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Nano-scale patterns of molybdenum on glass substrate for use in super-resolution imaging with metamaterials.

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Abstract

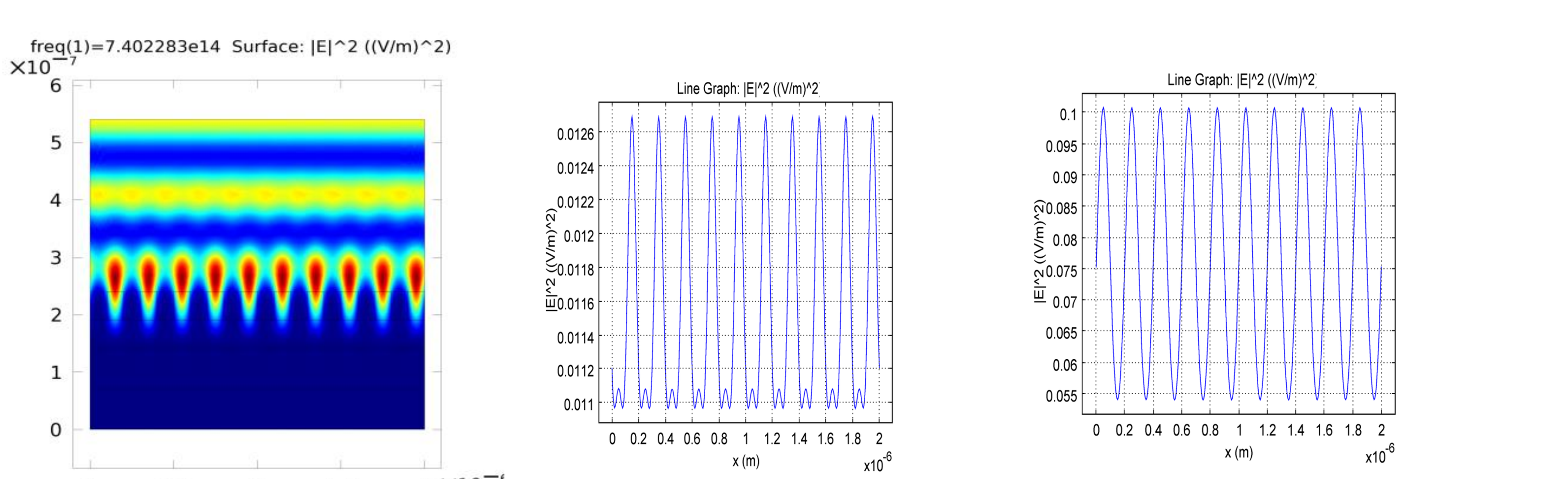
Photolithography is widely used to transfer a geometric pattern from a mask to a photoresist film, but the minimum feature sizes are limited by diffraction through the mask. Focused ion beam and electron beam lithography can be used when higher resolution is desired, but the write times are long and costly. Deep ultraviolet interference lithography, which is a maskless technique, can be used as an alternative to produce high resolution patterns with feature sizes as small as 100 nm. Since double negative metamaterial superlenses can be used for super-resolving and imaging sub-wavelength objects, there is a need for fabricating such objects to characterize the performance of these metamaterials. In this paper, simulations using standard finite element methods are first used to verify super-resolution and near-field imaging at 405 nm for such objects using a metamaterial superlens previously fabricated from silver and silicon carbide nanoparticles. Thereafter, results of fabrication and characterization of sub-wavelength objects using molybdenum of typical thickness 50 nm initially sputtered on a glass substrate is presented. A deep ultraviolet laser source at 266 nm is used. An anti-reflection layer followed by a high resolution negative tone photoresist is coated on the top of the molybdenum film. The cross-linked photoresist created after the development and bake processes is used as a mask for etching. Fabrication of the sub-wavelength object is completed using reactive ion etching in fluorinated plasma. Both 1D and 2D patterns are fabricated. The quality of the sub-wavelength objects during fabrication is checked using scanning electron microscopy, and the 1D object is characterized using TE and TM polarized illumination.

Objective

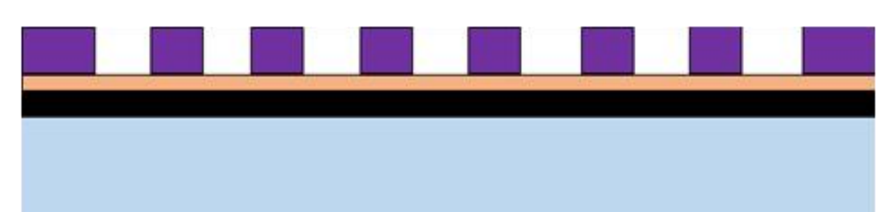
To simulate, fabricate and test a cost-effective metamaterial superlens which can image sub-wavelength objects with nano-scale features in the near-field for visible wavelengths, and for arbitrary polarization of the illuminating optical field.

