

Fabrication of 3D Morpho Structures With a 50kV EBL Tool

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The name *Morpho* comes from an Ancient Greek epithet meaning, “the shapely one”, for Aphrodite, goddess of love and beauty. Many morpho butterflies are colored in metallic, shimmering shades of blues and greens. These colors are not a result of pigmentation, but are an example of iridescence through structural coloration. Specifically, the microscopic scales covering the morpho's wings reflect incident light repeatedly at successive layers, leading to interference effects that depend on both wavelength and angle of incidence/observance.^[1] Thus, the colors appear to vary with viewing angle, but they are surprisingly uniform.

The wide-angle blue reflection property can be explained by exploring the nanostructures in the scales of the morpho butterfly wings. These optically active structures integrate three design principles leading to the wide-angle reflection: Christmas tree-like shaped ridges, alternating lamellae layers (or "branches"), and a small height offset between neighboring ridges. These naturally occurring structures were simplified in our nanofabrication process^{[2],[3]}, as shown in figures 1 and 2; SEM images as fabricated by the [Elionix BODEN 50kV tool](#).

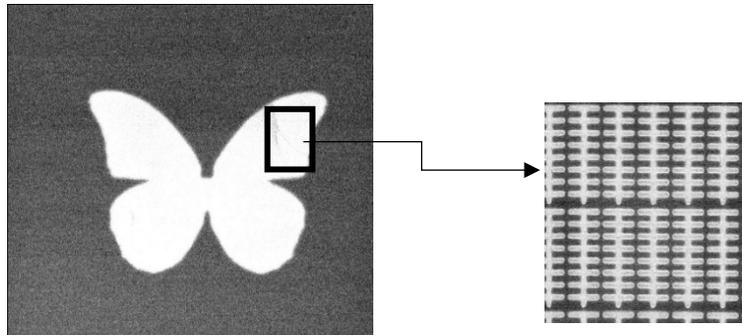


Figure 1. Top-down SEM images of the morpho butterfly structure fabricated with the Elionix BODEN 50kV tool.

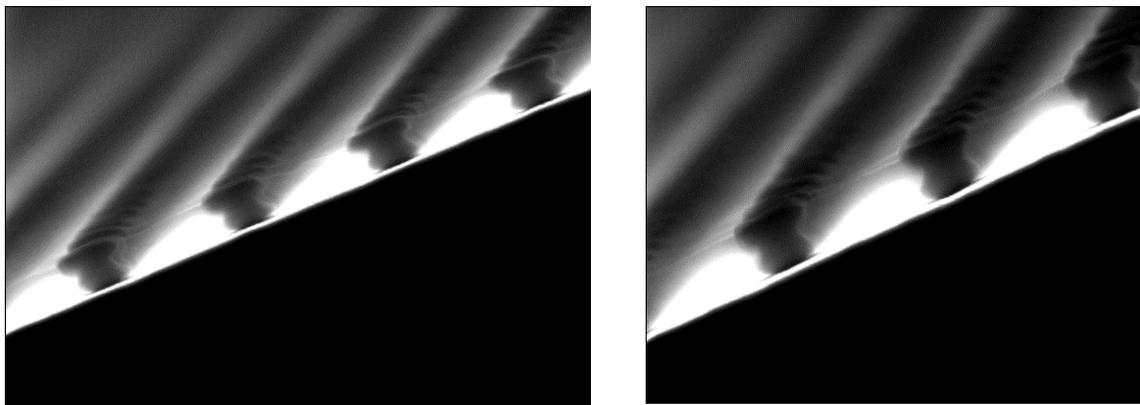


Figure 2. Cross sectional SEM images of the 3D scales from the morpho butterfly structure fabricated with the Elionix BODEN 50kV tool.

Nanofabrication of the Morpho Butterfly

A 3D morpho butterfly with bright blue reflection pattern was successfully fabricated using the Elionix BODEN 50kV tool. A beam current of 20nA was used, leading to a total write time of 39 hours with a 500 μ C dose.

The scales of morpho butterfly were simplified and a scale pattern of 1.82 μ m was incorporated. Four layers of resist (MMA EL6 and PMMA 495K A4) were coated alternatively onto a 6inch silicon wafer.

An “elms – Elionix Lithography Management System” software screenshot of the 6inch wafer, holder, and morpho butterfly CAD image is shown in figure 3.

