White Paper : Wire Grid Polarizers Using Nanoimprint Lithography

1. Executive Summary

Nanoimprint technology has been attracting attention as an inexpensive lithography technology that can form 10nm-level patterns on a wide range of substrate materials such as glass and resin. In recent years, it has become an essential technology for manufacturing nano-photonics optical devices that require particularly high environmental resistance, such as mobile devices, displays, automated driving, robotics, security, and AR (augmented reality). The wire-grid polarizers discussed in this paper are inorganic polarizers consisting of metal line and space patterns of several tens of nanometers formed on a transparent substrate.

2. Introduction

As shown in Fig. 1a, a wire grid polarizer works as a transparent material and transmits electromagnetic waves incident on parallel metal wires that have electric fields perpendicular to the wires (TM waves), while it works as a metal and reflects electromagnetic waves that have electric fields parallel to the wires (TE waves). This principle has been known for 100 years in the field of long wavelength radio waves. Such selective polarization transmission of electromagnetic waves occurs when the distance between the metal wires is less than half the wavelength of the electromagnetic wave and the effect of diffraction is negligible. With the progress of microfabrication technology, polarizers for infrared light and for visible light have been realized. As shown in Fig. 1b, a high-performance wire grid polarizer was achieved with a 100 nm pitch Al pattern processed by nanoimprinting that functions even in the ultraviolet light of 300 nm.

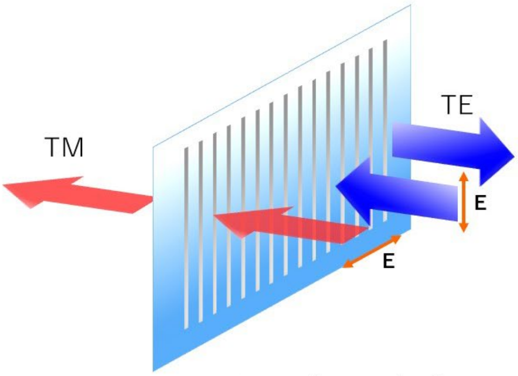

Fig.1 a Concept of wiregrid polarizer

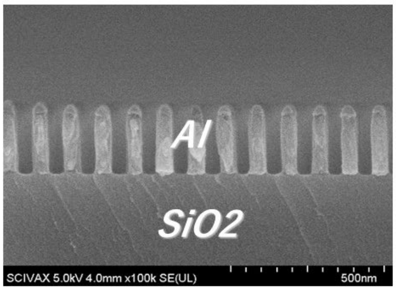

Fig.1 b Cross sectional SEM view of Al wire grid

Fig. 2 shows the process of the wire grid polarizer. A line and space resin pattern of several tens of nanometers is formed on the Al foil by nanoimprinting, and then the Al is processed by dry etching using this pattern as a mask to produce the wire grid polarizer.

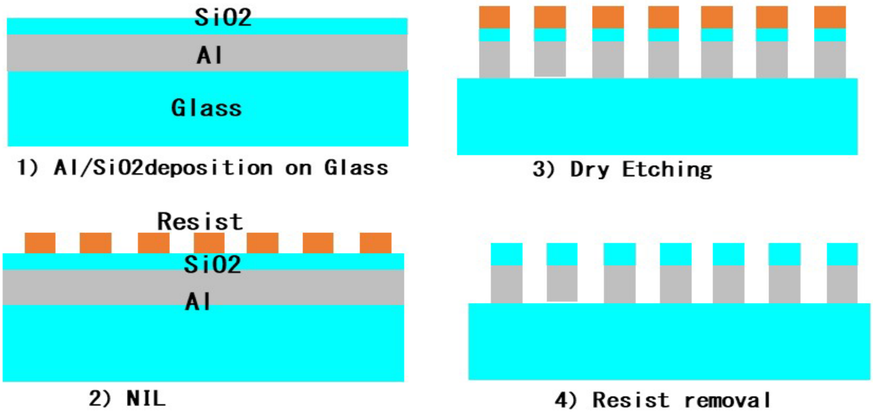

Fig. 2 Process flow

The wire grid polarizer has the following features.

