CHARLES UNIVERSITY
CENTRE OF ADVANCED MATERIALS

PHOTOACTIVE NANOFIBER MATERIALS

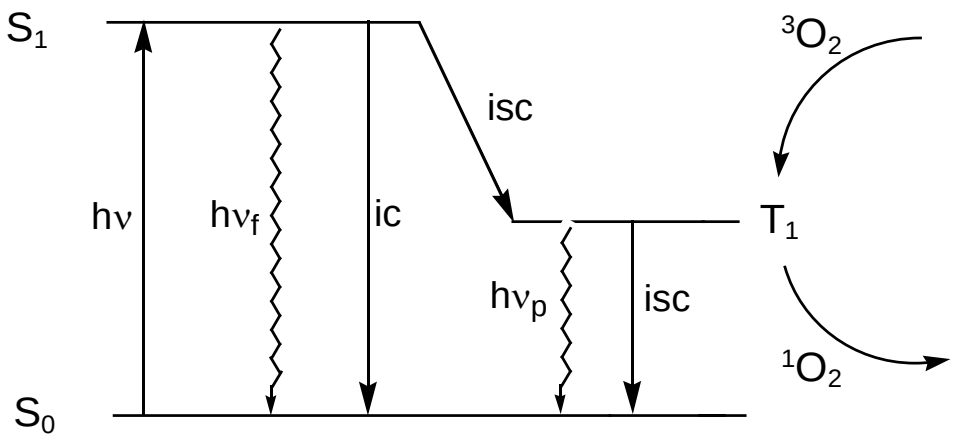
Jiří Mosinger

Research group: Photochemistry and Supramolecular Chemistry of Porphyrinoids

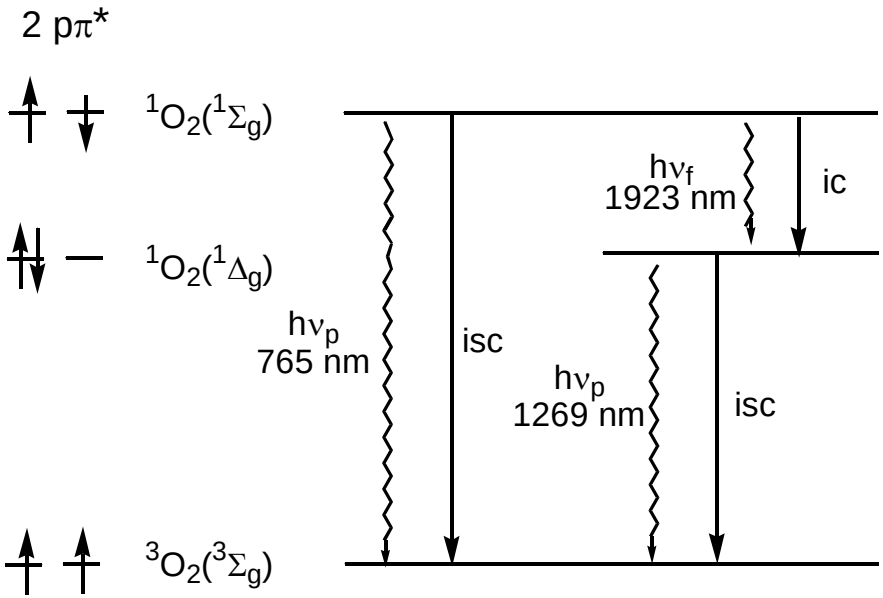
(Department of Inorganic Chemistry, Faculty of Science, Charles University , Hlavova 8, 128 43 Prague 2, Czech Republic)

mosinger@natur.cuni.cz

Mechanism of photosensitized production of $^1O_2$



Electronic transitions of O_2



ic – internal conversion, isc – intersystem crossing,
$h\nu_f$ –fluorescence, $h\nu_p$ – phosphorescence

Nanofibers with encapsulated nonpolar photosensitizers

Properties of $^1O_2$:

Strong oxidation effect

Strong cytotoxic effect

Short lifetime (activity "*in situ*")

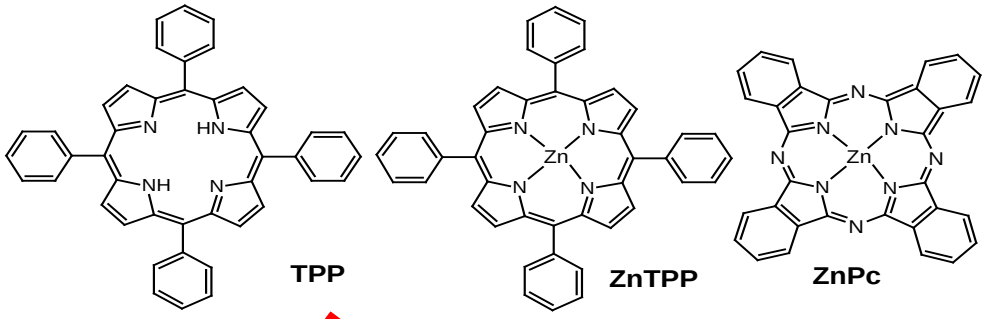
Properties of nanofiber materials:

Optical transparency

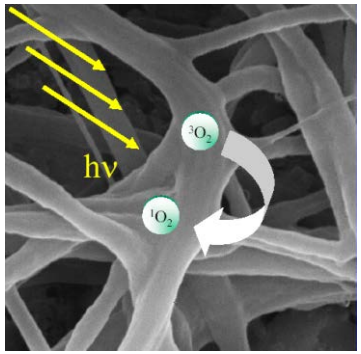
High oxygen permeability/diffusion

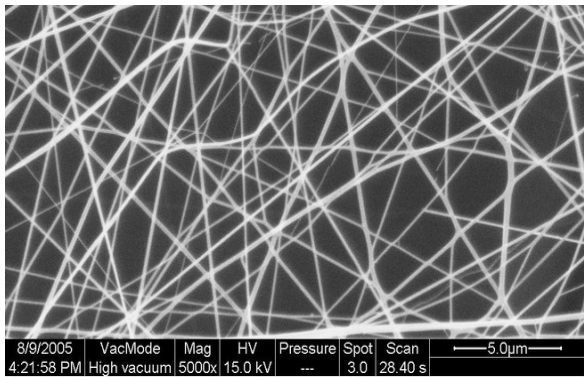
Large surface

Ability to detain bacteria or other pathogens on nanoporous surface



1-5 wt %

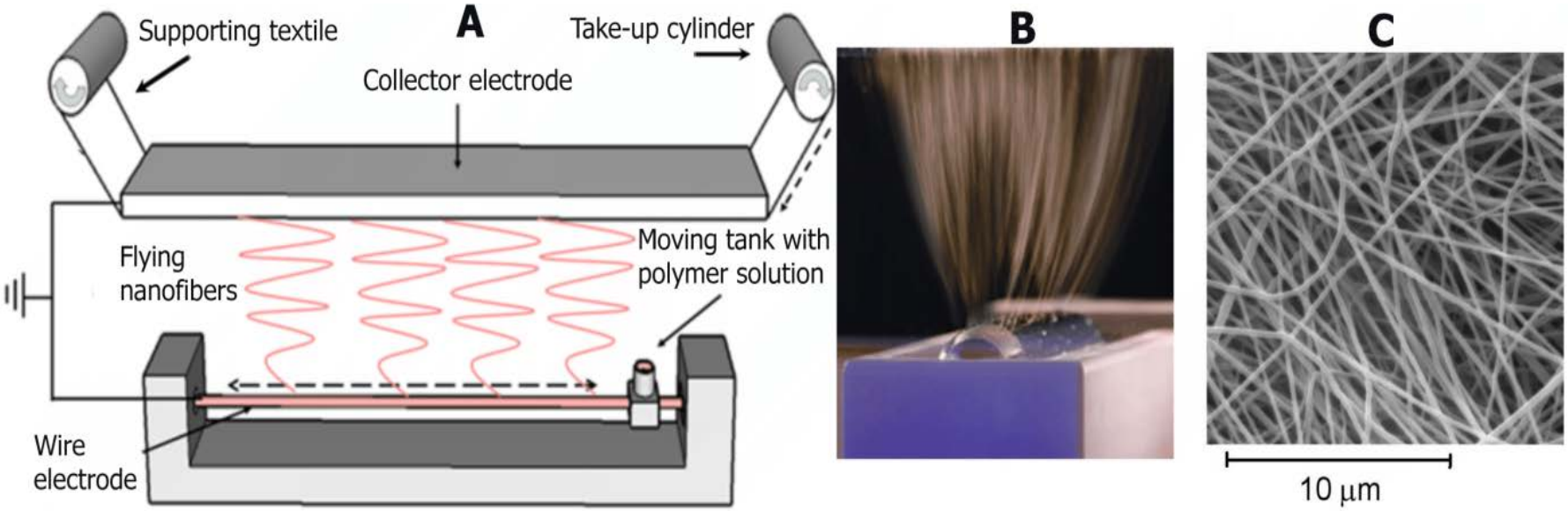




Nanofiber diameter: 150-350 nm

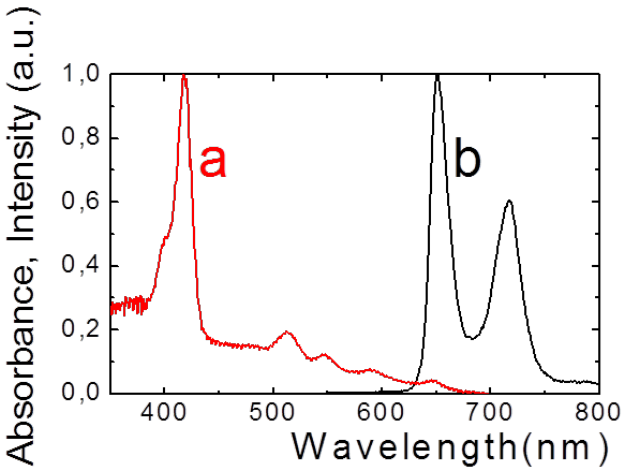
Novel photoactive nanomaterials

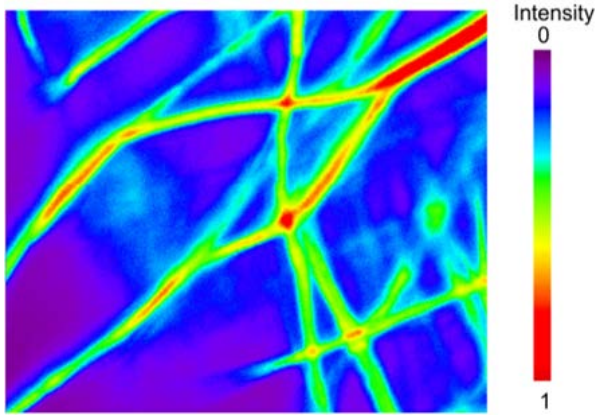
Electrospinning



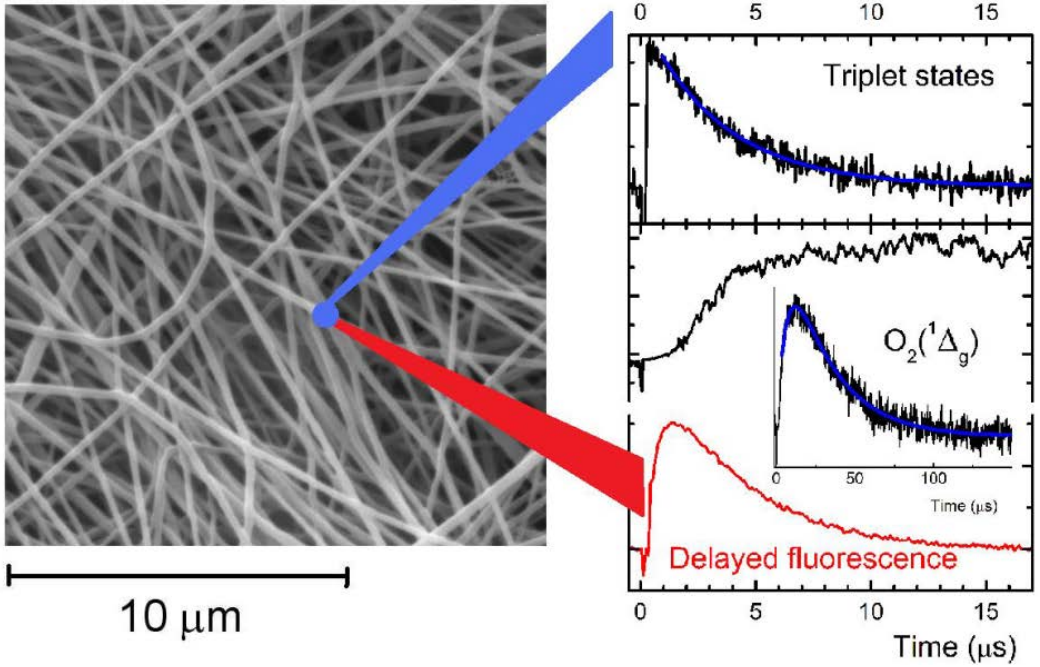
A: Scheme of an industrial electrospinning device Nanospider™.
B: Electrospinning device consisting of a roller electrode immersed in a tank with polymer solution. Flying nanofibers from a charged roller are placed on a grounded collector electrode. **C**: SEM of resulting nanofiber material.