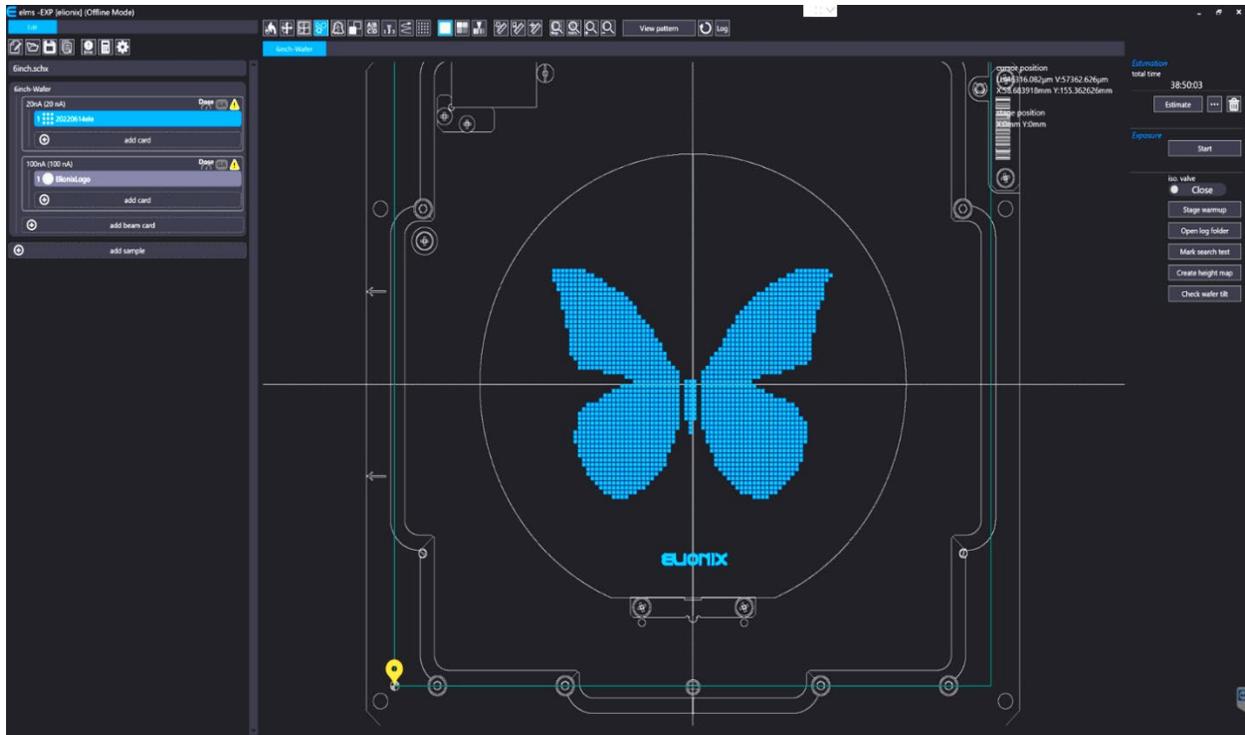


Figure 3. 6inch wafer, holder, and morpho butterfly CAD image with Elionix logo.

Resist Coating and Development

Multi-layer resist coating can be challenging here are few points that might help:

1. Pre-heat the wafer @180 °C for 1 minute.
2. Let it cool for about 1 minute. Use N₂ to remove dirt.
3. MMA EL6 is used as copolymer- spin coated at desired speed for 1 minute.
4. Post heat the wafer @180 °C for 1 minute.
5. Let it cool for about 1 minute. Use N₂ to remove dirt.
6. PMMA 495K A4 polymer is spin coated at a desired speed of 3000 rpm for 1 minute.
7. Let it cool for about 1 minute. Use nitrogen to remove dirt from wafer, if any.
8. Repeat step 2-7 for the next set of layers.

Note- always clean the inner parts of spin coater.

Spin coater settings- slope 3 seconds, initial speed of 500 rpm for 5 seconds then rise it to desired final speed at last slope 3 seconds.

As PMMA might become thick easily, time is very crucial.

Use a small size syringe filter for applying PMMA.

Development- MIBK: IPA (1:3) for 1minute and dry with nitrogen.

Contact Us

For more information on this paper, the Elionix BODEN EBL tools, or other applications, [email us](#).

References

- [1] P. Vukusic; J.R. Sambles; C.R. Lawrence & R.J. Wootton (1999). "[Quantified interference and diffraction in single Morpho butterfly scales](#)". Proceedings of the Royal Society B. **266** (1427): 1403–11. doi:10.1098/rspb.1999.0794. PMC 1690093.
- [2] Siddique, R. H.; Diewald, S.; Leuthold, J.; Hölscher, H. (2013). "[Theoretical and experimental analysis of the structural pattern responsible for the iridescence of Morpho butterflies](#)". Optics Express. **21** (12): 14351–14361. Bibcode:2013O Expr.2114351S. doi:10.1364/OE.21.014351. PMID 23787623.
- [3] Mudachathi, R., Tanaka, T. [Up Scalable Full Colour Plasmonic Pixels with Controllable Hue, Brightness and Saturation](#). *Sci Rep* **7**, 1199 (2017). <https://doi.org/10.1038/s41598-017-01266-6>

Photo

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