Utilizing radiative properties of Silver Ants

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Passive Radiative Cooling (PRC)

To achieve sub-ambient temperatures, the surface must emit more energy through infrared (IR) radiation than it receives from the sun. This requires a **high reflectance** between 0.3-3 µm (visible light to Near-IR) and **high emittance** between 8-11 µm (Mid-IR), where the **atmospheric window** is located. This window of transparency in the atmosphere allows for energy to be radiated directly into cold space.

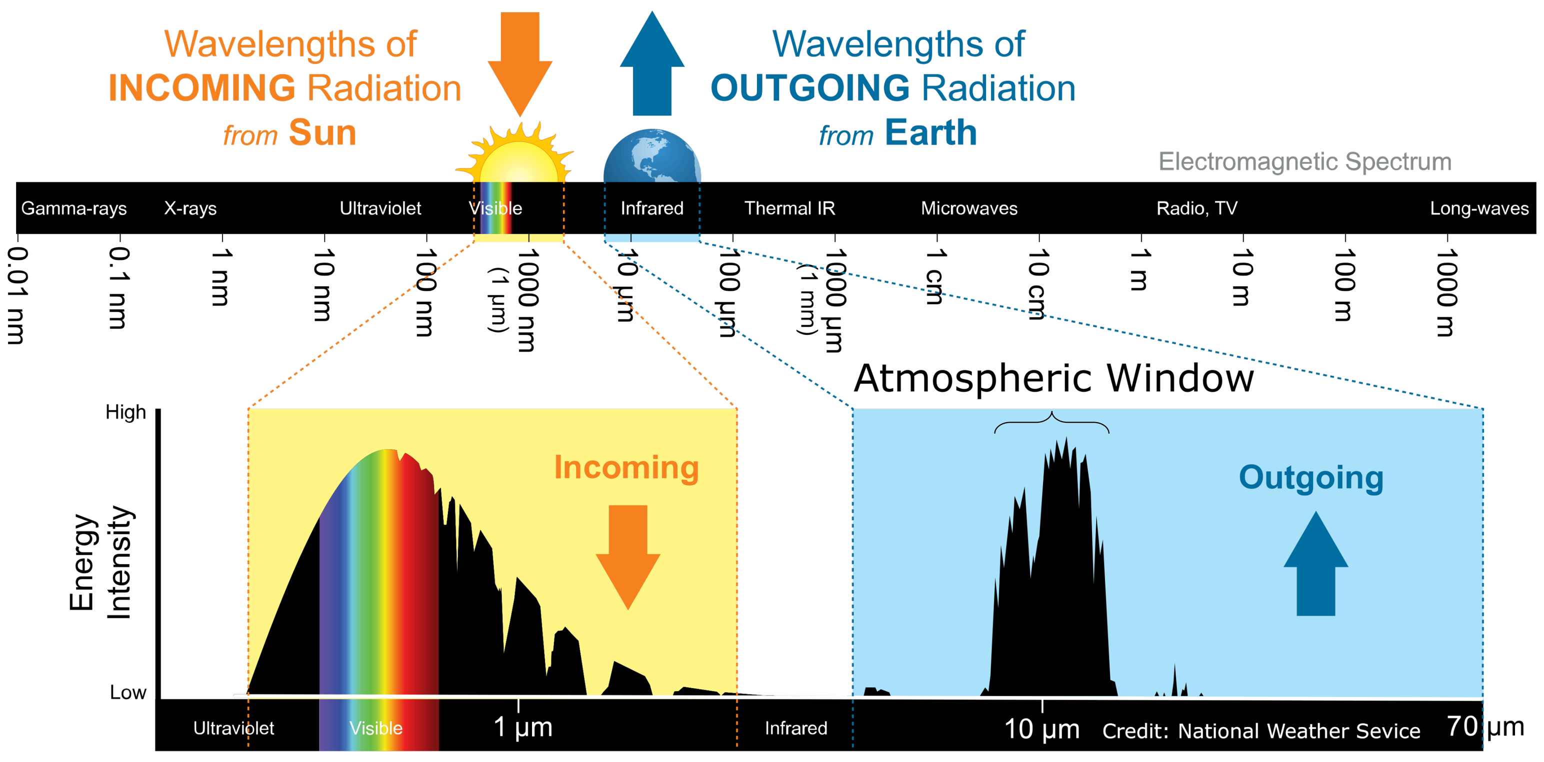


Fig. 1: Incoming and outgoing radiation across the EM-spectrum

Saharan Silver Ants

Saharan Silver Ants (*Cataglyphis bombycina*) have developed special hairs that induce passive radiative cooling. Figure 2a displays a SEM image of a hair with its characteristic indentations and its triangular cross-section (2b). The triangular shape enables **total reflection** on the bottom side over a wide incidence angle of sunlight, but also acts as a gradient refractive index, which suppresses reflectance of IR radiation and enables high emittance. The small indentations are of a comparable size to the wavelength of visible light, which results in **Mie-Scattering**. The cooling effect was shown by Shi et al. (2015) [1]

