Wire Grid Polarizers

NIL Technology

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Technology Summary

The polarization of electromagnetic waves (EW) describes the orientation of wave oscillations perpendicular to the direction of propagation. EW can be polarized in a linear, circular or elliptical fashion in respect to the travelling direction, but they can also be a mixture of the three or even be unpolarized where the EW has a random oscillation pattern.

In polarizers, EW in a mixed or unpolarized state are blocked and only specific polarization states are allowed to pass. A wire grid polarizer (WGP) functions as an absorptive polarizer, meaning that only allowed polarizations are transferred through the device, while the rest is absorbed. WGP's consist of a regularly placed grid of metallic wires situated in the plane of the EW oscillations. With unpolarized EW incident on the grid, the electromagnetic field oscillating parallel to the wires will generate electron movement along the wires in response to the oscillating field. The electron movement then creates a travelling wave cancelling the incoming waves oscillating parallel to the wires and reflects it in the same manner as a thin metal sheet. The components of the incoming wave having a polarization parallel to the wires are thus reflected, however with some loss due to Joule heating caused by electron movement in the wires.

On the other hand EW oscillating perpendicular to the wires and thus across multiple wires will not in the same way be able to induce electron movement along the polarization. Electron movement is in effect hindered by the non metallic spacing between the wires. Therefore the loss due to Joule heating and reflection is limited and the wave is transmitted through the device.

Since only specific polarizations are allowed through the wire grid, the resulting outgoing wave will have a single linear polarization, as illustrated in Fig. 1.

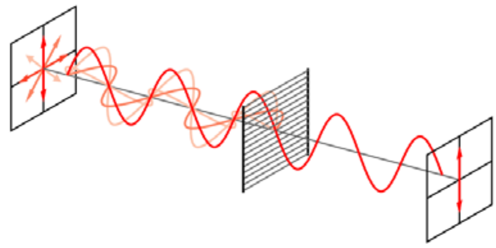

Figure 1: The working principle of a wire grid polarizer. [http://en.wikipedia.org/wiki/File:Wire-grid-polarizer.svg]

The spacing between the metallic wires and their widths determines how well and at which wavelengths the polarizer works. Generally, the lattice spacing should be smaller than the wave length of the EW and the wire's width even smaller. This condition means that the pitch of the grid should be less than 150 nm in order to function properly in the entire visible spectrum.

WGP are able to provide effective polarizers with a wide field of view and great working stability. They are also fairly simple and compact making them ideal for use as integrated polarizers in nano-optics.

Fabrication

In order to effectively fabricate WGPs in the entire visible spectrum, the metallic wires need to be defined in the nano meter scale with a very high pattern fidelity and resolution. This is why WGPs previously have been used exclusively in connection to microwaves. With the emergence of highly developed lithographic techniques, fabrication of WGPs in the visible spectrum has been made possible. So far WGPs working in the visible spectrum have mainly been fabricated in research context due to the costly processes involved. Standard UV-lithography is unable to produce the needed pitch size, but it is possible to obtain the needed pattern fidelity using modified photolithography such as immersion lithography. The modified techniques often require highly specialised and expensive equipment and often complicate the fabrication process.

To obtain the needed resolution one could instead use equipment such as electron beam lithography (EBL) which is able to provide very small and dense features. Unfortunately, EBL is a serial process with very low throughput and it is very expensive to acquire and run. In order to avoid using expensive serial tools such as EBL one can rely on stamps to be used in nano imprint lithography (NIL). The resolution of NIL is limited by how accurate the stamps can be manufactured and the post processing. Thus if the stamps can be fabricated using very precise equipment such as EBL and the following feature widening can be limited, then NIL can be used to imprint the nano features on wafer scale. Since the stamp can be reused many times and the imprint process is cheap and fast NIL is an excellent way of obtaining nano scale patterns.

Fabrication example

A fabrication example, using thermal NIL, for a WGP structure can be seen in Fig. 2. First the stamp is created; this is often been coated with an anti-sticking layer allowing for multiple imprints and easy release. For the imprint step a polymer is spin coated onto the substrate after the metal has been deposited. Essentially, the pattern will then be transferred to the imprint polymer by heating the sample whilst forcing the stamp into the polymer. The elevated temperature will decrease the viscosity of the imprint polymer thereby allowing it to flow into the cavities of the stamp. When the sample has been cooled, the sample and stamp can be severed, leaving the desired pattern imprinted in the polymer. After the imprint step, a thin residual layer will remain in the holes where the protrusions on the stamp have displaced the polymer; this residual layer can be removed by using for instance an oxygen plasma etch. The underlying exposed metal is then removed using metal etching. After the metal etch, the remaining imprint polymer is removed, thereby leaving a metal grating functioning as a WGP on the silicon.