(1) Cover a wide range of wavelengths from ultraviolet to far infrared.
(2) Wider tolerance to the larger incidental angle of light.
(3) Superior environmental durability to temperature and humidity with the inorganic formulation.
Because of the above features, wire grid polarizers are used in a wide range of applications where resin or prism-type polarizers are not fit.

Some application examples were shown in Fig.3

a) Since the wire grid is a reflective polarizer with high heat resistance, it is used as a polarizing beam splitter for projectors, head-up displays, and AR glasses.
b) Multi-directional polarizers for light-receiving sensors combined with photodiodes are also considered to be a promising field of application in the future. Polarization cameras, in which each camera pixel has a wire grid polarizer with a different direction, are used in industrial cameras to measure the texture of a subject or the stress distribution in a transparent object. New application fields such as environmental sensors, encoders, and coherent communications are being developed.
c) Wire-grid polarizers for UV light are also used in the process of aligning resin molecules by irradiating strong polarized light in the UV region onto the underlying resin to align the liquid crystal molecules in the manufacture of liquid crystal displays.

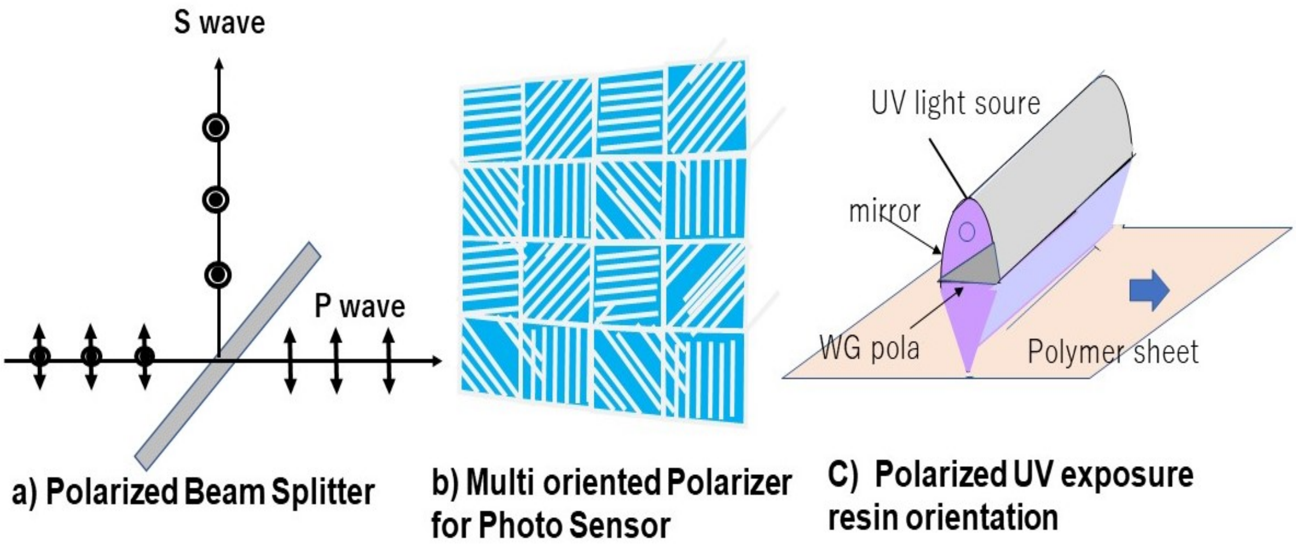

Fig.3 Application of Wire grid polarizer

3. Thesis Questions

Since wire grid polarizers are applied in a wide range of fields, various optical performance and environmental resistance are required for each product, as shown below.
(Viewing angle): Wire grid polarizers maintain their characteristics for a wide range of incident angles at 0° and 90° azimuth angles, but for incident light at 45° azimuth angle, the extinction ratio drops significantly, and the viewing angle becomes narrower, which can be a problem.
(Reflection contrast): Some polarizing beam splitters require the contrast of reflected light as well as the polarization contrast of transmitted light.
(Localized patterning and multi-angle pixelated formation): For polarization cameras and sensors, it is necessary to form localized wire grids on the device wafer or to form wire grids with multiple orientations.
(Surface protection): In some cases, it is necessary to protect the surface of the wire grid, which is vulnerable to contact.