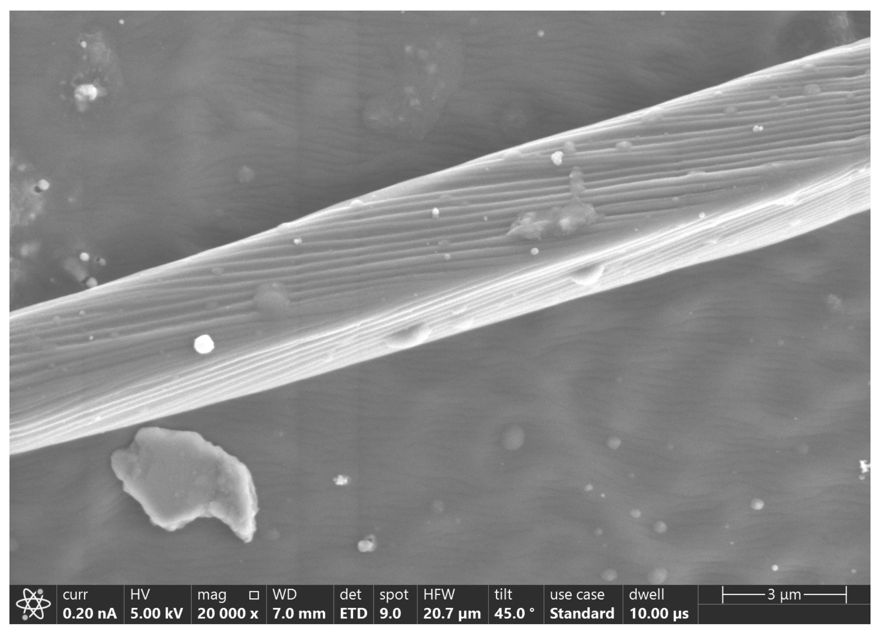


Fig. 2a: Single Hair

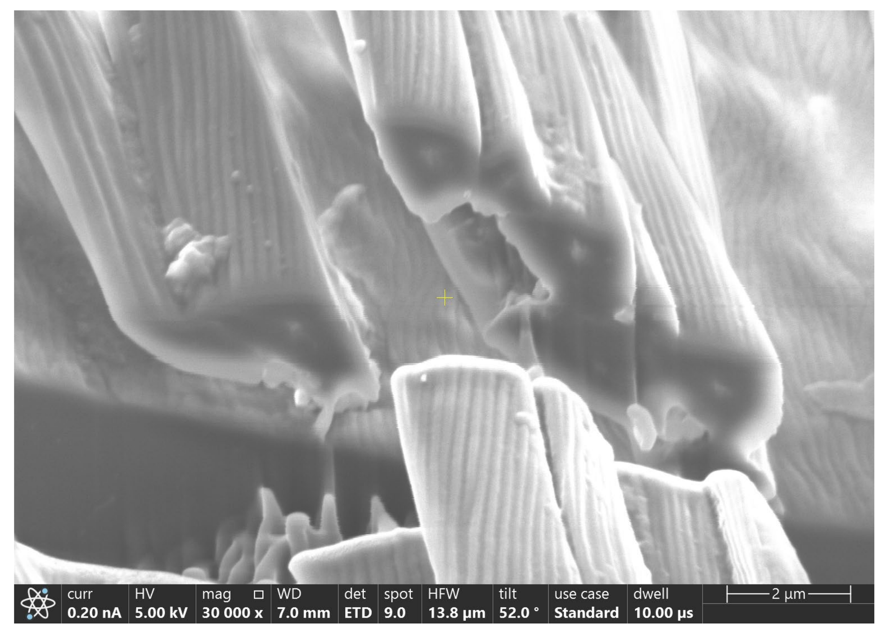


Fig. 2b: Cross-section cut with FIB

Shrimp Shells

Shrimp shells are **biodegradable**, **inexpensive** and composed of **chitin**, the same material as an ant body.
We subjected the modified shells to hot and cold climates in a climate chamber for three weeks. Fig. 3 demonstrates that there were no significant changes in the surface features, indicating good weather resistance. However, shrimp shells have a high scratch and indentation resistance and are therefore not suited to be modified by more sensitive methods.

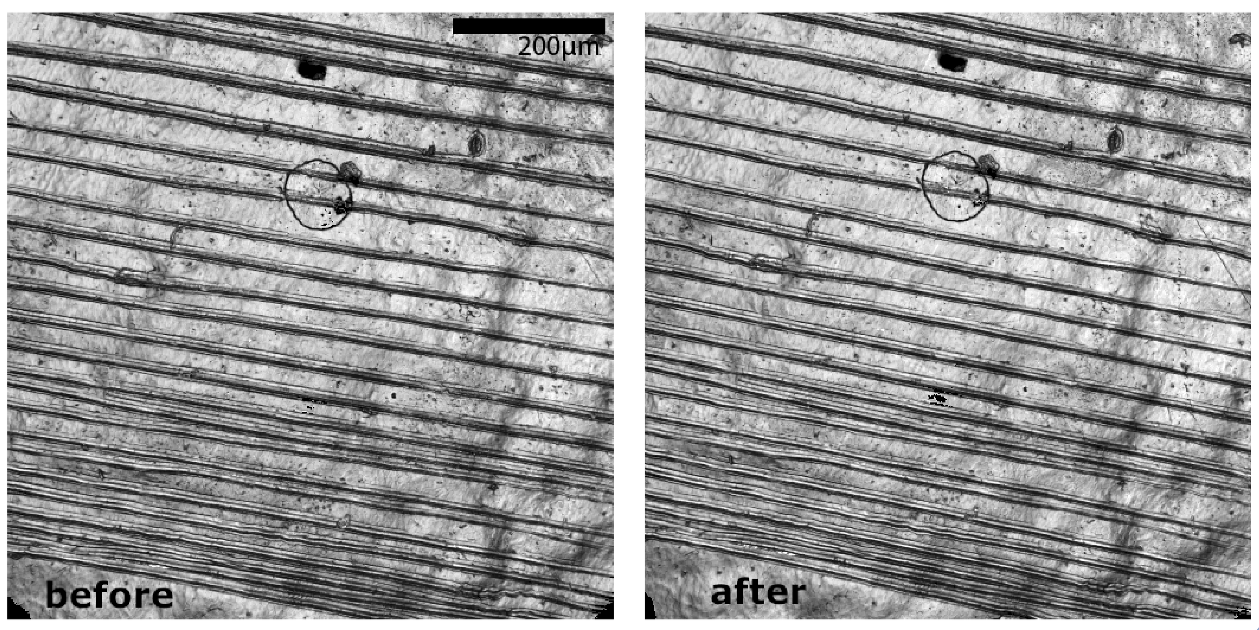


Fig. 3: Scratched shells before and after climate chamber exposure. Confocal Micro-scope, 20x magnification

Nanostructured Chitosan film

Chitosan films can be produced by following a simple procedure. Chitosan pills, a drug usually marketed as a fat binder, are dissolved in dilute acetic acid (~10 vol.%) under constant stirring and moderate heat (50°C). The resulting viscous liquid is then spread evenly over a target surface and left to dry.
By removing the protective silver coating of a CD, the micro-structure responsible for the characteristic **colored reflection** is exposed. This can then be used as target surface. The resulting chitosan film features beautiful reflections, just like a CD.

