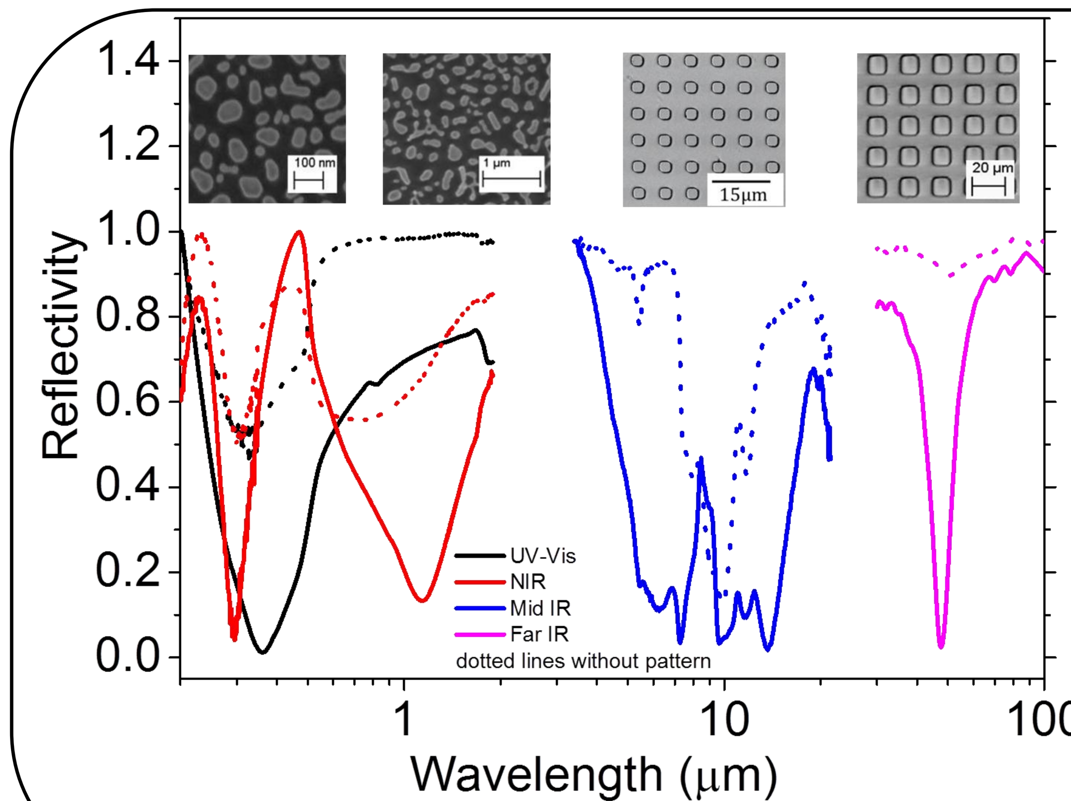


- ❖ 10nm of Au film on annealing forms nano-islands with average size of 71.5nm.



- ❖ 30nm of Au film on annealing forms nano-islands with average size of 282.3nm.

