An improved wire grid polarizer for thermal infrared applications

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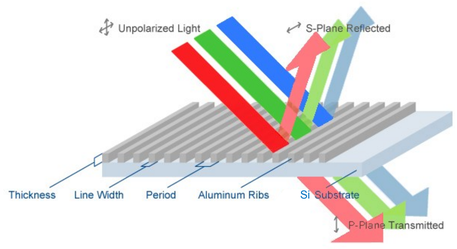
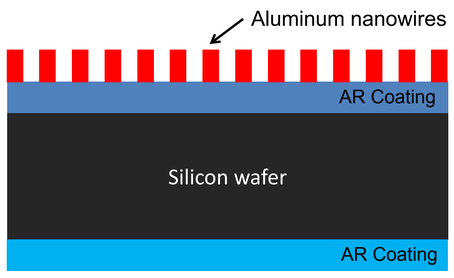


Motivation

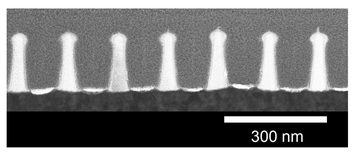
- The wire grid polarizer (WGP) is one of the most useful optical components in the field. Potential markets exist in Optical Isolation, Imaging, and Spectroscopic applications in Defense, Security, Forensics, Astronomy, Communications, and Industrial Lasers.
- The WGP consists of an array of metallic lines with sub-wavelength pitch (period) supported by a transparent substrate. It exhibits form birefringence and diattenuation (dichroisim), and an anisotropic reflectivity.
- Wire grid structures can be particularly effective as infrared polarizers due to:
  - broadband performance, large acceptance angle, compact size
- Existing WGP products designed for mid-wavelength (MWIR) and long-wavelength (LWIR) infrared applications are inadequate due to:
  - relatively large wire grid pitch (typically ≥ 370 nm)
  - low contrast (≤ 350) between transmission in passing and blocking configurations
- Moxtek has demonstrated a substantial increase in WGP contrast at visible and ultraviolet wavelengths by reducing the pitch.
- A dramatic reduction in pitch from that found in typical IR WGP products should greatly improve MWIR and LWIR contrast.
- Moxtek has therefore developed high contrast IR polarizers on AR-coated silicon suitable for MWIR and LWIR applications using our aluminum nanowire, large area patterning capabilities.

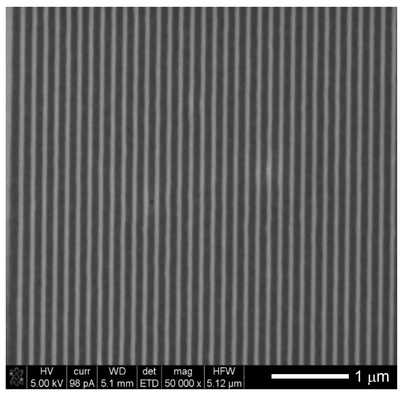
Approach

Aluminum Nanowire® Polarizer Technology

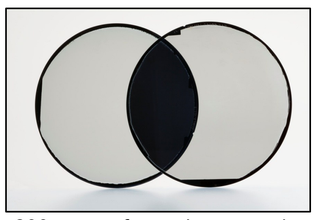


Al nanowires on AR-coated Silicon

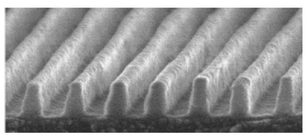




Highly regular Al nanowire grid on Silicon



200 mm wafer scale processing

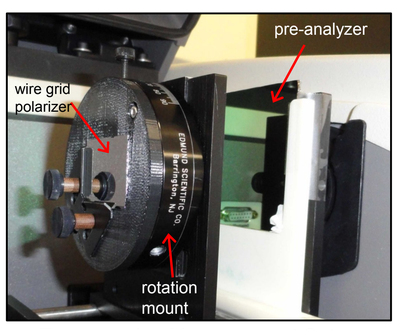


Standard Moxtek 144 nm pitch

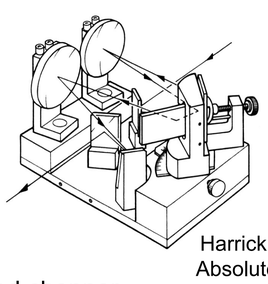
Metrology

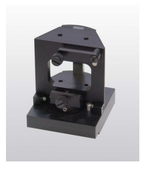
Instruments:

- Cary 670 Fourier Transform Infrared (FTIR) Spectrometer
  - Moxtek doubled SIR WGP as source pre-analyzer
- Nexus 870 FTIR ESP Spectrometer
  - Moxtek doubled SIR WGP as source pre-analyzer
  - Harrick Variable Angle Reflection Accessory
  - Harrick 12 & 45° Absolute Reflectance Sampling Stages
  - Harrick WGP on KRS-5
- FEI Nova 200 Dual Beam SEM/FIB
- Hitachi HD-2000 STEM
- Synrad Firestar CO_2 laser (360 µm spot size)
- Ophir 150C-sh thermopile detector
- Laser Precision Meter Rk-5720 Power Ratiometer with Laser Probe Rk-570 pyroelectric power head and integrated chopper



