Towards safety and sustainability in scalable production of semiconducting nano- and non-nanomaterials: Zinc oxide - a case study

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1) **VERDEQUANT manufacturing process**

2) Case: Nanodiffusors for the improvement of organic solar cell efficiency

VERDEQUANT label

Certifies that **nanomaterials are manufactured in a sustainable** way

Incentivizes **consumers** to choose a product based on **high performance nanomaterials**, manufactured by a **sustainable process** for: agriculture, food, cosmetics, etc.

Provides **transparency** for the **manufacturers' benefit.**

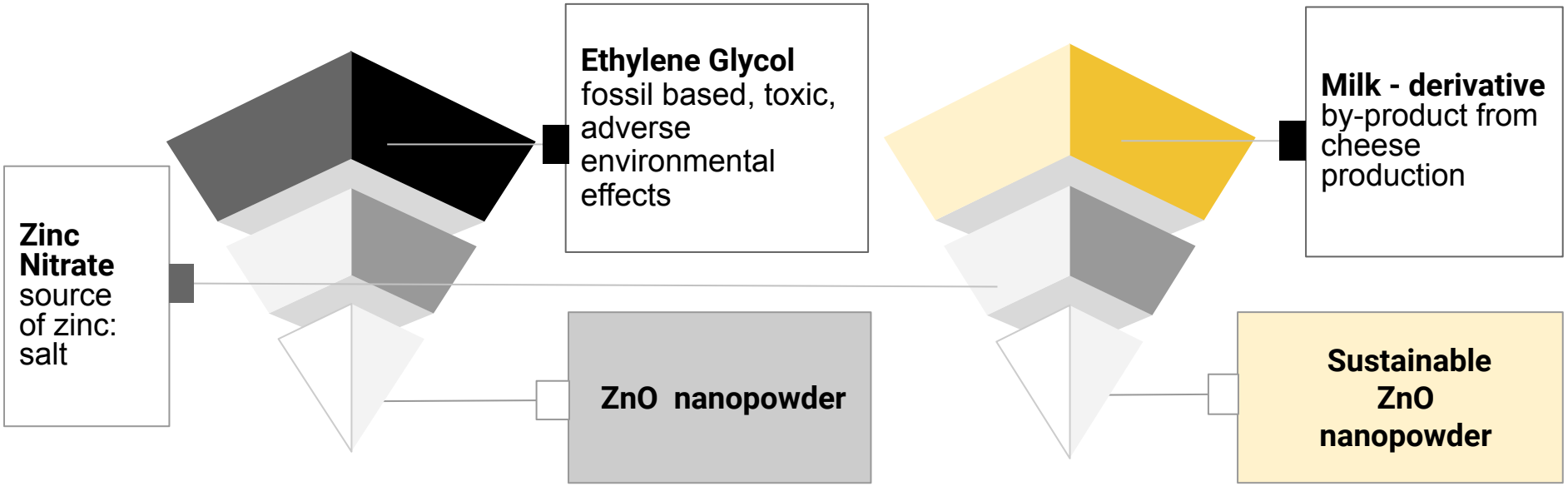
VERDEQUANT sustainable nanotechnology

SUSTAINABILITY is defined by 2 basic prerequisites:

1. **VERDEQUANT** processes are **free from the use of fossil** based reactants and substitutes them with ones obtained from renewable sources, such as e.g.: plants, dairy products or fungi and use vegan reactants whenever possible.
2. **VERDEQUANT**processes are **free from toxic solvents**, preferably water.

