# Rubins J. Spaans – Project Report

## Overview:

AlchLight, a U.S. developer of laser fabricated materials, was commissioned to both develop new structural coloring techniques, and to apply these new techniques to two titanium plates.

## Project Details:

Working closely with Dr. Chunlei Guo and Erik M. Garcell (see Fig. 1), new structural coloring techniques were developed for application on titanium, and using these developed colors, designs by Rubins Spaans were processed on two titanium plates (see Fig. 2). Structural coloring was optimized for optical blue and black appearance, and analyzed using spectrophotometry and microscopy. Final laser processing was performed on titanium plates, provided by Rubins J. Spaans.

*Fig. 1: Photo of Rubins J. Spaans (center) visiting Dr. Chunlei Guo (left) and Erik M. Garcell (right) at the University of Rochester's High-Intensity Femtosecond Laser Laboratory.*

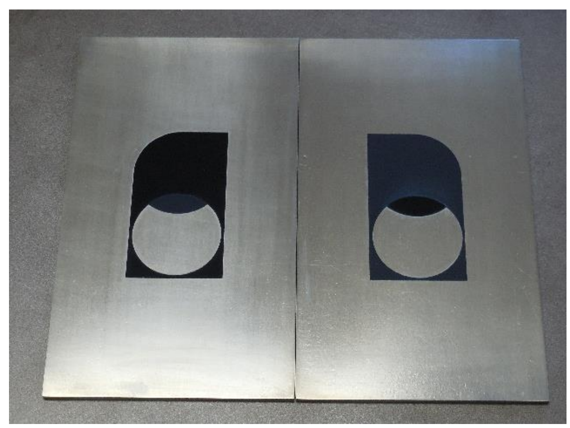

*Fig. 2: Finalized laser irradiated titanium plates, as commissioned by Rubins J. Spaans.*

# Methodology:

Using a laser system capable of outputting laser pulses at a width of 50 femtoseconds, we performed experiments to optimize our laser induced surface structuring technique for the formation of deep blue and black structural coloring on titanium (see Fig. 3). To irradiate the desired final area, a raster scanning technique was employed for laser processing of the metal surface. Verification of color was performed using a spectrophotometer, enabling the identification of frequencies reflected from the processed samples. For blue structural colorization, optimization was performed to maximize reflection in blue frequencies, while black structural coloring optimization was performed to maximize reflection in all visible frequencies.

*Fig. 3: Optimized black and blue laser-induced structural colorization on titanium. Samples of titanium were irradiated with a femtosecond-pulsed laser at optimized parameters to form deep black and blue angle-independent structural colorization.*

Once optimal laser parameters were selected, a mask was carefully laser cut out of acrylic to match the design as specified by Rubins J. Spaans (see Fig. 4a). By carefully placing and ordering these acrylic masks on the titanium surface, the laser beam can be blocked from irradiating the masked areas, thus enabling the processing of the desired multicolor complex design (see Figs. 4b-e).