4. Solutions

SCIVAX offers three types of wire grid polarizers with standard optical performance (visible light transmission, visible light beam splitter, and wide wavelength range) as standard products, and also designs and manufactures high performance custom products to meet customer product specifications.
The wire grid structure is designed using electromagnetic field simulation (RCWA) to optimize the pitch, width, and height of the Al wires to achieve the desired transmittance, reflectance, and contrast.
Fig. 4 shows the correction of the polarization axis shift at large viewing angles to improve the viewing angle dependence. In terms of light leakage characteristics in a crossed Nicols configuration, the corrected structure (b) shows no increase in light leakage with azimuthal angle change and no degradation in extinction ratio compared to the standard structure (a).

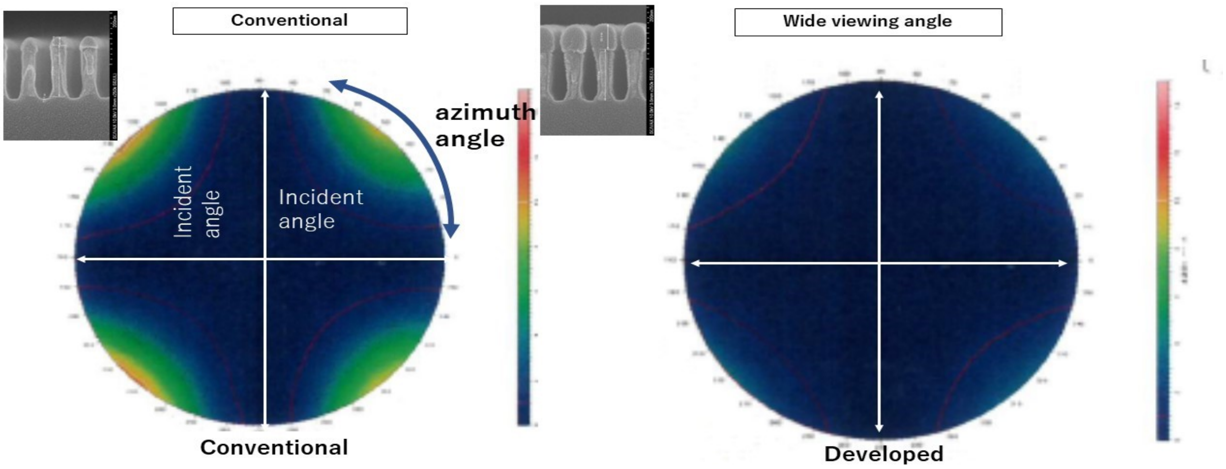

Fig. 4 Incident Angle Dependence of Wire Grid Leakage in Cross-Nicol Configuration

Fig. 5 shows an example of a wire grid coated with a SiO_2 film to improve mechanical strength, which is equivalent to 3H in a 750g-weighted pencil hardness test.

Fig. 6 shows an example of the process for forming a wire grid polarizer locally on a photodiode as shown in Fig. 3b). By using this technology to form the polarizer on a silicon wafer with an underlying device, it is possible to realize a light receiving sensor with new functions.

