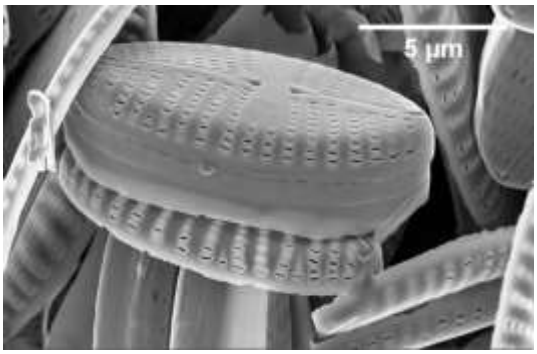
SWEDISH ALGAE FACTORY

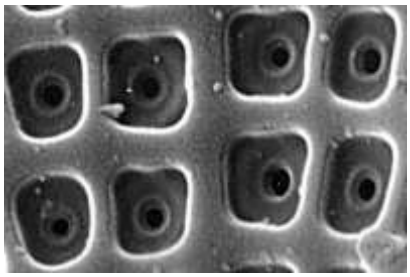
# ALGICA

The algae-based silica material with unique light manipulating properties, with the potential to boost solar panel efficiency with at least 4 %.




## Algica's nanoporous design

Algica is the nanoporous silica shell material of a microscopic algal group called diatoms. The scientific name of diatom shells is "diatom frustules". Diatom frustules consist of pure silica with hydroxyl groups on the surface. They have a transparent nanoporous structure with several layers of regular pores in decreasing size creating a funnel structure. This inorganic material has evolved to efficiently trap visible light, block UV radiation and down-convert light in order to protect the diatom cell and improve the photosynthetic capacity.

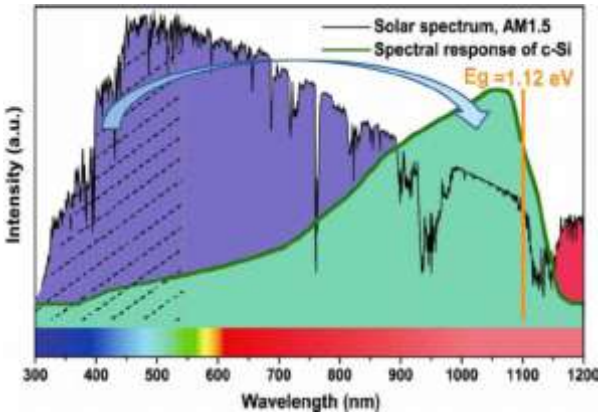


*Regularly sized pores of decreasing size*

## Down-conversion effect

Several researchers have recorded photoluminescence (PL) induced down-conversion from shorter to longer wavelengths when light interacts with diatom frustules. In tests e.g. UV radiation has been converted to blue radiation and blue radiation to green radiation.
(*Tommasi, 2017, Light Manipulation by Single Cells: The Case of Diatoms, De Stefano & Tomassi 2018, UV-shielding and wavelength conversion by centric diatom nanopatterned frustules*)

The source of the PL lies in a variety of surface defects, including oxygen defect centers such as non-bridging oxygen hole centers (• O-Si≡) or neutral oxygen vacancy (≡Si-Si≡), in addition to ≡Si-OH (silanol) and ≡Si-H groups. However, the most significant contributor is the recombination of self-trapped excitons (STE) localized by self-induced lattice distortion in presence of strong electron-phonon interactions. In the case of silicon dioxide, the electron component of the STE is an oxygen vacancy and the holes are associated with a peroxy linkage (≡Si-O-O-Si≡).




*Picture from Abrams, 2011, Solar energy enhancement using down-converting particles: A rigorous approach, that shows the mismatch between the solar spectrum, the spectral response of a c-Si cell and thereby the potential of enhancing the efficiency of a c-Si cell by down-converting the solar spectra towards longer wavelengths*

According to our research, diatom frustules can shift the whole wavelength spectra from shorter wavelengths to longer wavelengths with over 100 nm. This ability shifts the spectra of the incoming light to better resemble the spectral response of a silicon solar panel and, thus, enhances the efficiency of the solar panel.

## UV radiation blocking effect

Exposure of a UV sensitive film to UVR, through diatom frustules spread onto the film, showed that the frustules suppressed photobleaching of the film. The UV radiation blocking effect is derived both from absorption and reflectance and from manipulation of UV light to visible light.
*(Nature Scientific Reports: Aguirre, Wulff, Inganäs et al 2018 Diatom frustules protect DNA from ultraviolet light (Authors include two employees, Wulff and Hedblom), De Stefano & Tomassi 2018, UV-shielding and wavelength conversion by centric diatom nanopatterned frustules)*

## Light trapping effect

The light trapping effect is derived from the funnel structure of the pores. It prevents transmitted light from being backscattered and thereby enhances the light absorption. A significant light trapping and light focusing effect can be seen and is independent of the incident angle of light.
(*Chen et al, 2015*, *Numerical and experimental investigation of light trapping effect of nanostructured diatom frustules).*

## The use of Algica to enhance solar panel efficiency

Algica can be added to the encapsulant or in a coating on the glass of the solar panel. A less than 10 % coating coverage of Algica resulted in a 3-4 % relative solar panel efficiency enhancement in indicative flash tests. These results have been verified by an independent Swedish research institute (RISE) and in tests with potential customers. Furthermore, blocking the UV radiation can reduce degradation of solar panels over time. By adding higher concentrations of Algica and taking the UV radiation blocking effect into account, relative efficiency gains of 10 % should be expected based on the science of diatom frustules interaction with light.

Algica is as an inert, inorganic silica material with proven durability over hundreds of years. The height of the particles in a coating is about 2 µm and the length of the particles 15-20 µm. The small differences in particle size do not affect the size of the pores. The pore sizes depend on the diatom species used but within a single species, the pores are regular. We have chosen to cultivate a type of diatoms that have a pore structure suitable for solar panel efficiency enhancement.

## About Swedish Algae Factory

Swedish Algae Factory was founded 2016 based on years of research on the unique shell structure of diatoms. Our research team has over 100 years' combined experience in diatom research and engineering and is led by our cofounder, Professor Angela Wulff. Professor Wulff, as part of her research at Gothenburg University, collaborates with world-renowned physicists and biologists including Prof. Olle Inganäs and Dr Mario de Stefano. Our backers include the Swedish Energy Agency, EU LIFE and a former president of Akzo Nobel, Jan Svärd.

Swedish Algae Factory is the only large-scale producer of diatom frustules globally. We have patents pending for our diatom cultivation method and the use of diatom frustules from our facilities for efficiency enhancements of solar cells and panels and the formulation of Algica in a suspension/gel and its use for UV radiation absorption. We cultivate diatoms with the best proven performance and durability, in a cost efficient and resource efficient production process. Today we produce Algica in Kungshamn on the Swedish west coast and will during 2020 scale up our production to meet customer demand.

We are happy to answer your questions.

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