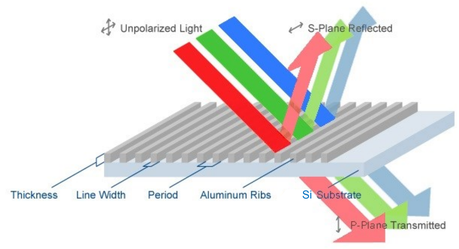
Nanowire grid polarizers for mid- and long-wavelength infrared applications

M. George*, B. Wang, R. Petrova, H. Li, J. Bergquist

Moxtek, Inc. Orem, UT
***mgeorge@moxtek.com**

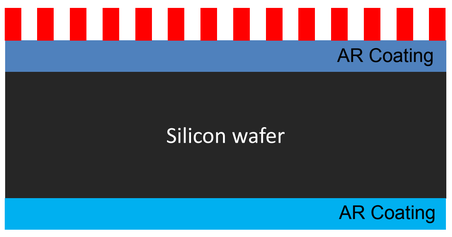


Motivation

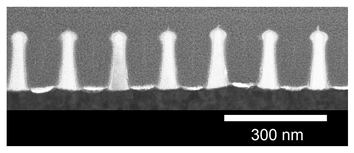
- The wire grid polarizer (WGP) is one of the most useful optical components in the field. Potential applications include optical Isolation, spectroscopy, and imaging in the defense, security, forensics, astronomy, and telecomm industries.
- The WGP consists of an array of metallic lines with sub-wavelength pitch (period) supported by a transparent substrate. It exhibits form birefringence and diattenuation (dichroisim) resulting in 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 large wire grid pitch & low contrast between transmission in passing & blocking configurations
- Moxtek has demonstrated a substantial increase in WGP contrast at visible and ultraviolet wavelengths by reducing the pitch, which should translate into the IR.
- Thus Moxtek has developed high contrast MWIR & LWIR polarizers on AR-coated silicon using our aluminum nanowire, large area patterning capabilities.

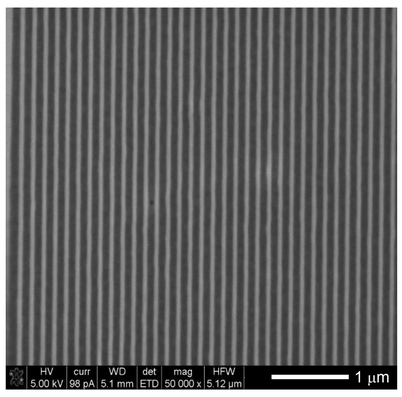
Approach

Aluminum Nanowire® Polarizer Technology

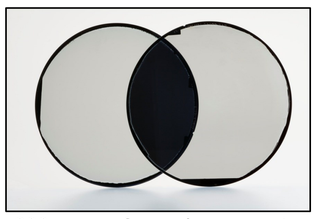


Al nanowires on AR-coated Silicon

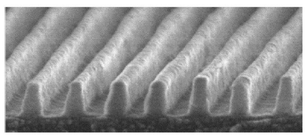




Highly regular Al nanowire grid on Silicon



200 mm wafer scale processing



Standard Moxtek 144 nm pitch

Metrology

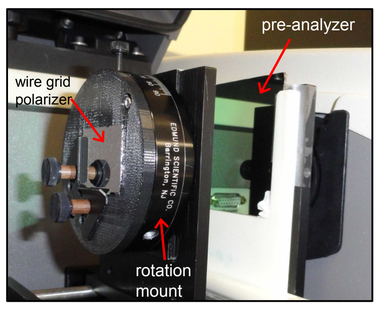
Instruments:

- Cary 670 Fourier Transform Infrared (FTIR) Spectrometer
- 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)
- Spectra Physics 1064nm, 25kHz HIPPO laser pumping

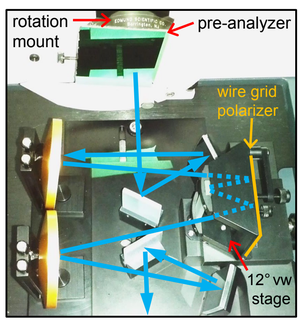
PPLN OPO for 7 ns pulses at 4.0 µm (95 - 370 µm spot sizes)

- 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



Reflection Measurement Setup

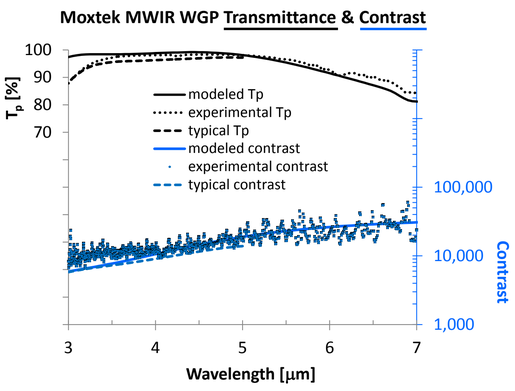
Optical Modeling

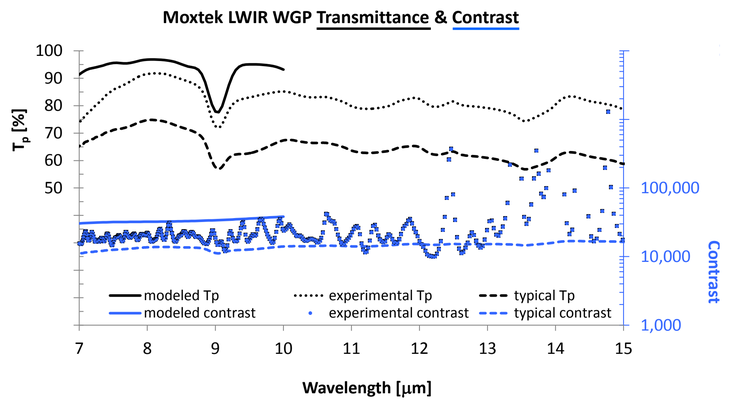
Rigorous Coupled Wave Analysis (RCWA) using Gsolver© software

