Superlens design and fabrication

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Abstract

Superlens has been scientists' interests in recent years. It is known for overcoming the optical diffraction limit by collecting propagating and evanescent waves through negative index materials. Under quasi-static limit, a slab of material with negative permittivity will act as superlens. On the basis of this principle, the superlens based on silver/dielectric multilayer was studied from theoretical and experimental perspectives in this work.

In the theoretical work, the anisotropic superlens with hyperbolic dispersion relation and the resonant cavity superlens were studied. The hyperbolic dispersion means that there is no cutoff value for high spatial components, a slab lens made of such kind of medium could convert evanescent waves into propagating ones through the surface coupling modes and thus has a super or even perfect resolution. One application is the near-field superlens consisting of complementary meta-materials, in which the diffraction effects in first slab are compensated in the second slab which has a complementary anisotropic permittivity. By tuning the effective permittivity in the complementary meta-materials, a near field superlens with tunable working wavelength and working distance could be realized. The second application is the far-field superlens (FSL) with coupled Fabry-Perot cavities, in which the image sub-diffraction objects can be transferred to the outer surface of FSL and resolved by the optical microscope. Meanwhile, high transmittance and good image fidelity in this far field superlens could be realized.

The resonant superlens proposed by J. Li et al. [100] was investigated and compared with the single silver layer superlens and the silver/dielectric multilayer superlens from an experimental point of view. In the experimental work, these near-field superlens devices were fabricated, the transmission and near-field imaging property of them were physically characterized.

Firstly, the angle resolved transmission experiment (ART) was used to measure the transmission properties of propagating waves in the three kinds of superlens devices,

the results show that resonant superlens with Fabry-Perot cavity has an omni-directional transmission property and high transmission efficiency for the p-polarized light. In comparison, the single silver layer superlens and the multilayer superlens have low transmission efficiency at the working wavelength. All experimental results agree well with simulation results.

The second experimental step is near field-imaging process. Commercial photolithographic technique was utilized to demonstrate the resonant superlens property. The superlens mask with various resolutions was fabricated by focused ion beam, and the superlens devices with optimized surface were fabricated on the superlens mask through the thin film deposition method. The sub-wavelength imaging resolution was realized in the resonant superlens, the single silver layer superlens and the multilayer superlens, of which the resonant superlens has higher imaging contrast and higher image fidelity. These results also agree well with theoretical predictions.

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