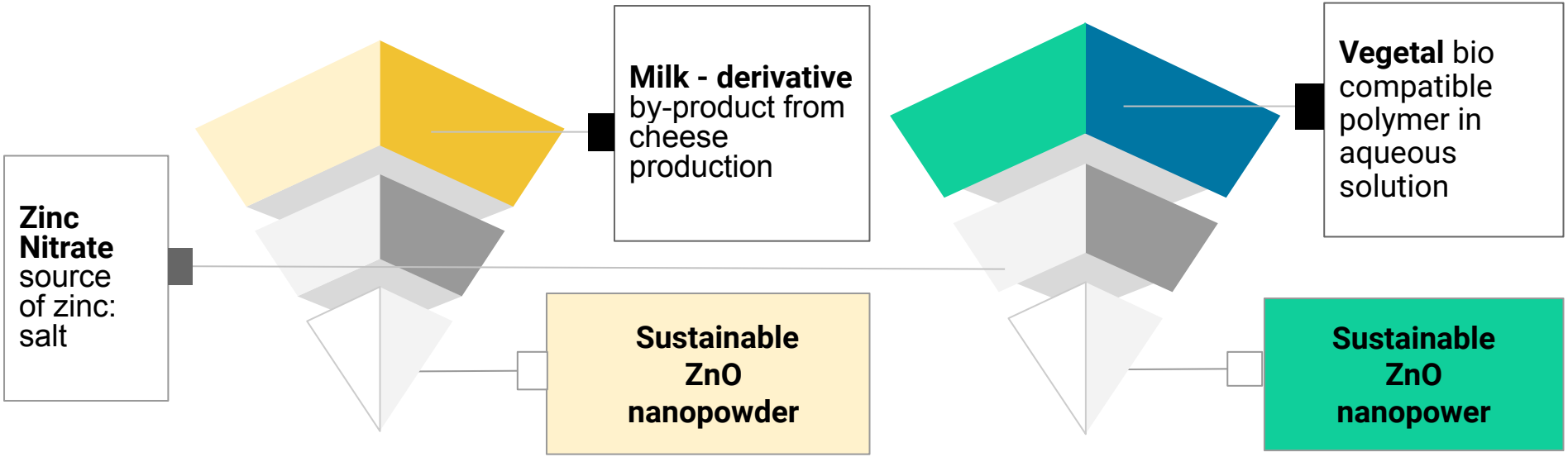
https://www.phornano.com/verdequant[4]

VERDEQUANT sustainable nanotechnology



VEREQUANT process for obtaining biocompatible zinc oxide nano- & non-nanoparticles (ZnO NPs). Fossil based ethylene glycol is substituted by whey, a by-product of cheese manufacturing, in a cascaded process configuration