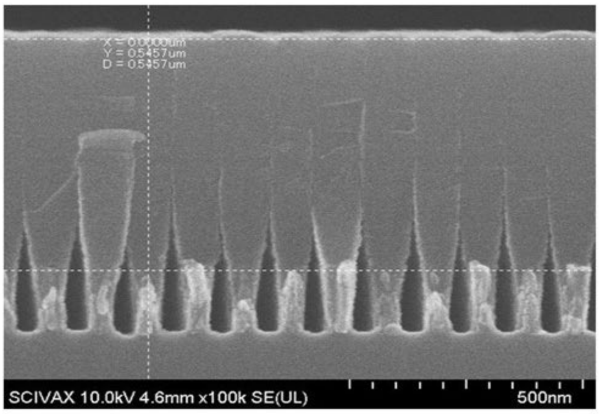

Fig. 5 SiO2 Coated wire grid

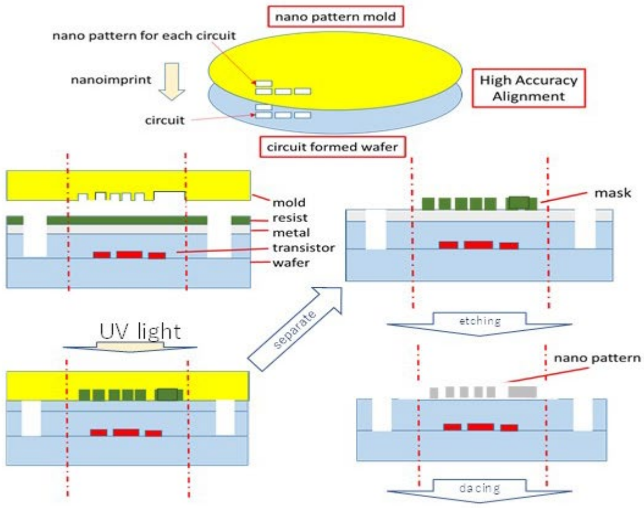

Fig.6 Wire-grid polarizers integrated into Si photosensors

5. Products Info

Table 1 shows the specifications of standard SCIVAX products in the catalog. In addition to the catalog products as described above, SCIVAX can design and manufacture custom products with specifications such as wavelength range, transmittance, reflectance, extinction ratio, incidence angle, viewing angle, local formation, multi-angle, etc. upon request.

Table 1 Polarizer Specifications for Catalog Products

1: Performance Specification

	MRLS 1 Visible WGP	MRLS 2 Beam splitter WGP	MRLS 3 Wide wave length range WGP
Wave length range	420nm to 700nm	420nm to 700nm	300nm to 2500nm
Transmittance (Tp)	83%(450nm) 85%(550nm) 85%(650nm)	83%(450nm) 85%(550nm) 85%(650nm)	83%(450nm) 85%(550nm) 85%(650nm) 90%(2500nm)
Extinction ratio (Tp/Ts)	200:1 (450nm) 300:1 (550nm) 500:1 (650nm)	200:1 (450nm) 300:1 (550nm) 500:1 (650nm)	200:1 (450nm) 300:1 (550nm) 500:1 (650nm) 1000:1 (2500nm)
Reflectance (Rs)	-	75%	-
Extinction ratio (Rs/Rp)	-	30	-
Angle of Incidence	0±20°	45±15°	0±20°

2. Substrate Characteristics

	MRLS 1 Visible WGP	MRLS 2 Beam splitter WGP	MRLS 3 Wide wave length range WGP
Sustrate Type	Alkaline Free glass	Alkaline Free glass	Fused Silica
Thickness	0.725mm	0.725mm	0.725mm
Index of Refraction	480nm 1.5160 643.8nm 1.5078	480nm 1.5160 643.8nm 1.5078	486.1nm 1.4633 656.3nm 1.4565
Thermal Expansion	31.7E-7 /°C (0-300°C)	31.7E-7 /°C (0-300°C)	5.5E-7/°C (0-300°C)

3: Others

Edge Exclusion	2mm (25mm□)	2mm(25mm□)	2mm (25mm□)
TA Torelance	±1°	±1°	±1°
Coating	Back side AR	Back side AR	-

6. Conclusion

As described above, wire grid polarizers manufactured with nanoimprint technology are used in a wide range of products and are recognized as an optical component with an expanding application market. SCIVAX provides Foundry Service for design, development and mass production using the best equipment, materials and processes developed in-house.