Fabrication of Silver MicroWire Polarization Filters

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Abstract:

Nanowires make good sensors because their small dimensions enhance their sensitivity. To be useful, wire sensors must be integrated with electronics capable of processing those signals. In this project, we demonstrated a method to fabricate arrays of micron-sized wire-grid optical polarization devices. Using photolithography and other experimental techniques, we developed a reliable procedure for producing silver wires with micron-scale features. This procedure was optimized by altering the dose and bake times so as to achieve the best possible fabrication process. The polarization filters produced in this project are prototypes of much smaller arrays that will eventually be implemented in optical engineering devices.

Introduction:

There are three fundamental properties of light: intensity, wavelength, and polarization. The latter has been overlooked mainly due to its invisibility to the human eye. However, polarization images contain information that is unreported in traditional color and intensity pictures, which makes improving the capabilities of polarization imaging sensors a novel and necessary endeavor. Recently, there has been an increased interest in developing nanostructures for optical applications [1,2]. Much work has already been done to integrate polarization filters into high-resolution imaging devices [3,4].

Propagation of light within a biological medium depends on its optical properties. Scattered radiation contains information about the size and composition of the biological sample, so by examining the polarization of this radiation, scientists can learn valuable physical information [5].

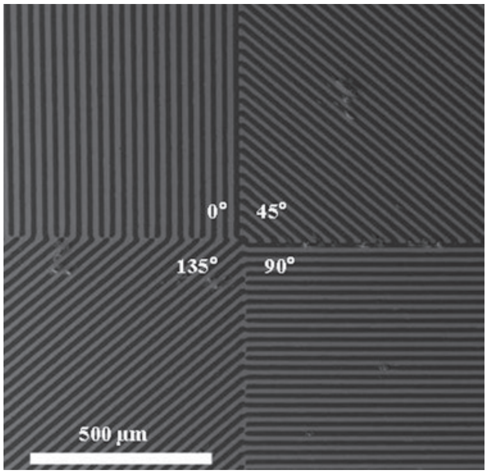

Figure 1: SEM image of 45º offset pixels.

Polarization-resolved imaging can provide insights into the composition and topography of biological environments, which can be used to detect bacteria and image cancerous tissues. Since the human eye is incapable of perceiving polarization effects without the aid of a polarization-sensitive imaging system, the development of such a system is essential to biologists and medical professionals.

Experimental Procedure:

1. Bake glass slide to ensure substrate is completely dry.
2. Spin-coat with Omnicoat™ to promote adhesion. The Omnicoat layer helps lift the resist and remove it from the substrate during the development step.
3. Spin-coat the negative resist SU-8-2010 at 500 rpm for five seconds with 100 rpm per second acceleration, then at 3000 rpm for 30 seconds with 300 rpm per second acceleration.
4. Prebake the resist at 95°C for 3 minutes.
5. Expose the slide with a chrome mask for 10 seconds with 12 mW/cm^2 intensity radiation. The mask used to pattern features contained three different arrays, one with 10 μm wires and 10 μm spaces, another with 10 μm wires and 20 μm spaces, and a third with 20 μm wires and 10 μm spaces.
6. Post-bake the sample at 95°C for 3.5 mins and develop.

In a negative resist, the exposed portion of the material cross-linked to become insoluble in the developer solution. The unexposed portion remained soluble and was consequently removed. The final features on the substrate were those exposed to the ultra-violet light. Silver was deposited on top of a chrome adhesion layer via thermal evaporation. Finally, the sample was submerged in Microchem's Remover PG.

Results and Conclusions:

The pixels were arranged in four different orientations offset by 45°, as shown in Figure 1. During lift-off, the structures were completely removed from the glass slide. To solve this problem, the original experimental procedure was amended to eliminate the Omnicoat layer in favor of a second layer of photoresist. This additional layer was spin-coated on top of the first layer, following a hard bake of one or more hours. The dual layer approach resulted in improved lift-off, with the array remaining intact, as shown in Figure 2. We varied the pre-bake and post-bake times in an effort to achieve reliable line width and spacing. Table 1 lists the different bake times and indicates the optimum combinations for sample preparation.

Additionally, we experimented with varying exposure times. Under-exposing resulted in tapered features with scalloped edges. The best samples were produced using an exposure of 10 seconds. Based on the recipe described in *Experimental Procedure*, the width of the features should be 10 μm; however, the true size of the structures was around 8 μm. Figure 3 shows the height of the wires determined by atomic force microscopy (AFM).

Pre Bake (minutes)	Post Bake (minutes)	Most Accurate (■)
3.5	4	X
	4.5	X
	5	■
4	4	X
	4.5	X
	5	■
4.5	4	X
	4.5	■
	5	X

Table 1: Pre-bake and post-bake times. The samples with most accurate feature sizes are indicated with a box.

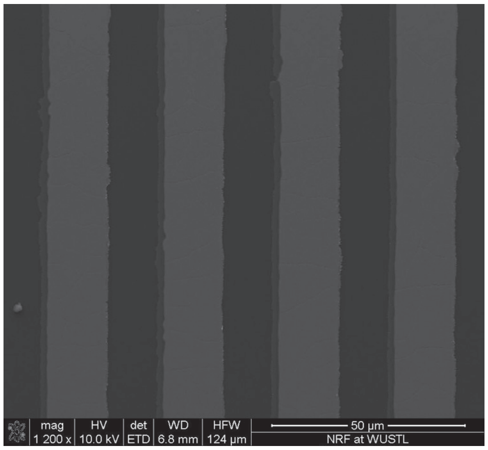

Figure 2: SEM image of 20 µm wire and 10 µm space pixel.

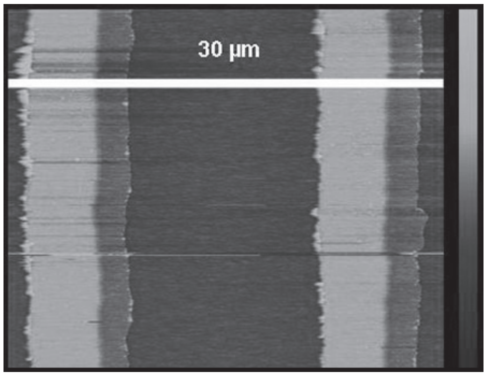

Figure 3: AFM image of wire height.

Future Work:

Future projects include fabrication of nanometer-sized wire arrays for improved optical capabilities, which can be achieved by using electron beam lithography instead of photolithography. Metal nanowires are important components of future imaging technologies, since wire-grid polarizers are easily incorporated within a pixel detector array. Additional fabrication experiments with other materials like gold and aluminum will also be necessary. The ultimate goal of this research is the successful integration of nanowire polarization filters in a high-resolution mega pixel camera.

Acknowledgments:

The guidance of Dr. Viktor Gruev was especially appreciated. Additionally, Kristy Wendt and Brent Riggs of the WUSTL Nano Research Facility provided invaluable advice and assistance. Financial support through National Science Foundation's National Nanotechnology Infrastructure Network Research Experience for Undergraduates (NNIN REU) Program is gratefully acknowledged.

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