Transmission Measurement Setup

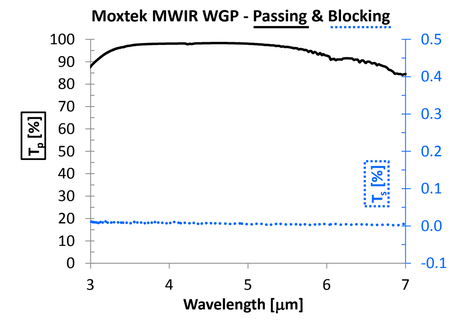


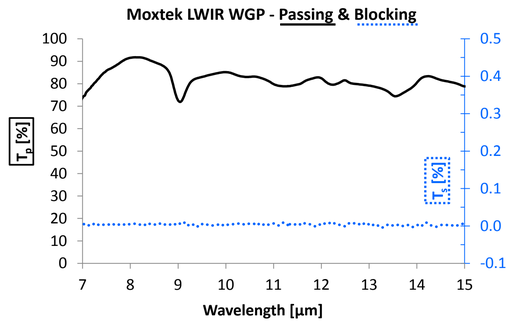


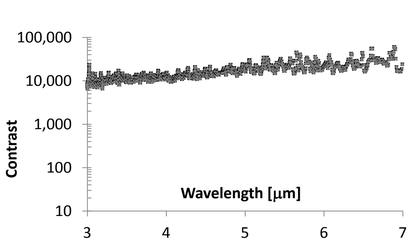
Harrick Reflection accessory and 12° Absolute Reflectance Sampling Stage

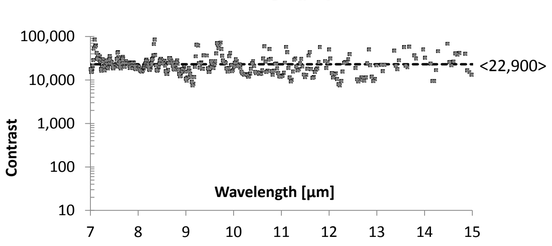
Key Results

Performance in Transmission (normal incidence)

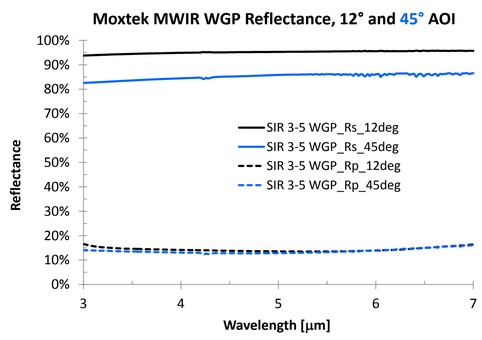


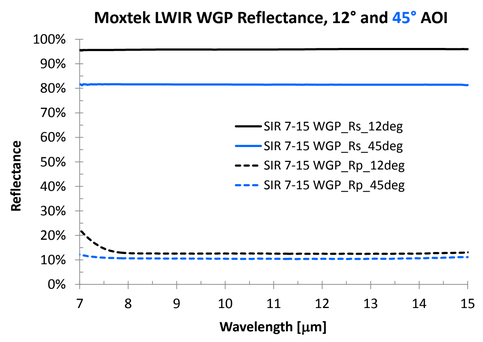






Performance in Reflection (12 & 45° angle of incidence)

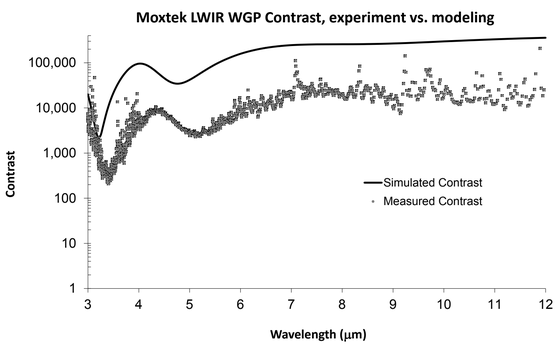


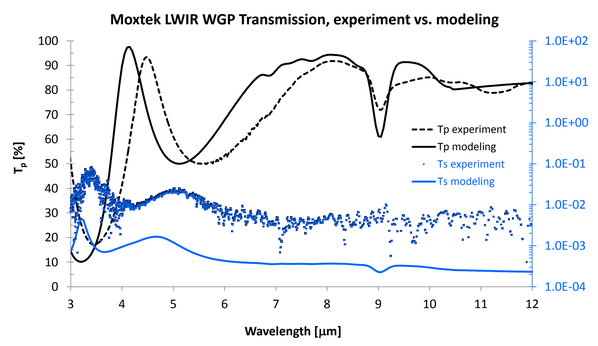


Optical Modeling vs. Measured Transmission

Rigorous Coupled Wave Analysis (RCWA) using Gsolver© software

- Retained +/- 10 diffracted orders
- Rectangular cross section, 190 nm tall Aluminum ribs with fixed duty cycle of 35%
- IR Aluminum optical constants and Silicon IR-VASE analysis from J.A. Woollam
- AR coating data from Universal Thin Film Laboratory





Summary

Moxtek has developed high contrast IR wire grid polarizers on AR-coated silicon suitable for MWIR and LWIR applications.

- MWIR polarizer shows:
  - high contrast (>35 dB) between blocking and passing states.
  - greater than 95% passing state transmission between 3.3 - 5.7 µm.
- LWIR polarizer shows:
  - high contrast (>40 dB) between blocking and passing states.
  - greater than 70% passing state transmission between 7.0 - 15.0 µm.
  - FTIR transmission measurements show qualitative agreement with optical modeling results from a commercial RCWA software package.
  - Preliminary laser damage threshold tests reveal LWIR WGP withstands 110 kW/cm^2 of 10.6 µm cw laser radiation in the blocking state and 10 kW/cm^2 in passing state.

Acknowledgments

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www.UniversalThinFilmLab.com
Spica Technologies Inc.
J.A. Woollam Co., Inc. Ellipsometry Solutions

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