Methodology

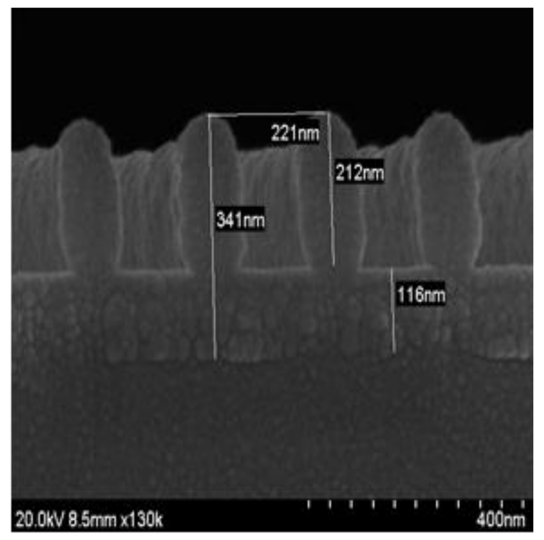
- ✓ Simulations based on this design for both TM and TE polarization conditions using finite element method (FEM) software such as COMSOL is reported.
- ✓ The fabrication technique of 1D and 2D sub-wavelength objects from Mo deposited on a glass substrate using interference lithography is discussed.

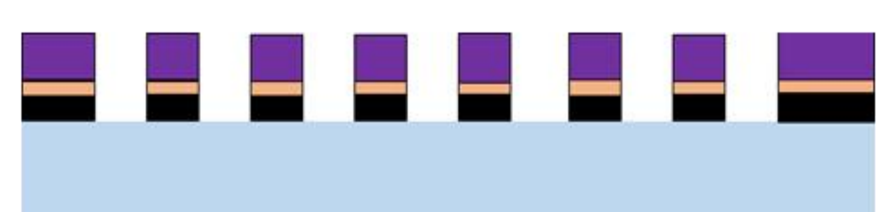


(a) COMSOL simulation of TE propagation through near field metamaterial imaging structure of periodic object, (b,c) plots of intensity variation on image plane with and without metamaterial, respectively.

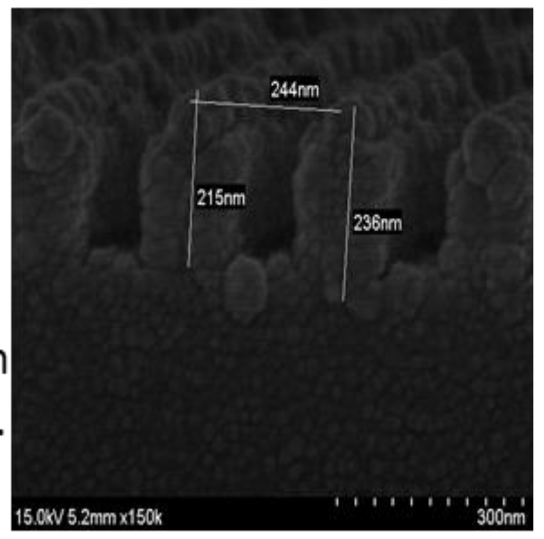


After the development on the exposed photoresist. A grating with period of sub-wavelength is completed.

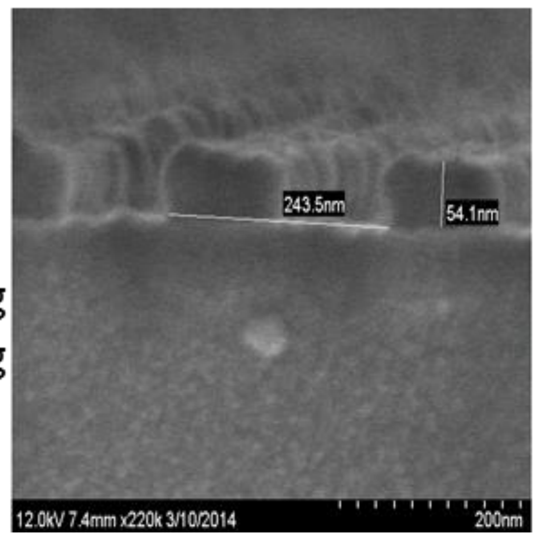




Using the photoresist grating as the etch mask. The sub- wavelength object of Mo is etched by reactive ion etching in a fluorinated plasma.



The left photoresist and BARC on Mo object are stripped by pouring acetone and followed by the treatment in the O2 plasma etching system.



Future work

- ➢The superlens will be illuminated with a normally incident TM & TE light source with wavelength at 405 nm;
- ➢ After the exposure and development, the pattern from the object will be imaged on the photoresist;
- ➢AFM will be used to characterize the pattern on the photoresist;
- ➢Multiple exposures will be taken and averaged to increase the signal-to-noise ratio.
- ➢NSOM may be considered to replace the AFM to characterize near field super- resolution.

References

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