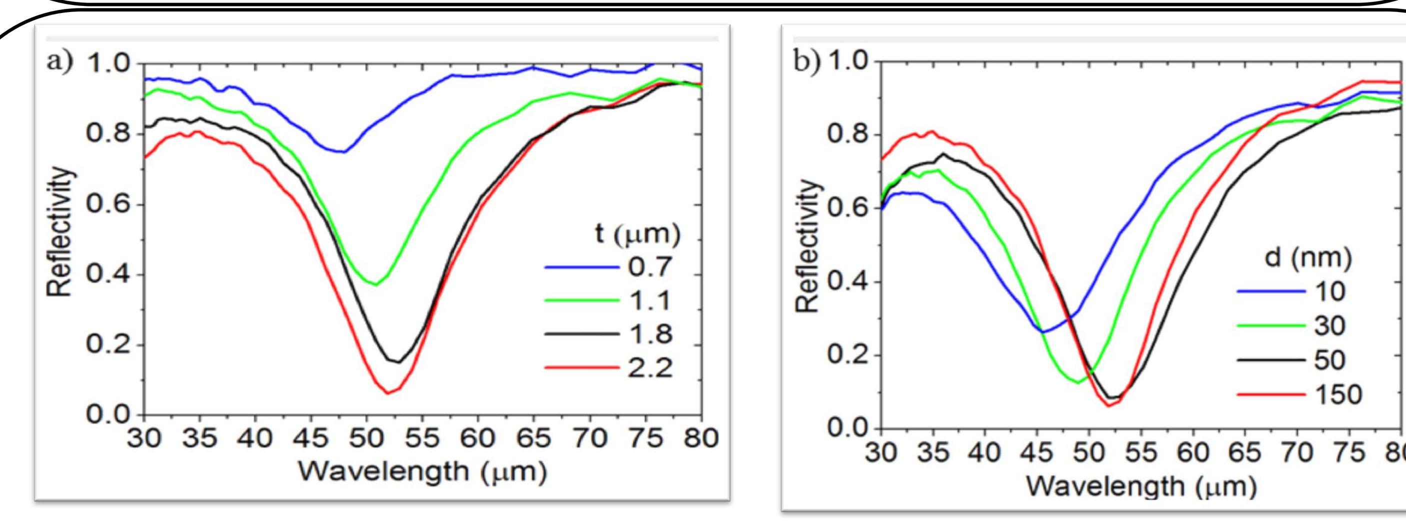
Results



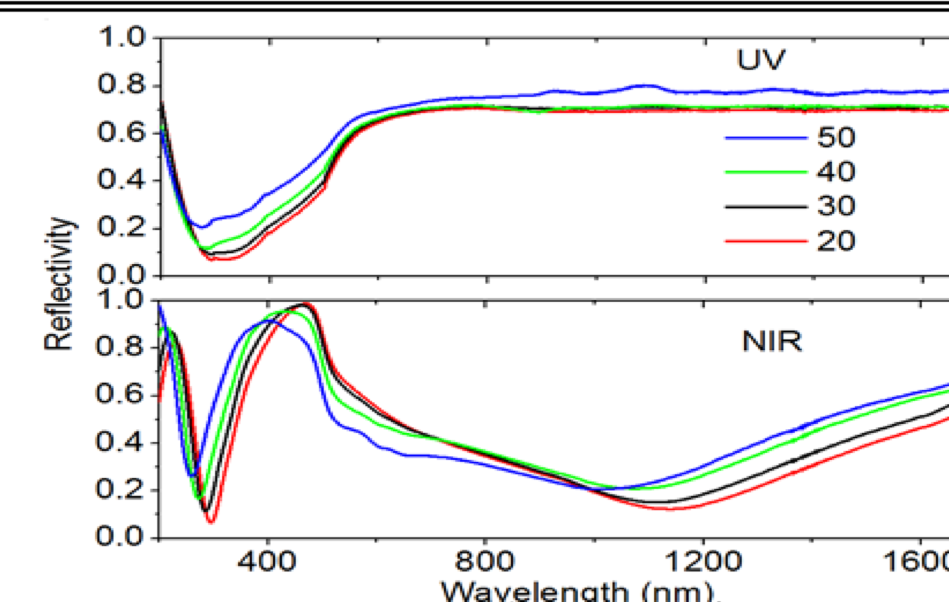
UV and NIR measurement = Cary500i UV-Vis-NIR spectrometer

Mid-, Far-IR measurement = PerkinElmer Spectrumone FTIR, BOMEM FTIR

Reflectivity spectra showing strong absorption up to 99%



Reflectivity spectra for sample in far IR as a function of thickness of (a) SiO_2, (b) top gold square. Optimum thickness of SiO_2 and top gold square are necessary for perfect absorption to occur.



Reflectivity spectra in UV and NIR with varying angle of incidence show sustained strong absorption up to wide angle of incidence.

Summary

We have experimentally demonstrated strong design-tunable absorption up to 99% in the near-UV, near-, mid-, and far-IR wavelength regions for surface composed of gold squares or islands separated from a gold plane by a SiO_2 dielectric layer. The positions of the resonances are predicted with reasonable accuracy using a simple analytic model.

Acknowledgement: This project is funded by EMX International LLC.