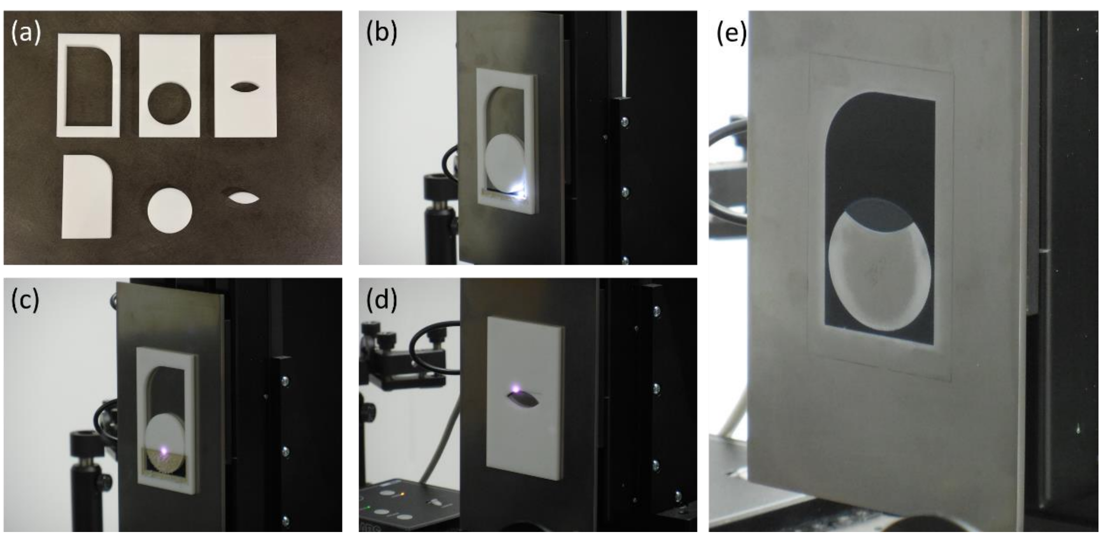


Fig. 4: Laser processing of the Rubin J. Spaans design. (a) Acrylic masks used for processing. (b) Placement of the first acrylic mask and initial laser raster scanning of the titanium plate. (c) Raster scanning of black structural coloring on titanium. (d) Raster scanning of blue structural coloring on titanium. (e) Titanium plate, after masked irradiation of both black and blue structural coloring.

# Colorization Details:

*Blue Structural Colorization of Metals*

Blue color is caused by a greater absorption of green and red light waves. These spectral optical properties of blue titanium result from the surface nanostructures that induce a higher plasmonic absorption at green and red wavelengths as compared with blue wavelengths (see Fig. 3).

*Black Structural Colorization of Metals*

Black color is caused by surface structural features ranging from the nanoscale to microscale (see Fig. 4). Nanoscale structures, being smaller than a light wavelength, contribute to light absorption due to the antireflection effects of random subwavelength surface textures in terms of a graded refractive index at the air/solid interface.

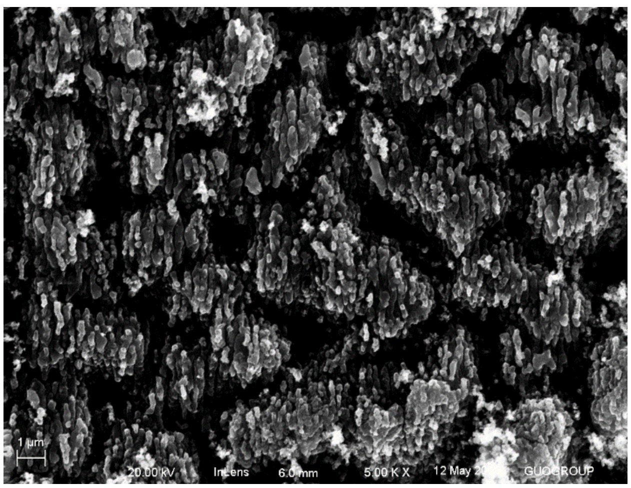


Fig. 3: Photo taken by a scanning electron microscope of the blue structural colorization developed for the Rubin J. Spaans project.

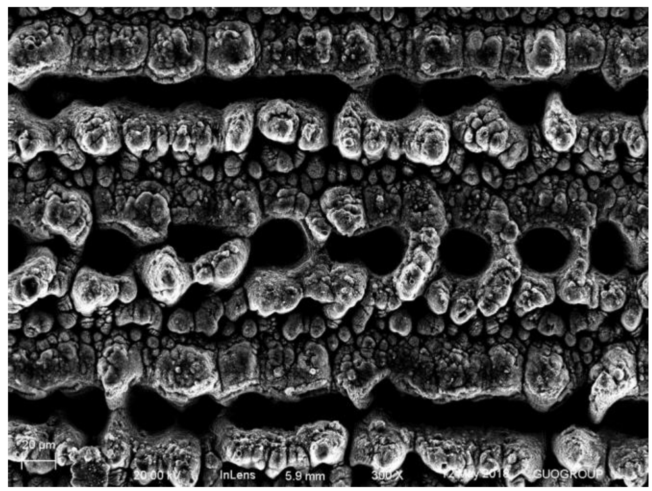


Fig. 4: Photo taken by a scanning electron microscope of the black structural colorization developed for the Rubin J. Spaans project.

Citations:

1. Vorobyev, Anatoliy Y., and Chunlei Guo. "Direct femtosecond laser surface nano/microstructuring and its applications." *Laser & Photonics Reviews* 7.3 (2013): 385-407.
2. Vorobyev, Anatoliy Y., and Chunlei Guo. "Metal colorization with femtosecond laser pulses." *High-Power Laser Ablation VII*. Vol. 7005. International Society for Optics and Photonics, 2008.
3. Vorobyev, Anatoliy Y., and Chunlei Guo. "Metallic light absorbers produced by femtosecond laser pulses." *Advances in Mechanical Engineering* 2 (2010): 452749.