3D printing of bioinspired super black microstructures

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Structural antireflective (AR) coatings are efficient to reduce reflections and improve performances in optical systems. A recent study showed that some peacock spiders display very good AR properties due to structures in the form of a microlens array, on top of an absorbing melanin layer. [1] Due to their relatively simple shape and large size, these microlenses would be ideal for mass replication. More importantly, such microlenses can increase the mean light path in underlying layers, and could therefore greatly improve the efficiency in photovoltaics for example. [2]

Here, we print microlens arrays with different geometries based on the spider structures, we image them with SEM and study their AR properties.

The structures were 3D printed on a Nanoscribe Photonic Professional GT+ system (Karlsruhe, Germany). This system relies on two-photon polymerization (2PP) with a lateral resolution of around 200 nm, which is ideal to achieve high precision and accuracy.

The microstructures were designed based on the surface equation from [1]:

\[ z(x, y) = R_0 h_0 \left[ 1 - \frac{x}{R_G} \right] \left[ 1 - \frac{y}{R_G} \right] - \frac{R_0 h_0}{2} \]  

II

SEM was used to characterize the printed structures.

III

The structures reflectance and transmittance were measured at normal incidence with acceptance angles of 14.5° and 47.2°, respectively.

IV

Optimized AR sample

3. Results

Measured Reflectance/Transmittance

1. Hemispheres \( R_0 = 5 \mu m, n_0 = 1, N = 21 \)

| Radius increase: | Reflectance increase | ~ same Transmittance |
| Radius decrease: | More discretization errors (limited printer resolution) |

II

Chosen optimal Radius: \( R_0 = 5 \mu m \)

2. Varying parameters \( (n_0, h_0, N) \) with \( K = 5 \mu m \)

<table>
<thead>
<tr>
<th>Parameters:</th>
<th>( n_0 )</th>
<th>( h_0 )</th>
<th>( N )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference hemispheres:</td>
<td>( n_0 = 1, h_0 = 5 \mu m )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both the reflectance and transmittance:</td>
<td>increase with ( K )</td>
<td>decrease with ( h_0 )</td>
<td></td>
</tr>
</tbody>
</table>

III

Influence of the structures geometry

1. Reflectance spectrum of a flat sample and optimized AR sample

2. Ratio (Flat/Optimized AR)

With this technique, we demonstrate the fabrication of AR structures based on peacock spiders.

We show that the created structures:

• Have very low specular reflectance

• Are tunable with the shape parameters

In addition, such structures show great potential for mass replication and applications involving solar cells.

References:


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