Bio-inspired structural colors obtained from micro-buckling and micro-folding: a computational study

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Introduction

Structural color, as opposed to pigmented color, comes from the interaction of light with nanostructures. The most well-known example is the Morpho Rhetenor butterfly which produces a bright and saturated blue color, stable across viewing angles.

Figure 1: Images of a Morpho Rhetenor butterfly structure.

Two fundamentals features are necessary for highly saturated and broad-angle structural color [1,2];
- A multilayer or hierarchical structure with a wavelength-selective reflectance spectra
- Irregularity in the periodic arrangement to cancel the grating effects

Origami and kirigami are 3D structures obtained from folding and buckling of 2D materials. I propose origami- and kirigami-inspired designs at microscale to produce saturated and wide-angle structural color.

Finite Element Method

- Linear buckling analysis for critical buckling strain and corresponding mode
- Post-buckling deformation with a static Riks analysis

Finite-Difference Time Domain

- Two-dimensional analysis of the periodic-structure reflectance
- SU8 epoxy-based polymer with \( n = 1.4 \)

Methodology

Figure 3: The mechanical deformation is computed with FEM and the optical response is performed with the FDTD method.

Simple ribbon parameters

- In the CIE 1931 XYZ color space, X and Z represent the chromaticity of the color and Y the brightness.
- The saturation is calculated in the xyY space and is used to optimize the wavelength-selectivity.
- The color distance, \( \Delta E^* \), describes the perceived difference between two colors. The limit distance is at \( \Delta E^*_{lim} = 0.02 \).
- Each parameter is optimized to ensure the maximal saturation and a reasonable brightness

Reflectance contour plot

Figure 5: Multiple peaks are present for each ribbon length parameter value. The diagonal features are representative of a 2D photonic crystal behavior. The noise comes from the FEM results.

Optimization method

- Optimization of the geometrical parameters with multiple peaks.
- Optimization of the geometrical parameters enable high saturation \( S = 0.55 \).
- Far-field calculations show that randomization cancels the grating effects.
- Deformation induces significant color change.

Future Work

- Optimization of the hierarchical design.

References