VERDEQUANT sustainable nanotechnology

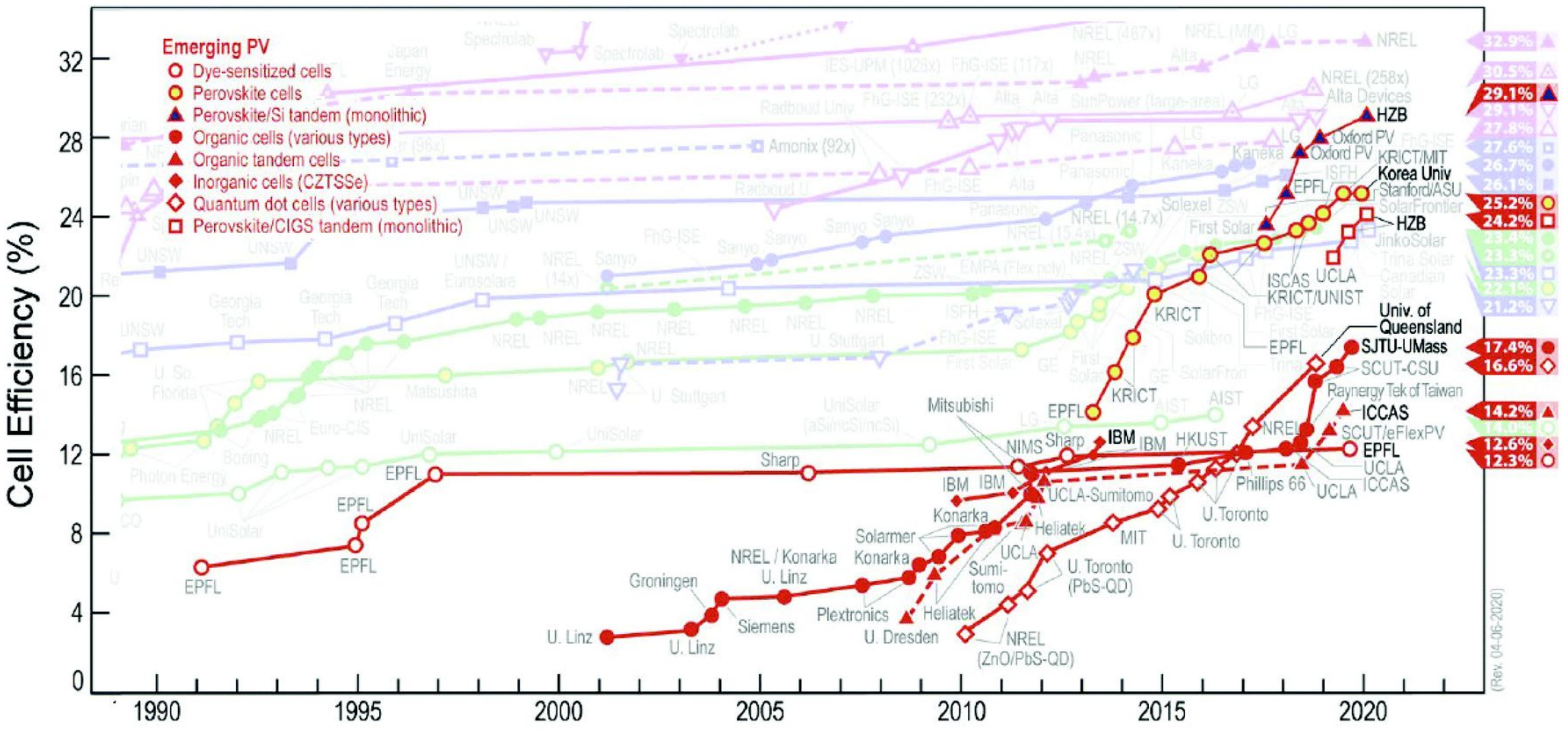


In a 2nd step, fossil based ethylene glycol is substituted by a 100 % vegan alternative (Patent WO2021046586A1).