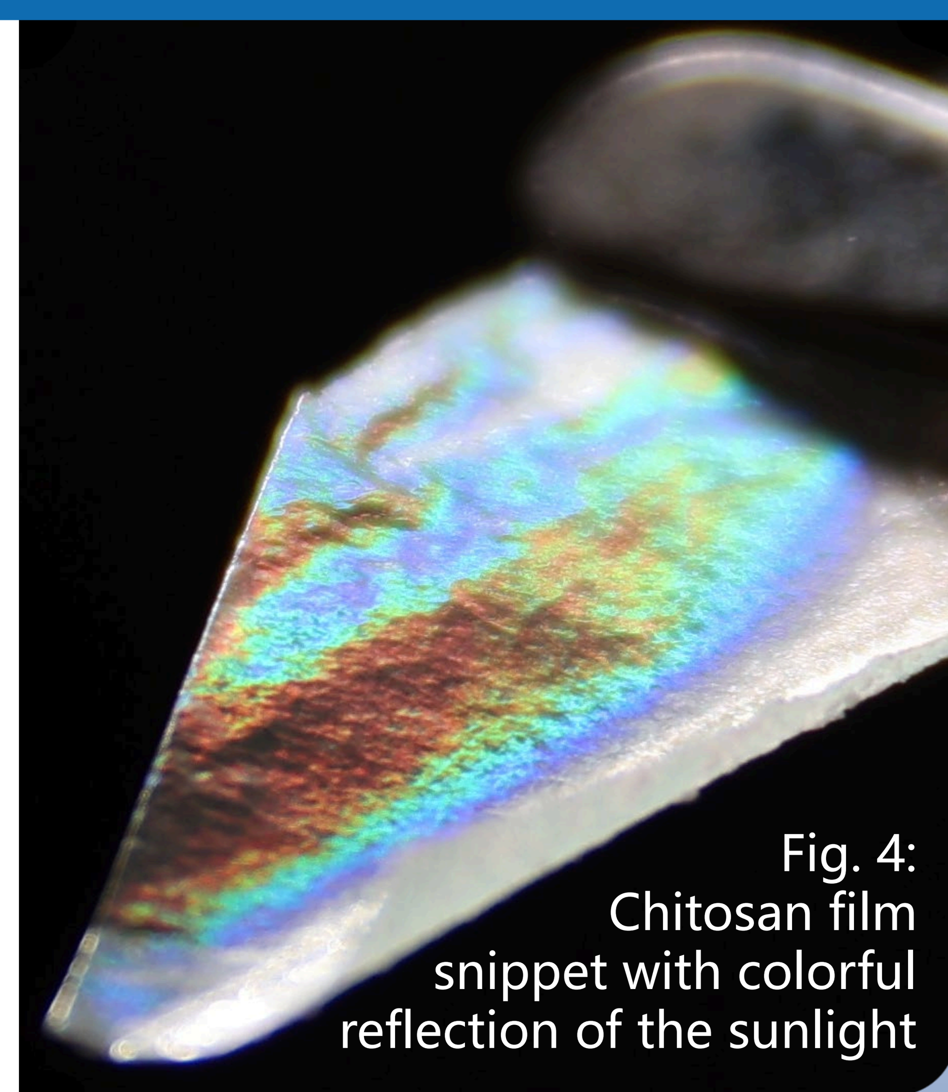
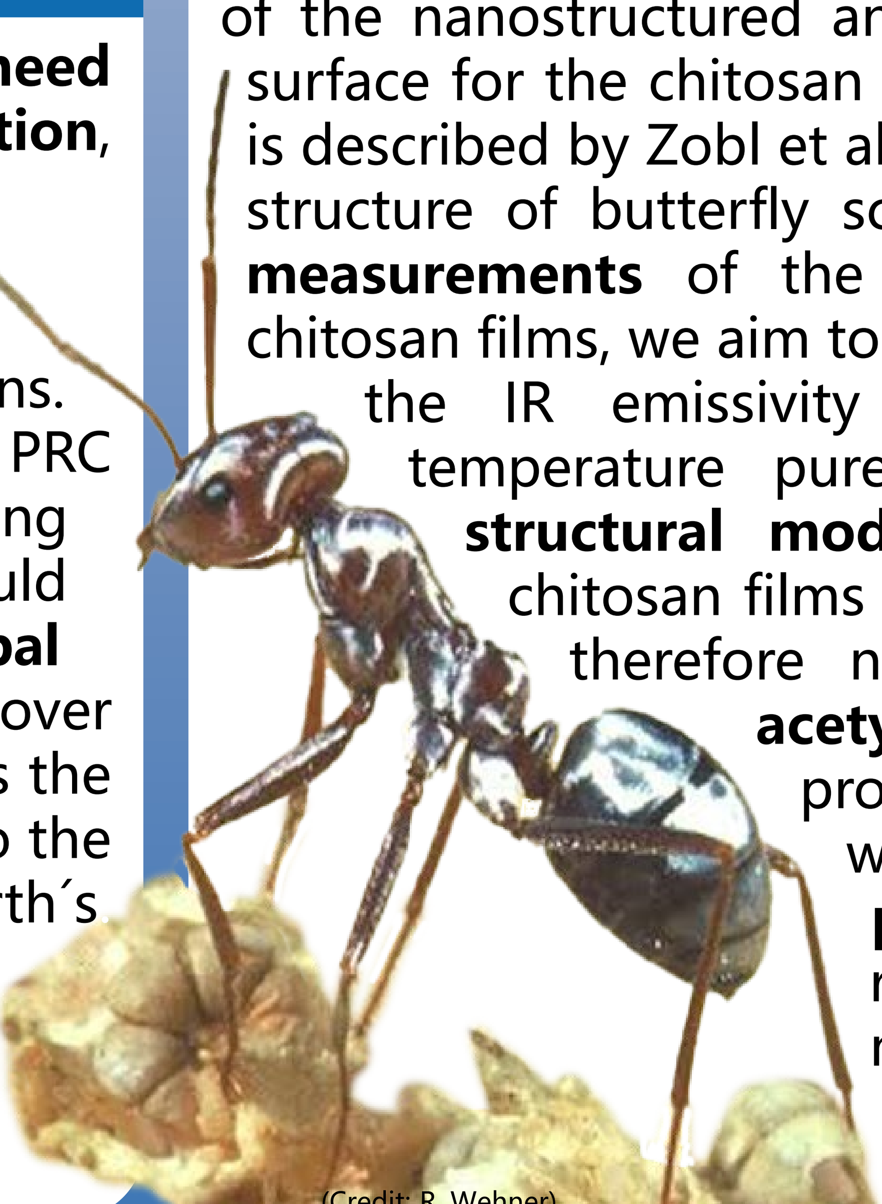


