Tunable, All-Dielectric Metasurfaces using Insulator-to-Metal Transition Material VO$_2$

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Abstract

- Metasurfaces have a wide range of possible applications.
- Escarra lab has designed and modeled highly efficient all-dielectric metasurfaces.
- Effect of these surfaces is fixed after fabrication.
- By using metal-insulator-transition (MIT) material vanadium dioxide (VO$_2$) we hope to develop dynamically tunable metasurfaces.

Why VO$_2$?

- Most conventional materials require extreme stimulus for required tunability.
- VO$_2$ strongly tunable with minimal stimulus.
- Reversible transition from insulating state to metal state when exposed to heat, electric field, or intense light.
- When critical concentration of charge carriers is reached, lattice structure of VO$_2$ changes from monoclinic to tetragonal.
- Dramatic increase in conductivity (on the order of $10^{11}$), accompanied by a large change in refractive index (on the order of $n=1$).
- Intermediate states within this transition are stable, with changing material properties following a nearly linear trend [2].

Background

- Arbitrary manipulation of light via introduction of abrupt phase discontinuities on a subwavelength scale [3,4].
- Highly efficient, dynamically tunable metasurfaces will allow the creation of tunable and reconfigurable optics.
- The applications of this technology are endless: windows with tunable transmission of IR light, displays that can become mirrors with the flick of a switch, optical zoom for cameras in flat form factor, solar panels tracking the sun without moving, as well as many others.

Film Growth and Characterization

- Grown using pulsed laser deposition (PLD).
- Deposition parameters such as substrate temperature, vacuum pressure, oxygen flow rate, laser power, and pulse frequency must be optimized.
- Film is characterized by measuring resistance as a function of temperature and incident light power.
- Looking for MIT, expected to occur around 68 ºC, or around 800 µW of incident power [1,2].

Conclusions

- Performed exhaustive search for tunable materials.
- VO$_2$ was chosen as the antenna material for MIT, strongly tunable index.
- PLD used to grow preliminary films.
- Grown films do not show characteristic behavior.
- Films show a linear change in resistance with temperature, characteristic of a typical semi-conductor.
- Process refinement required to grow crystalline VO$_2$.

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References