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3D printing of bioinspired super black microstructures

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Antireflective (AR) coatings play an essential role in domains such as imaging optics, optical communication, solar cells or photolithography, where reducing reflections, minimizing losses or enhancing absorption can greatly increase system performances. Over the years, several approaches such as index-matching, interferences or micro –and nanopatterning have been used to develop AR surfaces targeting these applications. More recently, a lot of attention was drawn towards the super black technology called Vantablack with early developments made at the National Physical Laboratory in the UK, which demonstrated a new way to obtain a very low reflectance using carbon nanotube arrays. To this day, different approaches to obtain the blackest material have been explored. However, existing solutions focus on nanostructures, so they usually require long and complex fabrication processes.

Another interesting way to obtaining structures with super black properties is by using biomimicry. Super black structural colors have been found in nature for example in moth eyes, male bird of paradise and male peacock spiders. Moth eyes structures, relying on a hierarchical micro- and nano-composite rough surface to obtain super black properties, have been successfully replicated and used as AR coatings [1-2]. However, in birds of paradise and peacock spiders, the super black properties are achieved through a combination of microstructures and underlying absorbing layer, i.e. barbule microstructures and cuticular bumps, respectively [3]. This makes them particularly suited for replication using fast prototyping techniques.

Here, we report the fabrication and characterization of AR microarrays inspired from the male peacock spider's cuticles. On the one hand, the structures are fabricated using two-photon polymerization (2PP) 3D printing (see Fig.1) [4-5]. We make use of both the high resolution (< 200 nm) and versatility of our 2PP 3D printer to test various geometries derived from the peacock spider's cuticles. The printed geometries are then imaged using a scanning electron microscope (see Fig.2). On the other hand, the reflectance and transmittance of the microstructures are characterized using a dedicated optical setup. From these measurements, we demonstrate which of the printed geometries are capable of achieving super black characteristics. Finally, we discuss the influence of the different shape parameters on the AR behavior of the microstructures.

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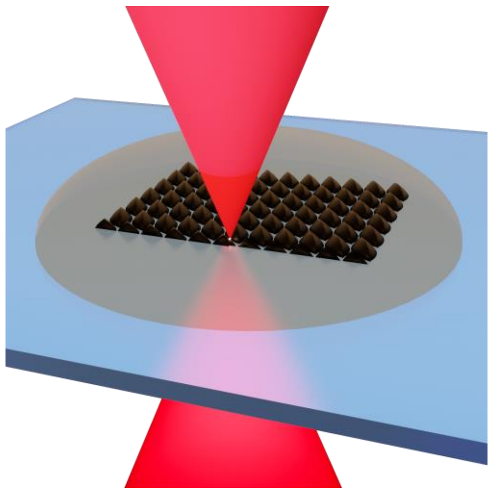

Figure 1. Schematics for the process of printing antireflective microarrays inspired from the male peacock spider's cuticles using a two-photon polymerization 3D printer.

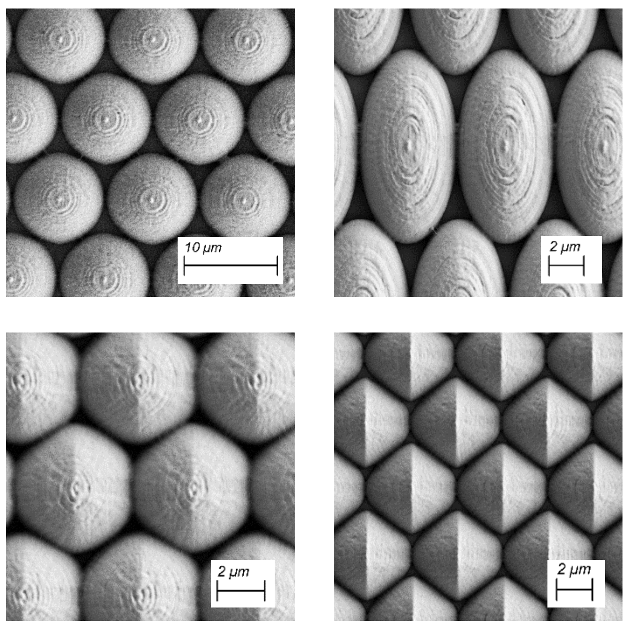

Figure 2. Scanning electron micrographs of different types of printed geometries. Top left: hemisphere. Top right: elliptical structure. Bottom left: moderately pyramidal structure. Bottom right: highly pyramidal structure.