Fig. 4: Chitosan film snippet with colorful reflection of the sunlight

Applications

Applying PRC solutions to house facades can **decrease the need for conventional cooling**. On top of the **energy free operation**, PRC has the benefit of not warming the surrounding air and therefore **avoiding heat accumulation** in dense urban areas. Lower than ambient temperatures also lead to dew formation, which can be used for **water harvesting** in dry regions.
The global application of low-cost and environmentally sound PRC solutions could significantly slow down global warming. Increasing the Earth´s emissivity by approximately **1 W/m²** on average would shift the energy flux enough to slow down or even **stop global warming**. This terraforming approach would require to cover around half of the Saharan desert with PRC material [2], but has the advantage of being **easily reversible**, unlike releasing gases into the atmosphere to reduce the greenhouse effect or increase the Earth´s reflectance. We want to provide proof-of-concept for a low-cost, biodegradable and easily scalable PRC solution. This ensures that it can be utilized in poorer countries, which are most affected by climate change.


(Credit: R. Wehner)

Outlook

Our future work involves creating a Polyvinyl siloxane **(PVS) imprint** of the nanostructured ant body. This imprint will serve as target surface for the chitosan film. The process of producing an imprint is described by Zobl et al. (2016)[3], who successfully replicated the structure of butterfly scales. By comparing **FT-IR spectroscopy measurements** of the **emissivity** of flat and nanostructured chitosan films, we aim to demonstrate that it is possible to increase the IR emissivity and therefore decrease the surface temperature purely through functionalities induced via **structural modification**. It is worth noting that the chitosan films we currently use are soluble in water and therefore not suitable for outdoor use. With an **acetylation reaction**, which is the inverse process of obtaining chitosan from chitin, we want to decrease the solubility **while preserving the nanostructure**. Lastly, a rooftop setup shall be designed to directly measure the amount of cooling our solution can provide under outdoor conditions.

References:
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