- Retained +/- 12 evanescent diffracted orders
- Rectangular cross section, 165 nm tall Aluminum ribs with fixed duty cycle of 27.8%
- IR Aluminum optical constants and Silicon IR-VASE analysis from J.A. Woollam
- AR coating data from Universal Thin Film Laboratory
- Two step transmittance simulation. Ignoring coherent effects from reflections off front / back of wafer.

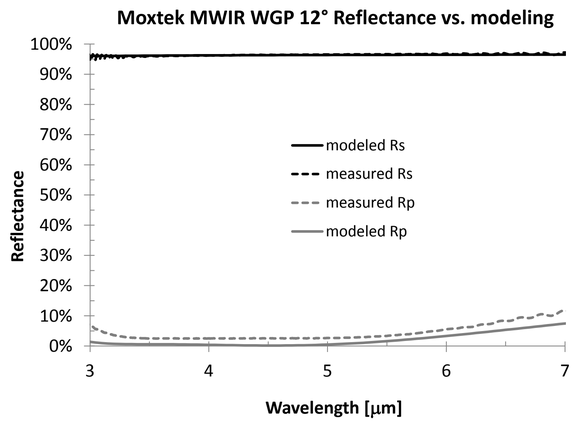
Key Results

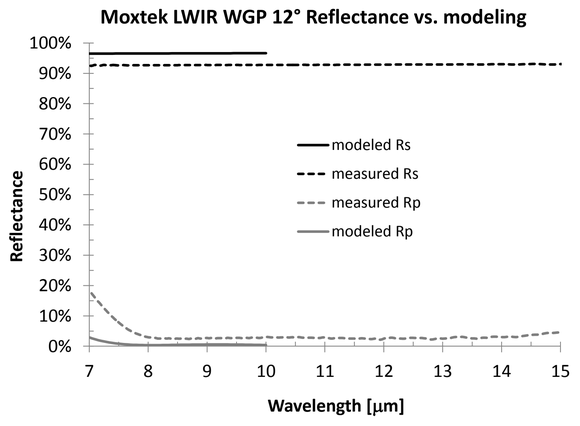
Performance and Modeling in Transmission (normal incidence)



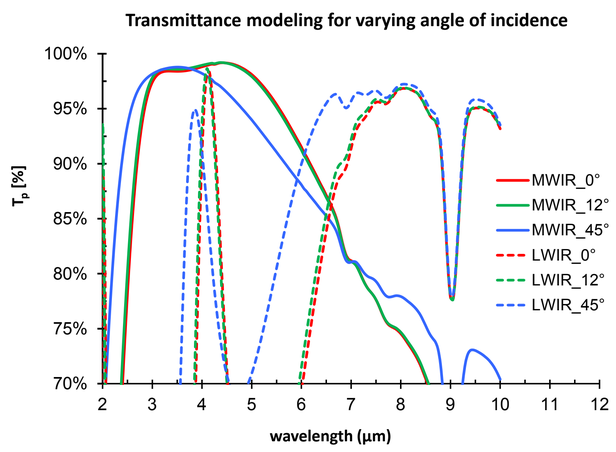


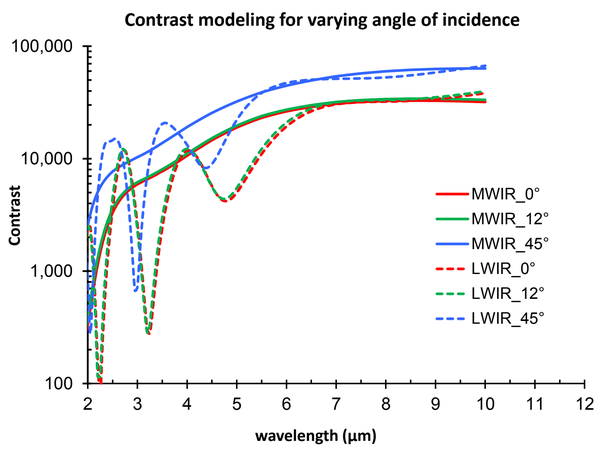
Performance and Modeling in Reflection (12° angle of incidence)





Transmittance and Contrast Modeling with Varying Angle





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 (>37 dB) between blocking and passing states.
  - greater than 95% passing state transmittance between 3.5 - 5.5 µm.
  - Preliminary laser damage threshold tests reveal MWIR WGP withstands 650 W/cm^2 of pulsed laser radiation at 4 µm in blocking state and 14 kW/cm^2 in passing state.
- LWIR polarizer shows:
  - high contrast (>40 dB) between blocking and passing states.
  - between 55% and 90% passing state transmittance between 7.0 - 15.0 µm.
  - 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.
- FTIR transmission and 12° reflectance measurements show qualitative agreement with optical modeling results from a commercial RCWA software package.

Acknowledgments

Ball Aerospace & Technologies Corp.
www.UniversalThinFilmLab.com
Spica Technologies Inc.
J.A. Woollam Co., Inc. Ellipsometry Solutions

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