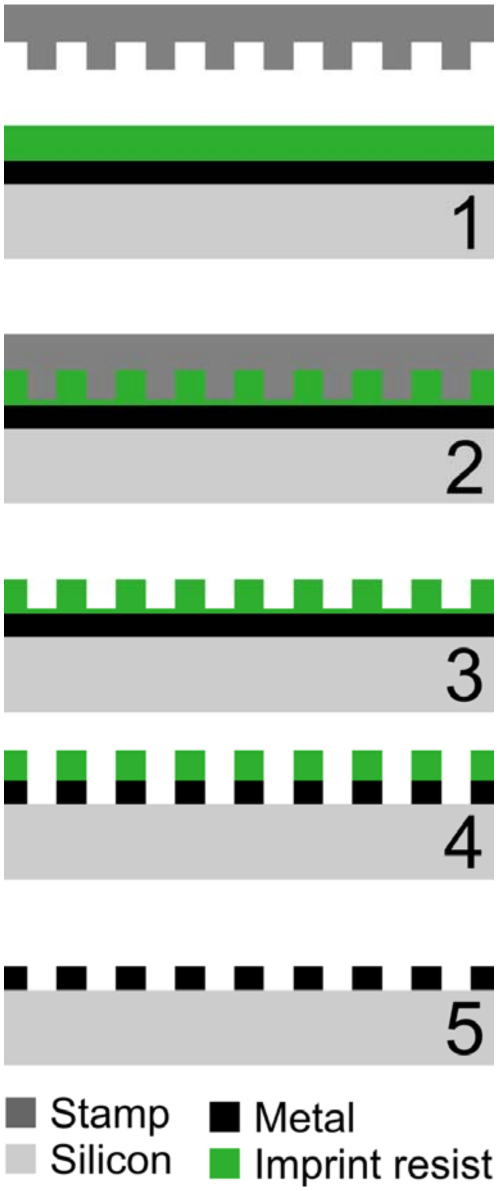

Figure 2: Fabrication of WGP on silicon using NIL. 1) Metal is deposited on the silicon and an imprint polymer is spin coated onto the sample. 2) The manufactured stamp is then imprinted into the polymer. 3) When the stamp is removed the reverse pattern remains in the polymer with a thin residual layer. 4) After removing the residual layer with an anisotropic oxygen etch, the pattern is etched into the exposed metal layer by using the imprint resist as an etch mask. 5) Finally, the remaining resist is removed such that the metal grating is exposed.

Fabrication done by NIL Technology

At NIL Technology we are experienced with the entire process of making stamps, doing high quality imprint and etching the metal nano wires. Below are some SEM images of a stamp for nano wire imprinting and a finished substrate with WGP metal structures.

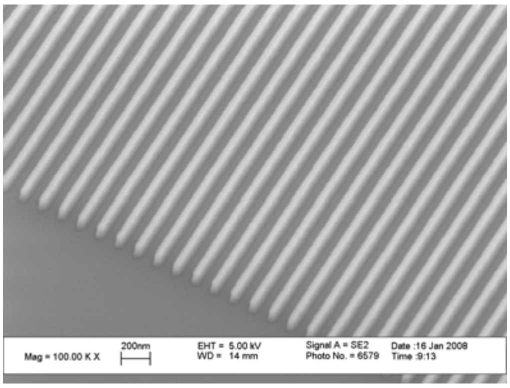

Figure 3: An example of a silicon stamp used for imprinting of WGP structures.

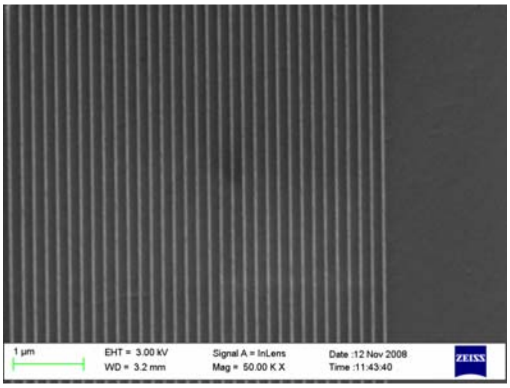

Figure 4: Metal wires, 30 nm wide, defined by NIL and dry etching of Al.