Application of steady-state spectroscopy



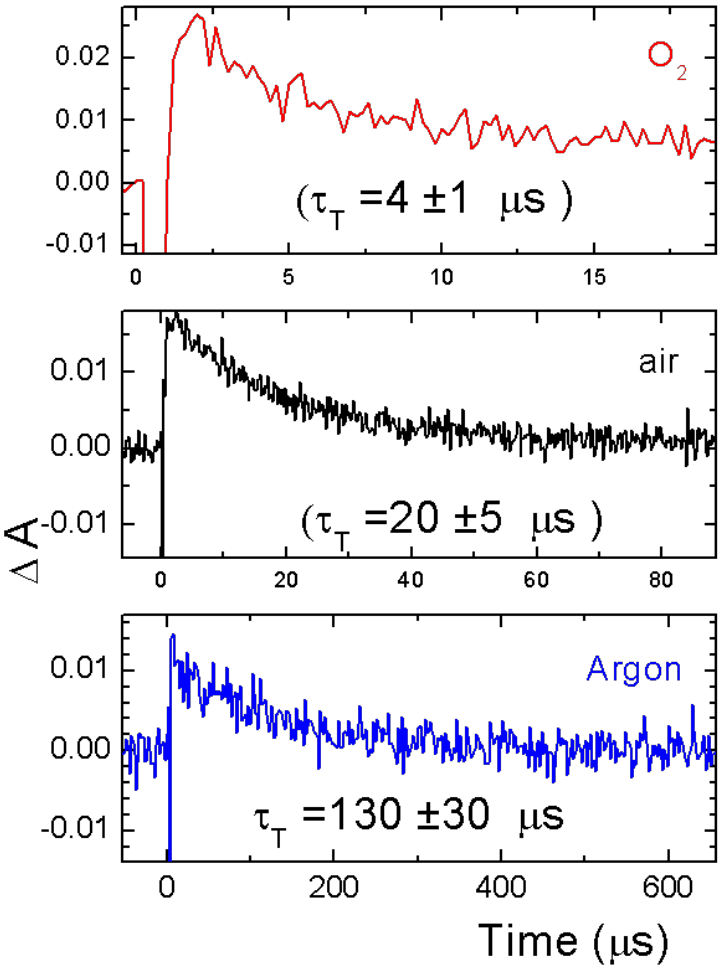


Application of time-resolved spectroscopy



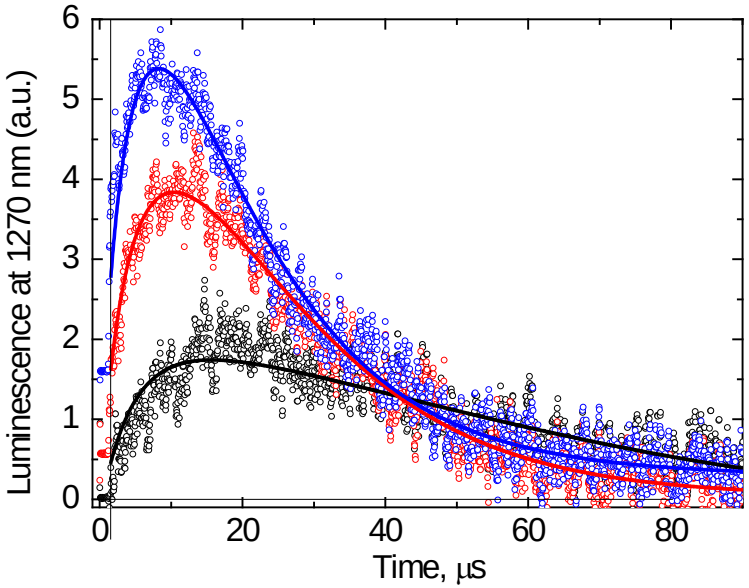
Kinetics/lifetimes of T-states

$$[A^T] = [A_0{}^T] \exp(-t/\tau_T)$$



Kinetics/lifetime/diffusion pathway of $O_2(^1\Delta_g)$

$$[O_2(^1\Delta_g)] = A_{SO}\,\tau\Delta/\,(\tau T-\tau\Delta)(\exp(-t/\tau T)-\exp(-t/\tau\Delta))$$



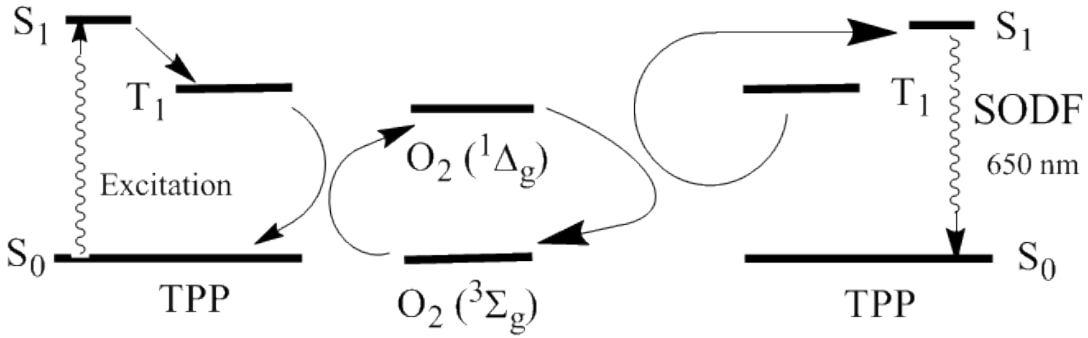
Time–resolved phosphorescence of $O_2(^1\Delta_g)$ at 1270 nm at oxygen pressure 100 (blue), 60 (red) and 13.3(black) kPa of oxygen

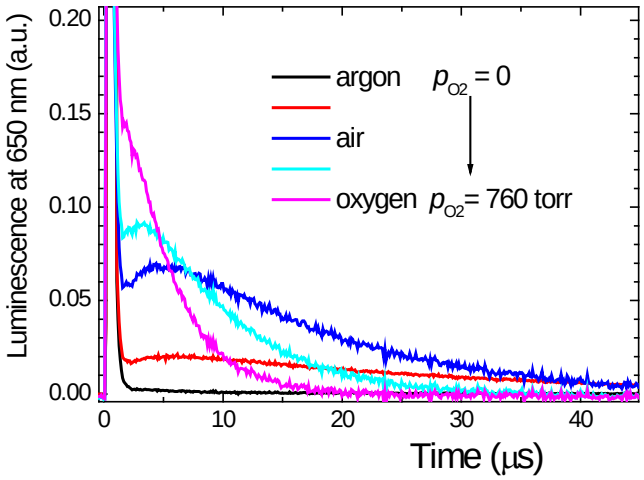
~ 20 μs (air); D_0 ~ 1.1 × 10^{-6} cm^2 s^{-1} (PUR)

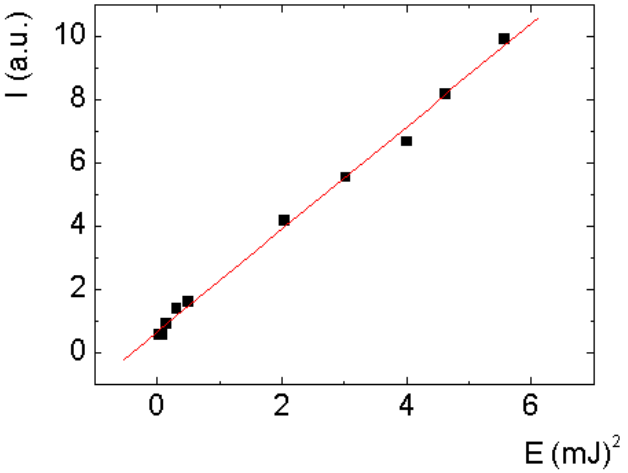
Diffusion pathway: $l_r=(6D_0\tau_\Delta)^{1/2}$ ~ 115 nm

Photooxidation effect ONLY on the surface !

