Structure of certain types of beetle shells could inspire brighter, whiter coatings and materials

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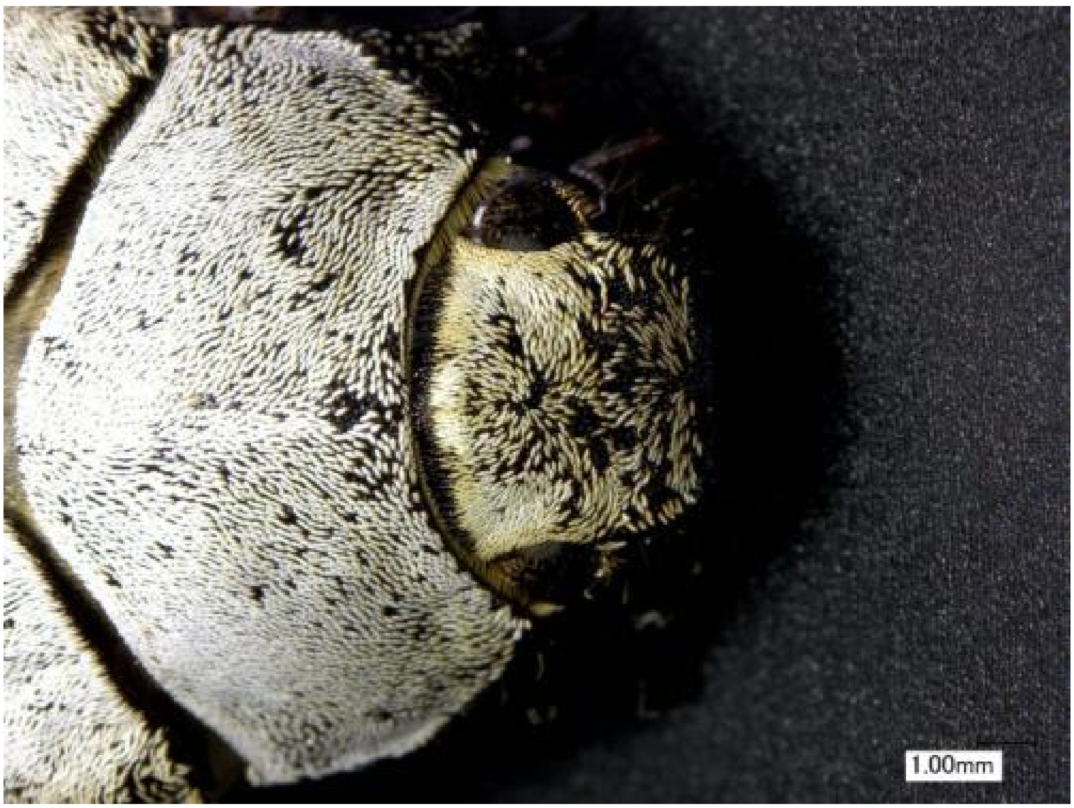

A stereo-microscope picture of the two beetle *Cyphochilus* and *Lepidiota stigma*. Credit: Lorenzo Cortese and Silvia Vignolini

The physical properties of the ultra-white scales on certain species of beetle could be used to make whiter paper, plastics and paints, while using far less material than is used in current manufacturing methods.

The *Cyphochilus* beetle, which is native to South-East Asia, is whiter than paper, thanks to ultra-thin scales which cover its body. A new investigation of the optical properties of these scales has shown that they are able to scatter light more efficiently than any other biological tissue known, which is how they are able to achieve such a bright whiteness. The findings are published today (15 August) in the journal *Scientific Reports*.

Animals produce colours for several purposes, from camouflage to communication, to mating and thermoregulation. Bright colours are usually produced using pigments, which absorb certain wavelengths of light and reflect others, which our eyes then perceive as colour.

To appear as white, however, a tissue needs to reflect all wavelengths of light with the same efficiency. The ultra-white *Cyphochilus* and *L. Stigma* beetles produce this colouration by exploiting the geometry of a dense complex network of chitin – a molecule similar in structure to cellulose, which is found throughout nature, including in the shells of molluscs, the exoskeletons of insects and the cell walls of fungi. The chitin filaments are just a few billionths of a metre thick, and on their own are not particularly good at reflecting light.

The research, a collaboration between the University of Cambridge and the European Laboratory for non-Linear Spectroscopy in Italy has shown that the beetles have optimised their internal structure in order to produce maximum white with minimum material, like a painter who needs to whiten a wall with a very small quantity of paint. This efficiency is particularly important for insects that fly, as it makes them lighter.

A stereo-microscope picture of the beetle *Cyphochilus* Credit: Lorenzo Cortese and Silvia Vignolini

Over millions of years of evolution the beetles have developed a compressed network of chitin filaments. This network is directionally-dependent, or anisotropic, which allows high intensities of reflected light for all colours at the same time, resulting in a very intense white with very little material.

"Current technology is not able to produce a coating as white as these beetles can in such a thin layer," said Dr Silvia Vignolini of the University's Cavendish Laboratory, who led the research. "In order to survive, these beetles need to optimise their optical response but this comes with the strong constraint of using as little material as possible in order to save energy and to keep the scales light enough in order to fly.

Curiously, these beetles succeed in this task using chitin, which has a relatively low refractive index."

Exactly how this could be possible remained unclear up to now. The researchers studied how light propagates in the white scales, quantitatively measuring their scattering strength for the first time and demonstrating that they scatter light more efficiently than any other low-refractive-index material yet known.

A stereo-microscope picture of the beetle *Lepidiota stigma.* Credit: Lorenzo Cortese and Silvia Vignolini

"These scales have a structure that is truly complex since it gives rise to something that is more than the sum of its parts," said co-author Dr

Matteo Burresi of the Italian National Institute of Optics in Florence. "Our simulations show that a randomly packed collection of its constituent elements by itself is not sufficient to achieve the degree of brightness that we observe."

In recent years, many engineers having been looking to structures found in nature to inspire their designs. "The lessons we are learning from these beetles is two-fold," said Dr Vignolini. "On one hand, we now know how to look to improve scattering strength of a given structure by varying its geometry. On the other hand the use of strongly scattering materials, such as the particles commonly used for white paint, is not mandatory to achieve an ultra-white coating."

These findings will likely be relevant for many applications, enabling objects such as paper, plastics, paints, as well as white-light reflectors inside new-generation displays to be made whiter, while at the same time using a smaller amount of material.

More information: Burresi, M et al. Bright-White Beetle Scales Optimise Multiple Scattering of Light. *Scientific Reports*; 15 Aug 2014

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