Nanoscale functionalities in transparent animals inspiring novel approaches in Architecture

CRAWFORD, A. E.[1,a], HIRHAGER, N.[2,b] AND GEBESHUBER, I C.[3,4,c]

[1] Faculty for Architecture: Spaces and Objects, Central Saint Martins, Granary Building 1 Granary Square, King's Cross, London N1C 4AA, United Kingdom
[2] Faculty for Architecture and Planning, Vienna University of Technology, Karlsplatz 13, 1040 Vienna, Austria
[3] Institute of Microengineering and Nanoelectronics, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Malaysia
[4] Institute of Applied Physics, Vienna University of Technology, Wiedner Hauptstrasse 8-10/134, 1040 Vienna, Austria

[a] alys.crawford@googlemail.com, [b] nicole.hirhager@gmx.at, [c] gebeshuber@iap.tuwien.ac.at

(i) *Aurelia aurita*

(ii) *Cochranella spinosa*

(iii) *Periclimenes holthuisi*

(iv) *Periclimenes psamathe*

ABSTRACT. In Nature we can find many examples for the benefits of translucency and transparency.
Animals with translucent bodies use these properties in two different ways. Either they serve as camouflage, misleading their predators by seeming invisible, or the transparency is related back to the evolutionary adaption of their special habitat.
The deep sea fish *Opisthoproctus soleatus*, commonly known as Barreleye fish or spook fish with its transparent head maximizes the perception of light allowing it to travel directly to its specialized eyes. Within sea life a vast collection of species demonstrate the use of transparency. In addition to these deepwater animals, transparent or translucent squid, sea cucumbers and shrimp can provide valuable information.
Land animals and plants that carry these features to their advantage include glass-frogs (owing their name to a transparent skin) which appear nearly invisible on rainforest ground, and glass-winged butterflies (e.g., Greta oto) with partly transparent wings.
These species were selected as point of origin to show how animals can serve as role models for architectural innovation.
Construction research has focused primarily on glass and plastics (synthetic or semisynthetic organic solids) and has yet to reach over to Nature with its wide range of possibilities. Biomimetics of transparency in organisms can yield the development of new construction materials to replace or upgrade known transparent materials. In many cases, structure is reliable for the function, and not material. The transfer of the nanoscale biological structures to new technological materials is the primary focus of our ongoing research. Within the framework of this procedure we investigate the potential of the development of casting methods (fast, easy, reliable, up-scalable) to transfer the functionality of biological surfaces to the technological materials. These materials are carefully selected - they are nontoxic, environmentally friendly, reusable and rewritable. And furthermore, casting methods yield zero-waste-processes - so different from various current functionalization approaches in architecture.
Inspired by the multifunctional, nanoscale-based properties of the wings of butterflies such as Greta oto, we have developed a concept for nanostructures that induce water to flow off in specific, user defined patterns - this could be used as a design element in glass surfaces.
The multi-functionality of natural materials, structures and processes yields improvements concerning the appliance of nanoscale coatings, including amongst others UV-light protection, antireflective surfaces, self cleaning materials and bird-protective glass facades. Aside these improvements, entirely new materials can be envisaged, displaying for example emotions on facades, textiles and reversible objects - sustainable, beautiful and based on nanoscale properties inspired from living Nature!

Casting methods

fast
easy
reliable
up-scalable

nanostructures of surfaces

reflectance and transmission of light

Selection of materials

nontoxic
environmentally friendly
reusable
rewritable

ZERO-WASTE PROCESS

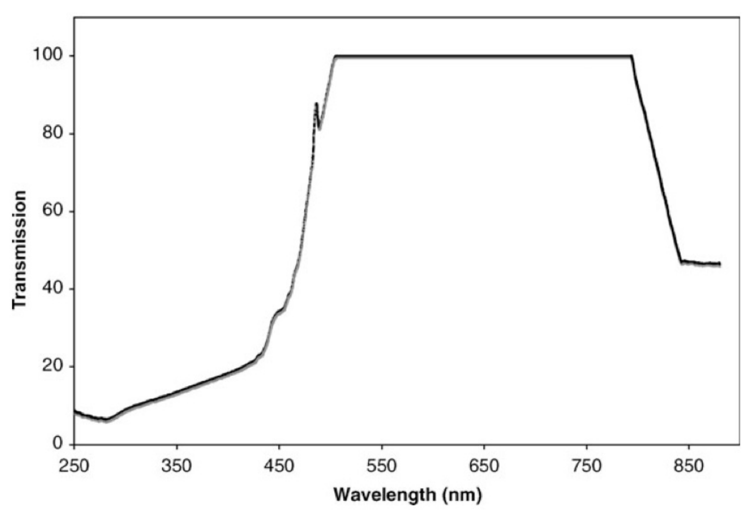
Appliance in Architecture, Design, etc.

self-cleaning materials
antireflective coatings
UV protection
bird protective glass
user defined patterns for glass surfaces
displaying emotions on façades, textiles, ...