SODF („Singlet Oxygen sensitized Delayed Fluorescence“)



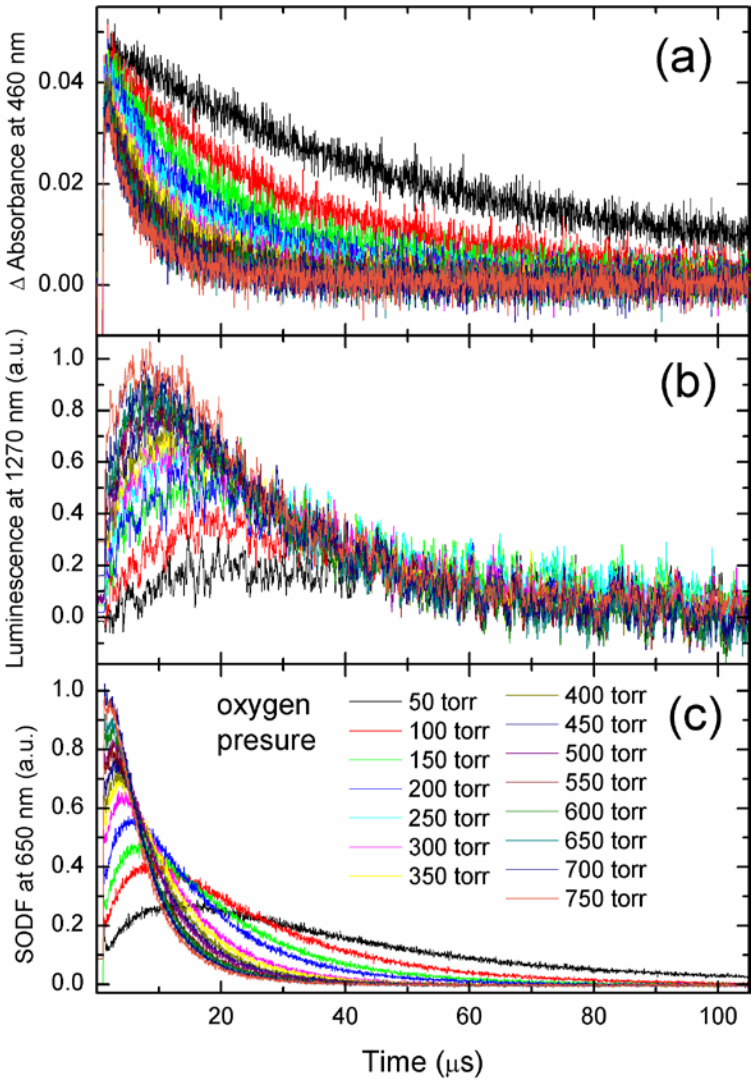


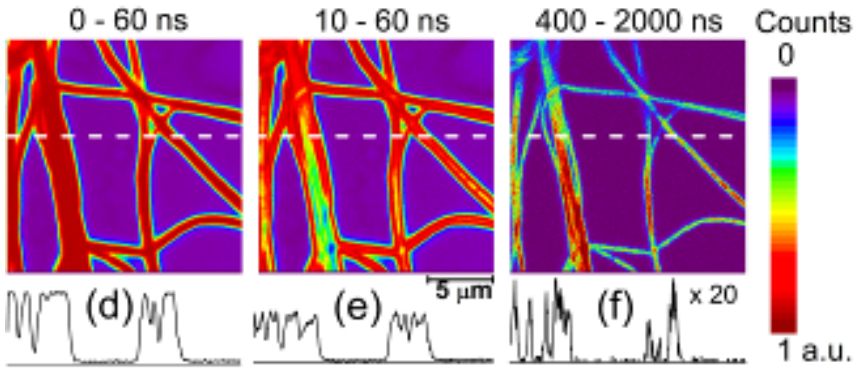


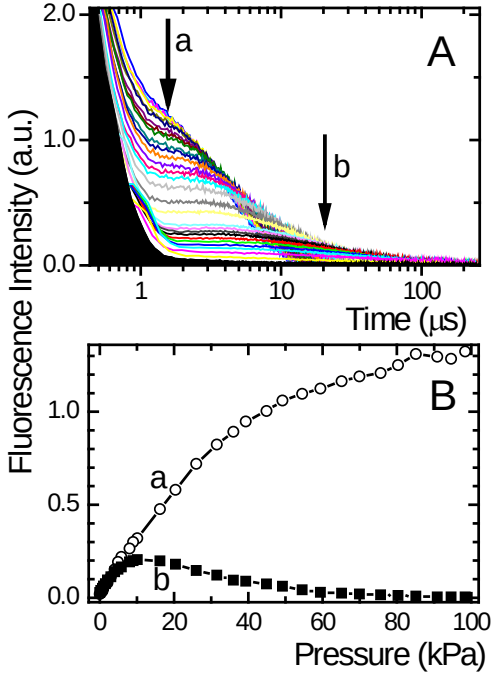
$$T_1 + O_2(^1\Delta_g) \rightarrow S_1 + O_2(^3\Sigma_g)$$

Detection and imaging of O_2/ O_2 ($^1\Delta_g$) by SODF

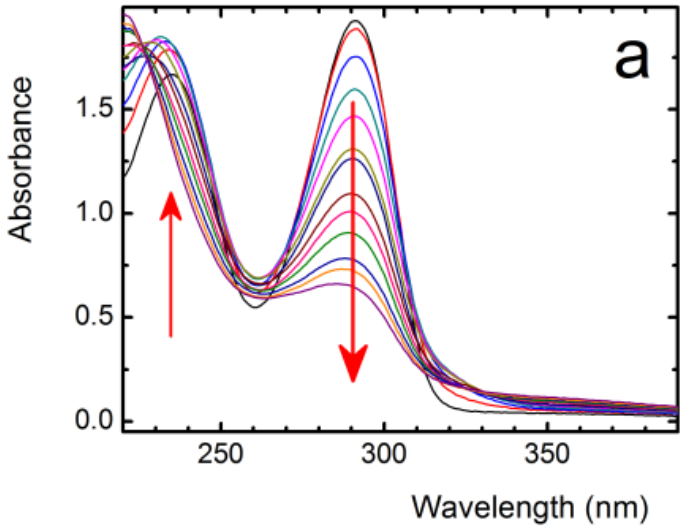
$$I_{SODF} = A_{SODF}\ \tau\Delta/\ (\tau T-\tau\Delta)(\exp(-t/\tau T)-\exp(-t/\tau\Delta))$$