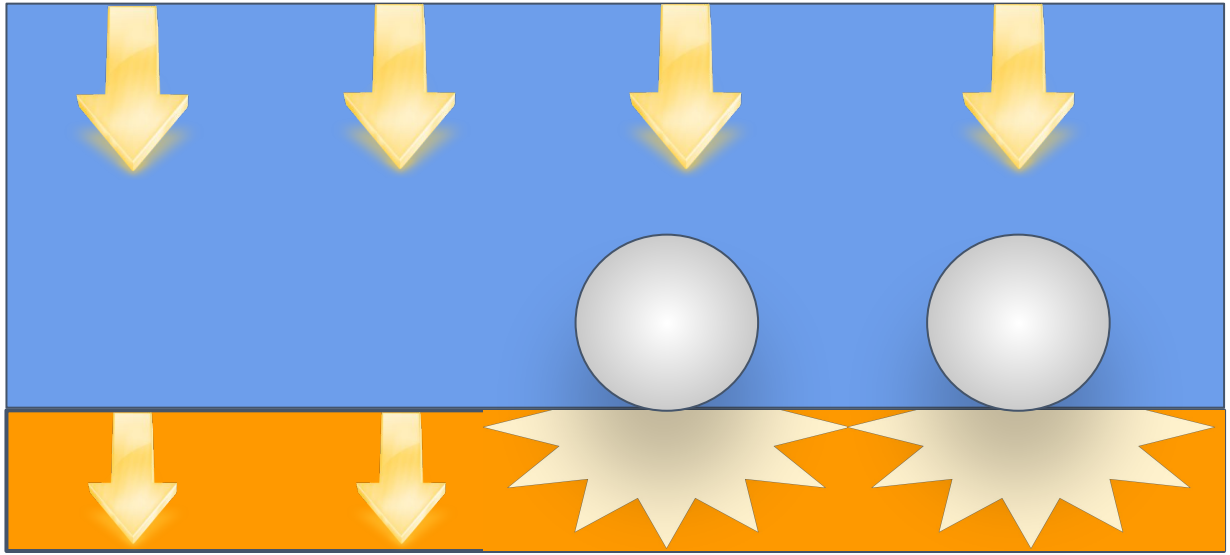
1) VERDEQUANT manufacturing process

2) **Case: Nanodiffusors for the improvement of organic solar cell efficiency**

Best Research-Cell Efficiencies

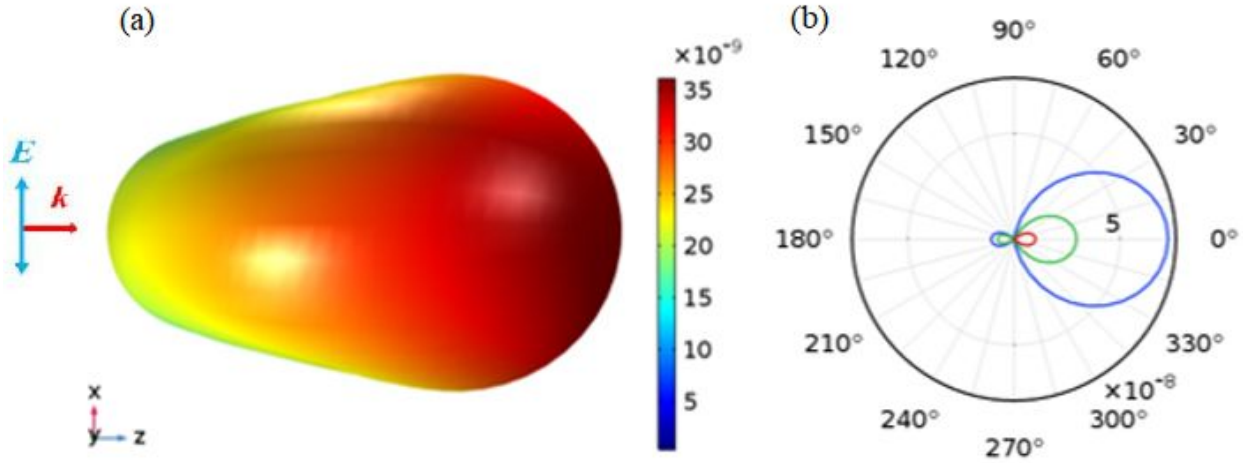


Optical enhancement - Light Scattering by nanodiffusors



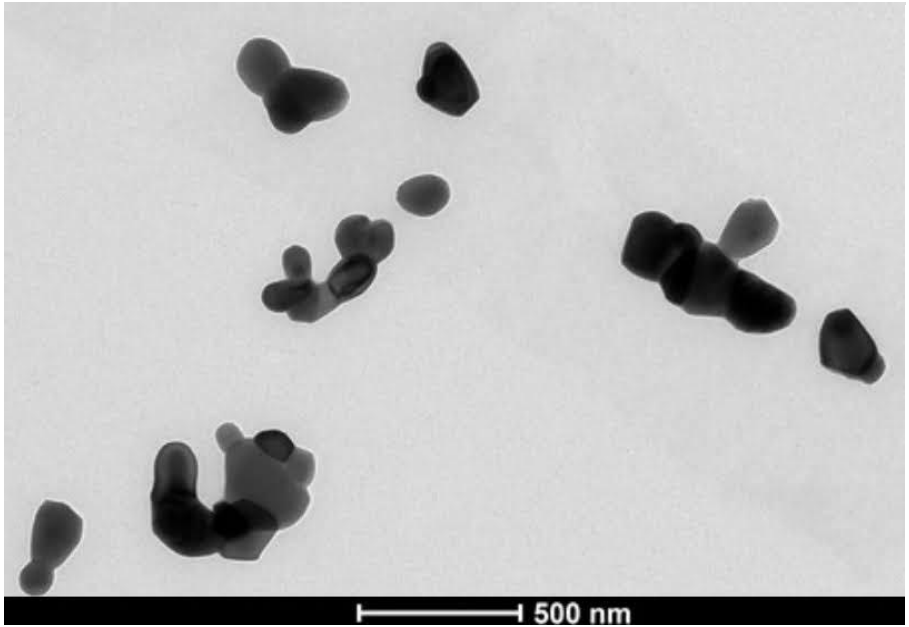
Left side: direct radiation, orthogonal pathways only. **Right side:** mimicking diffuse radiation, additional non-orthogonal pathways are created resulting in an enhanced absorption in the active medium (orange).

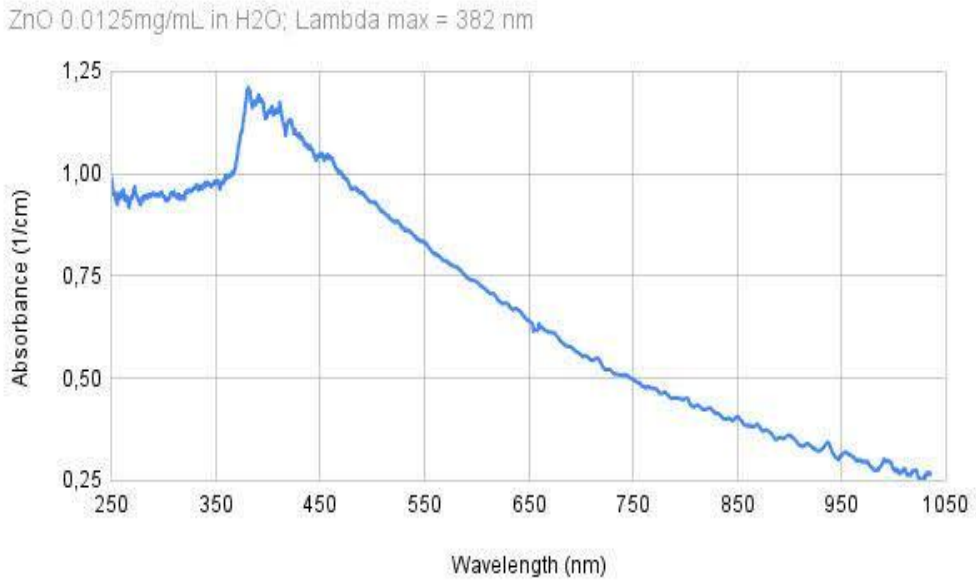
Optical enhancement - Forward Scattering



