Colours and metallic sheen in beetle shells - A biomimetic search for material structuring principles causing light interference - DTU Orbit (19/07/2019)

Colours and metallic sheen in beetle shells - A biomimetic search for material structuring principles causing light interference

Visual aesthetic has always played a vital role for the success of many products. This includes colours and glossiness and metal appearance which is often achieved using surface coatings. Present coating techniques do, however, have limitations. It is difficult to reach very bright and brilliant colours, colours tend to fade over time and many of the materials and coating technologies pollute and have other environmental problems. Beetles in nature have many of the desired properties: They have appealing brilliant colours and some even with metallic appearance. It is noticeable that the colours are long lasting as some of the beetles we have studied at the zoological museum are more than 200 years old and have colours and brightness as if they were still alive. Furthermore, the beetles in nature are part of sustainable ecosystems, which means that they are made from renewable materials that are broken down and recycled when the beetle dies. Beetles also possess another and very attractive property: Their metallic look originates from structures in organic materials which is both electrically and thermal insulating. The industrial perspective is to be able to manufacture products with attractive metallic surfaces that do not feel so cold to touch as their metallic counterparts and that do not represent an electrical shock hazard. The present paper presents a cross disciplinary biomimetic review of research results that explain the materials and nanostructure in beetle shells and the mechanisms that generate them. The metallic and bright colours of beetle shells are structural colours deriving from at least two different internal shell structures with different light reflecting properties. One nano-structure is the multilayer stack which is composed of layered pairs with different refractive indices and it can reflect all colours of the spectrum. Another structure is the Bouligand structure that resembles cholesteric liquid crystals with a twist of layer directions reflecting circular polarized light. The colours of the transparent structures are structural colours caused by light interference. The shells are mostly made of cross linked chitin (a polysaccharid) and proteins. The basic ingredients of the structure are released by living epidermal cells in a fluid deposition zone where after they self assemble to a layered mesh. That the structure is formed by self assembly gives the hope that similar structures with the same optical properties also can be formed artificially without templates. The paper also presents a review of existing applications with structural colours obtained by nano-structured surfaces and describes the goals for further research required in order to achieve industrially manufactured beetle-like surfaces with properties such as sustainability, aesthetics, insulation, durability etc.

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