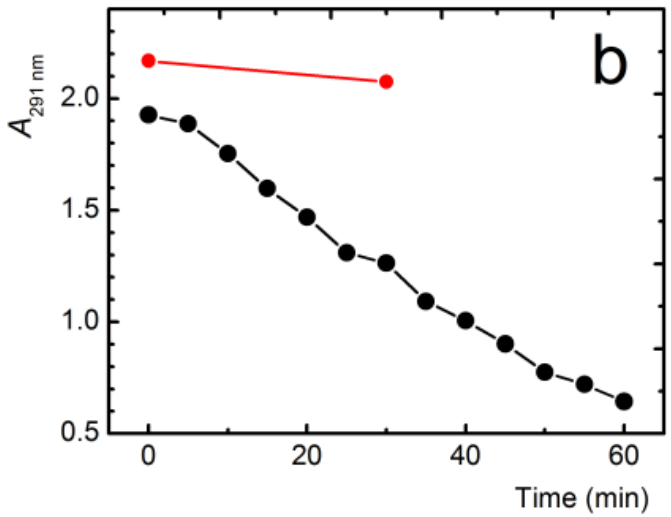


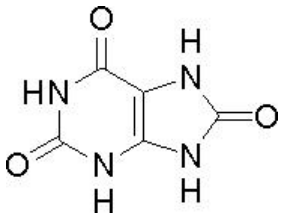




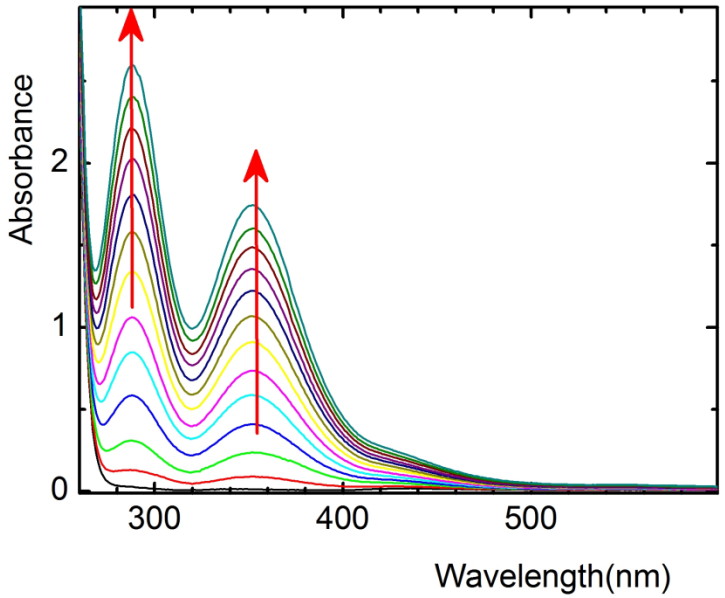
Photooxidation of organic/inorganic substrates







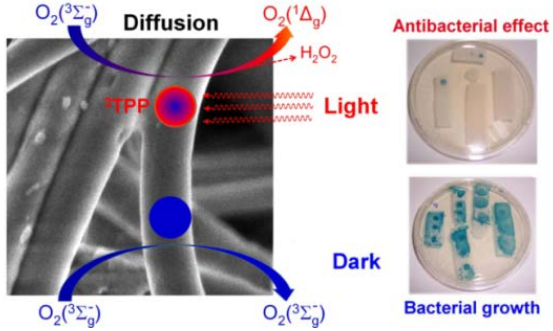
Uric acid photooxidation

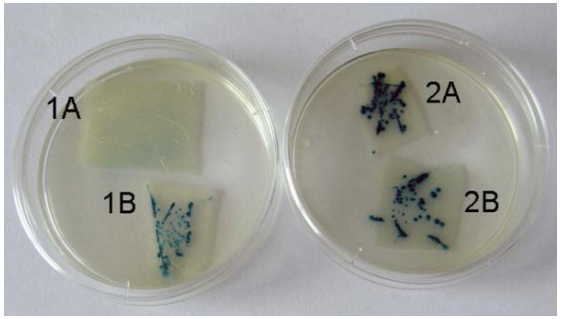


Iodide photooxidation

Antibacterial surface

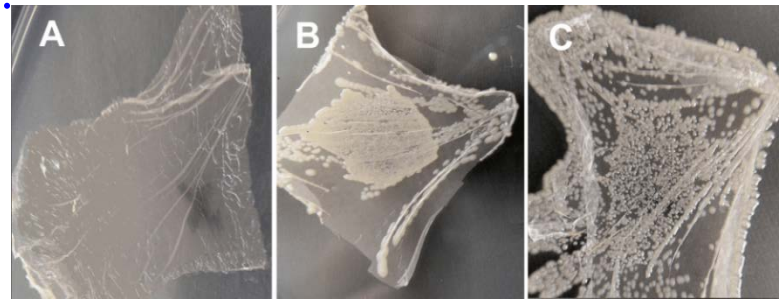
Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa





Escherichia coli DH5α+ plasmid pGEM11Z
X-gal (5-bromo-4-chloro-3-indolyl-β-D-galactopyranosid

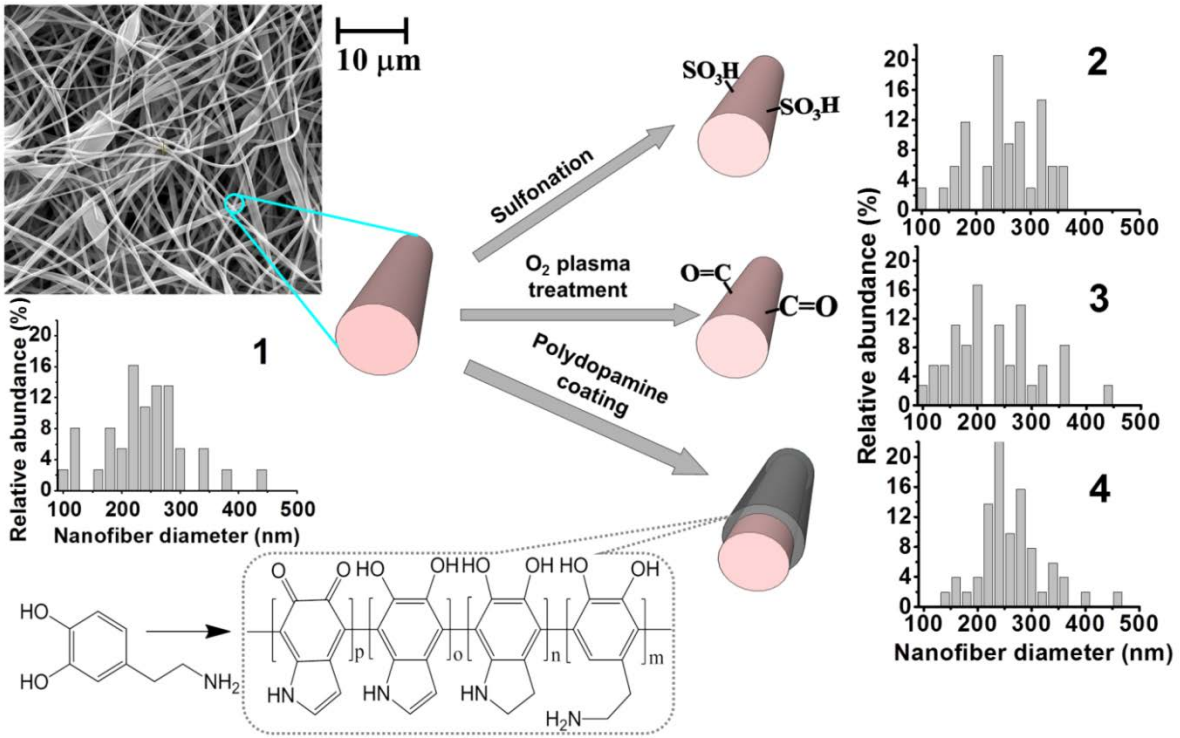
The antibacterial effect of Tecophilic™ nanofiber membrane with encapsulated 1% ZnTPP to *E. coli DH5a.* Agar plates with pieces of nanofiber membrane with encapsulated ZnTPP (**A**) and without photosensitizer (**B**) inoculated with *E. coli* exposed to white light (left, **1**) and kept in the dark (right, **2**).