(a) 3D scattering far-field map at 500 nm, and **(b)** polar farfield diagram for 400 nm (blue), 500 nm (green), 600 nm (red), considering ZnO nanoparticles with 160 nm diameter

Example 160 nm ZnO NPs for enhanced scattering

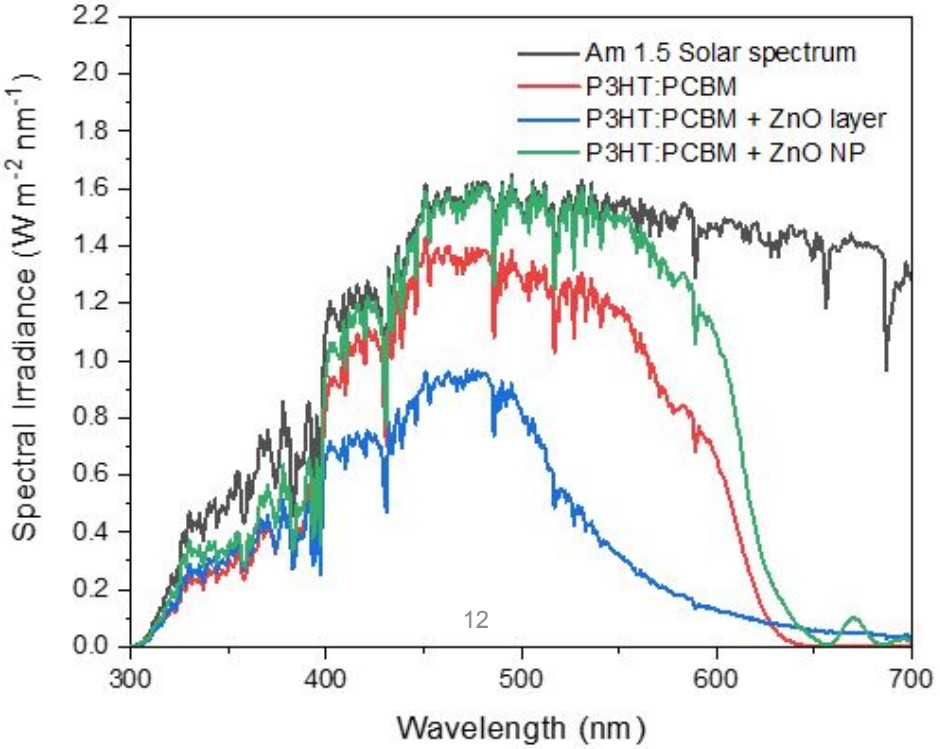




Enhancement of the short circuit current density by 27.9%.

- The use of ZnO NPs (160 nm diameter) on the organic solar cell top surface can reduce the device reflectance by forward scattering of up to 95% @ 530 nm

- promoting an efficient light-coupling into the P3HT:PCBM active layer increasing the OSC active layer absorbance (26%).



Cardozo, O., Farooq, S., Farias, P.M.A. *et al.* Zinc oxide nanodiffusers to enhance p3ht:pcbm organic solar cells performance. *J Mater Sci: Mater Electron* 33, 3225–3236 (2022). https://doi.org/10.1007/s10854-021-07524-8

INISS nano:

International Network Initiative on Safe & Sustainable Nanotechnology

www.bnn.at/iniss-nano-concept-paper-published/

http://doi.org/10.5281/zenodo.5004929

Thank you!

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The application of the patent was supported by FFG (Austrian Research Promotion Agency) project 871107

14