Research model:

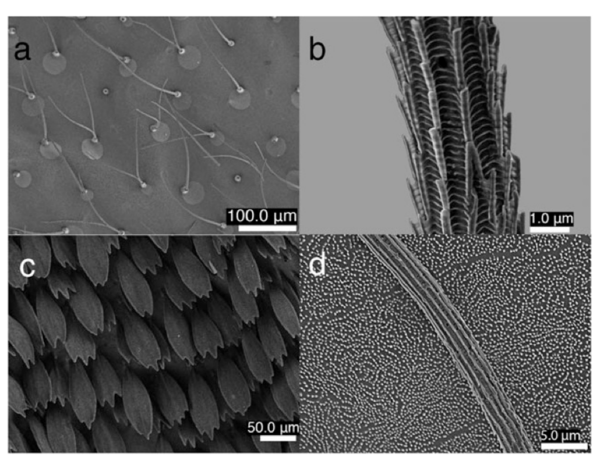
(v) *Greta oto*

transmission of light:

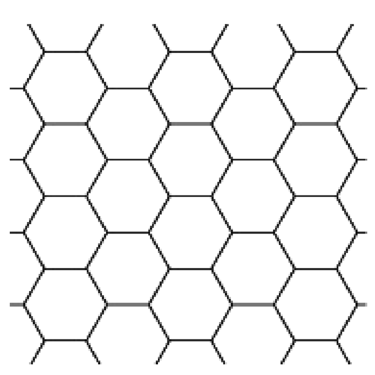


(vi) Transmission spectrum of transparent area of *G. oto* wing over wavelength range of 250–900 nm

nanostructures of surface:



(vii) Scanning electron microscopy images showing three distinct patterns on *G. oto* wing: **a.** piliform scales on transparent parts, **b.** detailed image of piliform scale, **c.** flat scales on brown colored parts, **d.** piliform scale and underlying pattern beneath piliform scales on transparent parts



hexagonal structure of petruberances in *G. oto* wings. which is responsable for transparency

transmission for wavelenght from ~450 nm to ~800 nm and hexagonal nanoscale structures

> basis for NEW transparent materials

no transmission for UV-wavelenght

> UV-protective materials / animal-protective materials

index refraction changes along the protrusions on G.oto wing, which inhibit light scattering (similar to "corneal nipple arrays" among other insects) .

> antireflective surfaces / coatings

microscopic structures of protrusions

> unique patterns on wet surfaces (e.g. control over water flow)

References. Binetti, V. R. et al., 2009. The natural transparency and piezoelectric response of the Greta oto butterfly wing. *Integrative Biology*, [e-journal] Issue 4, pp. 324-329. Available through: RSC Publishing [13 August 2012].
Images. (i) ben.chaney, 2009. Jellyfish. [photograph] Available at: <http://www.flickr.com/photos/epioles/3200656896/in/photostream/> [Accessed 13 August 2012]. **(ii)** Bgv23, 2009. *Teratohyla spinosa - Syn.: Cochranella spinosa.* [image online] Available at: <http://fr.wikipedia.org/wiki/Fichier:Cochranella_spinosa02.jpg> [Accessed 15 August 2012]. **(iii)** Sawitri, L., 2012. *Komodo13 1-1-12 - 44 transparent anemone shrimp.* [photograph] Available at: <http://www.flickr.com/photos/elsaw/6695832669/in/photostream/> [Accessed 13 August 2012]. **(iv)** Levy, E., 2012. *Transparent Commensal Shrimp Periclimenes psamathe*. [photograph] Available at: <http://www.flickr.com/photos/elevy/6997594095/> [Accessed 13 August 2012]. **(v)** Tiller, D., 2008. *Greta oto - Glasswing.* [photograph] Available at: <http://en.wikipedia.org/wiki/File:Greta_oto.jpg> [Accessed 09 August 2012]. **(vi)** Unknown, 2008. *Fig. 2 Reflectance and transmission spectra of transparent area of G. oto wing over the wavelength range of 250–900 nm: a is the reflectance plot taken of the wing placed on a polished silicon wafer, and b is the transmission plot.* [graph].**(vii)** Unknown, 2008. *Fig. 3 SEM images showing scales and patterns on the surface of the G. oto wing: a a combination of flat and piliform scales along a ''vein'' on the wing, b a combination of flat and piliform scales at the edge of the wing, c structure of the heart-shaped flat scale and d oval shaped scales and the underlying pattern beneath the scales.* [SEM images].