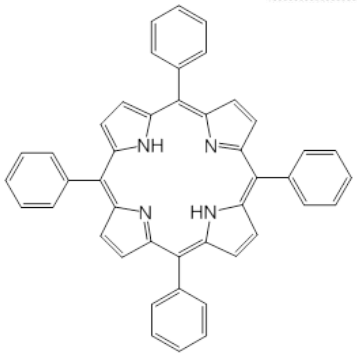


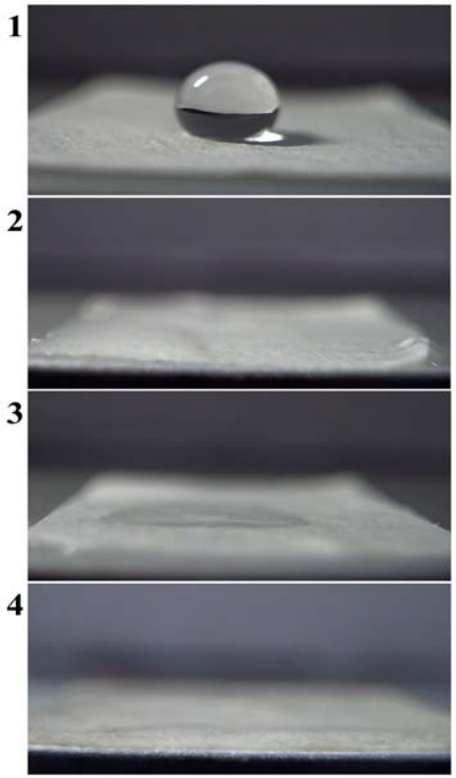
Staphylococcus aureus

The antibacterial effect of PCL nanofiber membrane with encapsulated 1% TPP. *Staphylococcus aureus* inoculated on surface of nanofiber membrane doped with photosensitizer (A) or without photosensitizer (B) and 30 min irradiated by white light. Inoculated doped nanofiber membrane left in the dark (C).

Nanofiber materials with encapsulated nonpolar photosensitizer and surface modifications

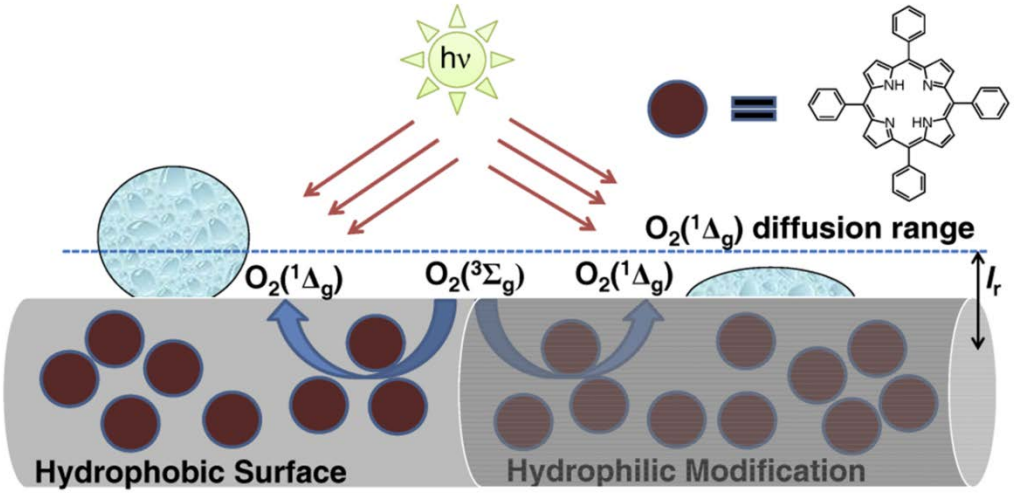






Increased wettability of the nanofiber surface

Enhanced antibacterial effect on the surface of nanofiber materials with post-processing surface modifications

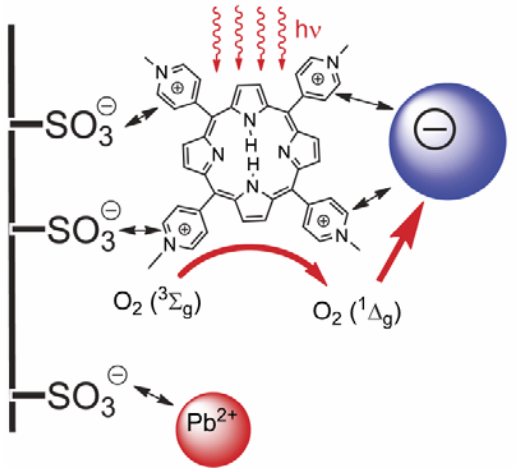


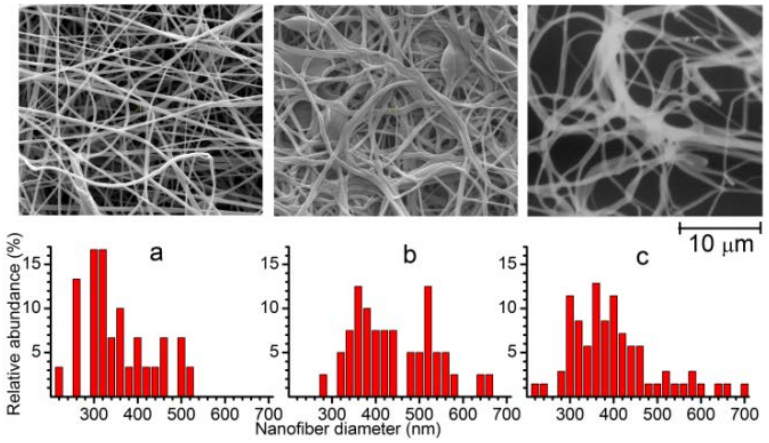
Light-activated, sterile nanomaterials for medical applications

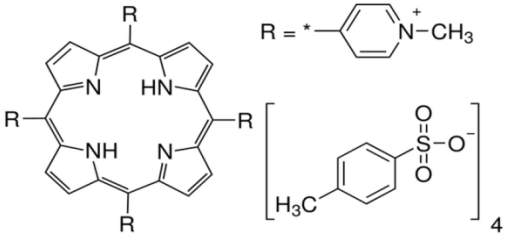
Clinical photographs of a patient with leg ulcers treated with illuminated PU (Tecophilic) nanofiber membrane with encapsulated TPP at the beginning of curing (A), after 15 (B) and 42 (C) days of the treatment.

Multifuntional photoactive nanofiber materials with externally bonding photosensitizer(s)

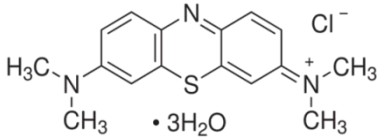
I) Photoactive cation exchange materials





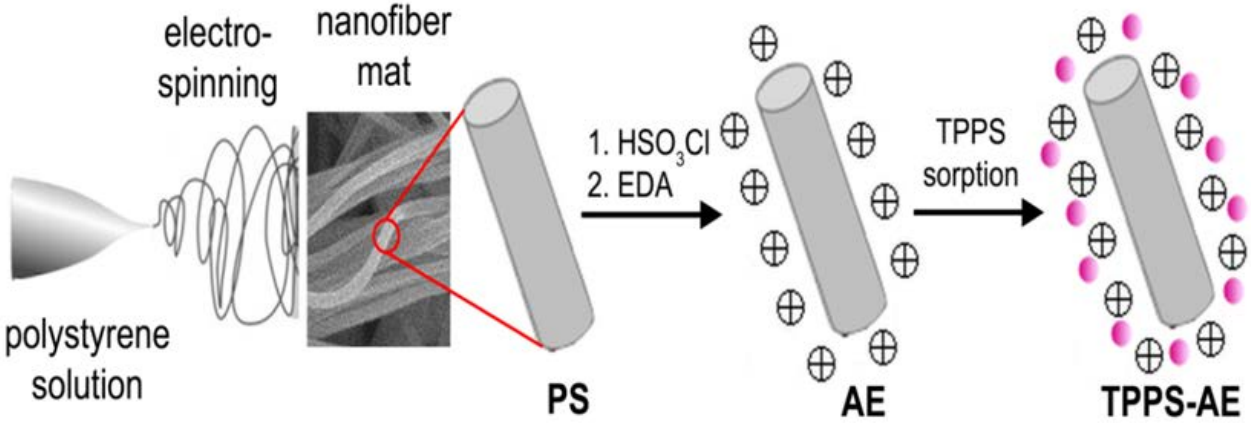


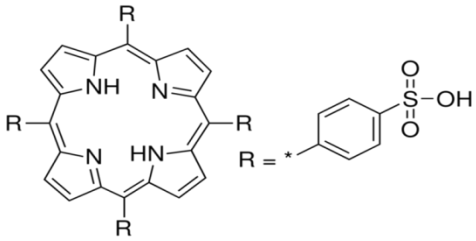
TMPyP



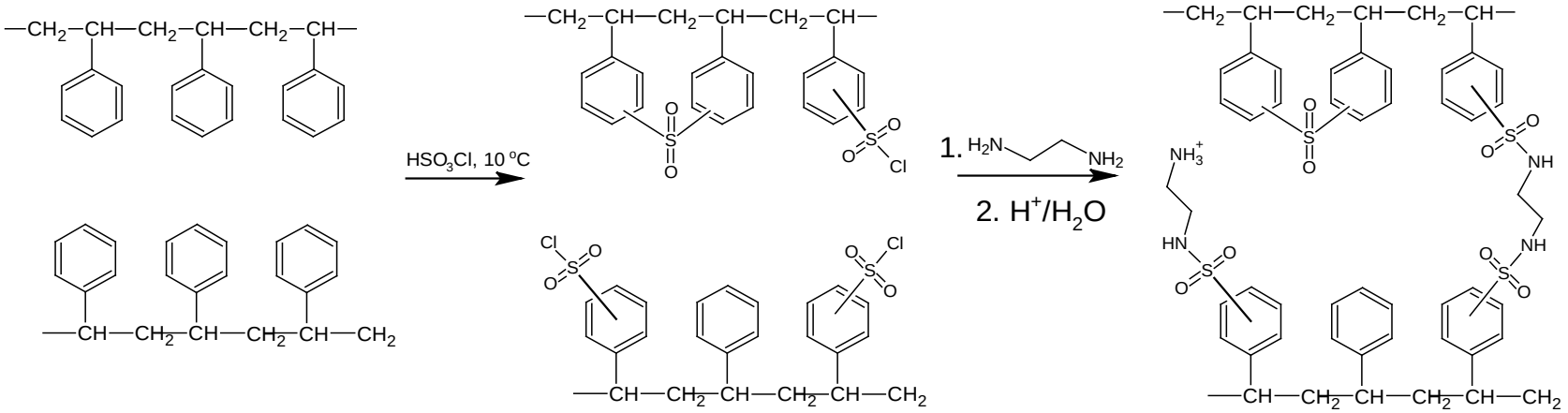
MB

II) Photoactive anion exchange materials

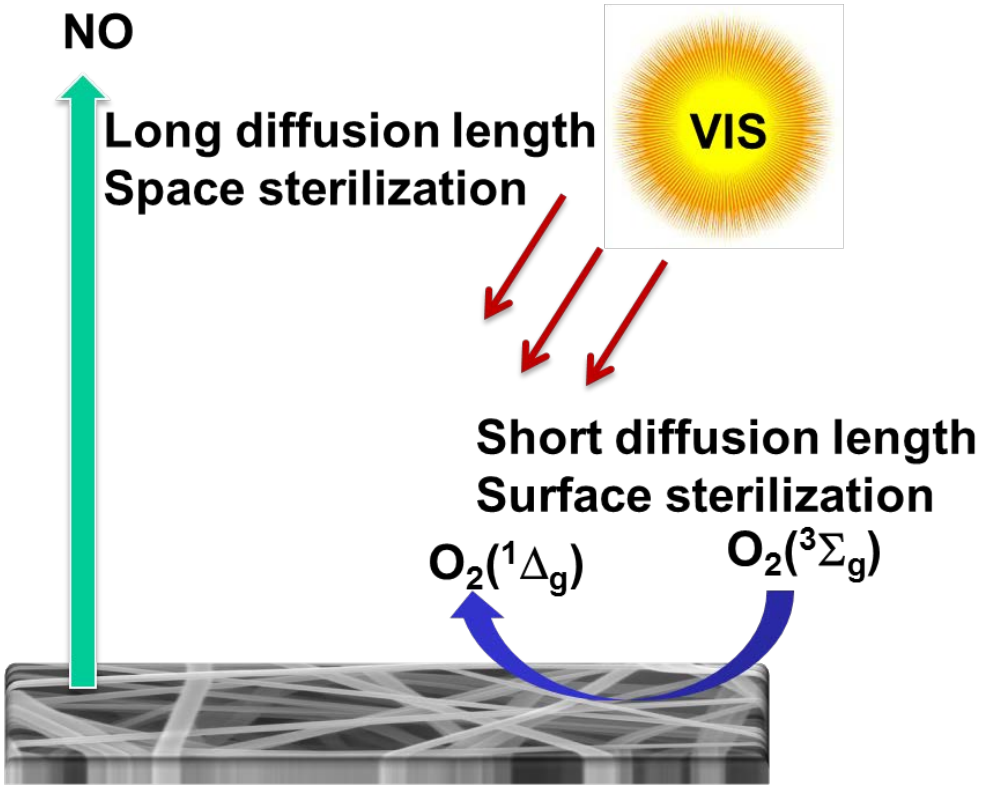




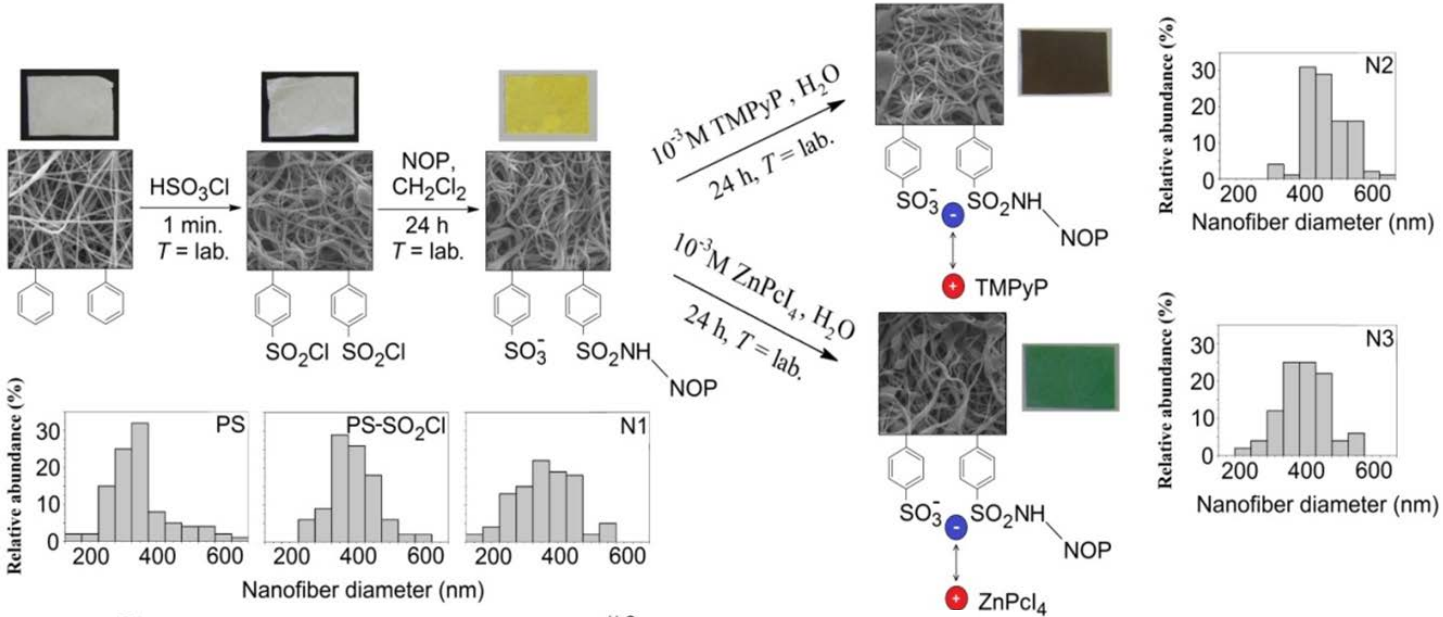
TPPS4

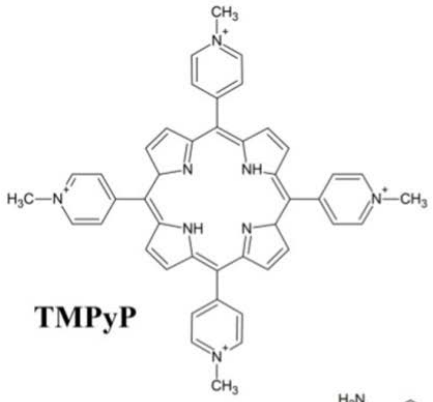


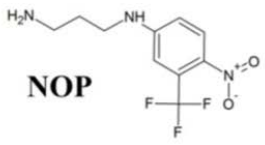
Nanofiber materials for visible light driven simultaneous generation of NO and $O_2(^1\Delta_g)$

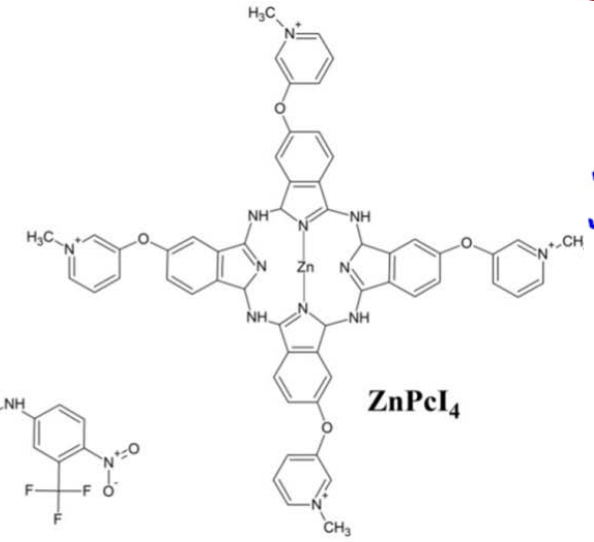


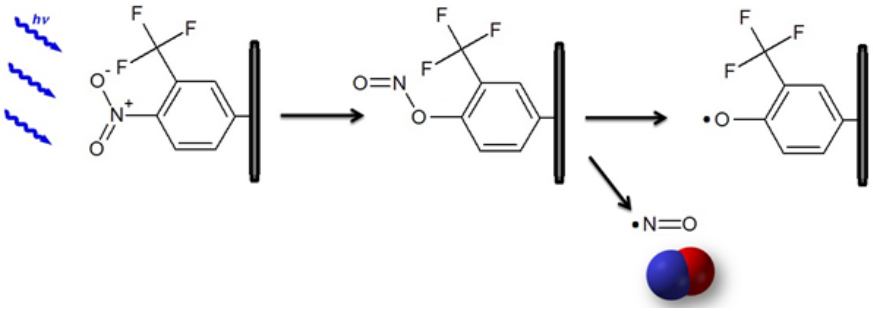
Preparation/characterization







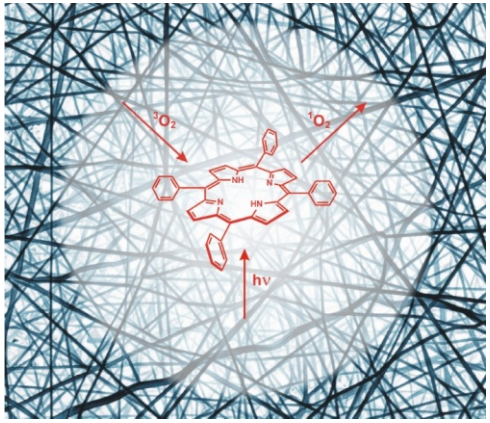




Conclusion

Strong photooxidation & phototoxic effect on surface of nanofiber materials

Sterile nanomaterials for medical applications (wound covering, surgical mask, oxygen sensors…) activated by visible light (daylight)



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Thank you for your attention !