Electronic Supplementary Information

Nanoscaled porphyrinic metal-organic frameworks: photosensitizer delivery systems for photodynamic therapy

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Figure S1. Typical size distributions along the major axis of nanoMOF-A (top), nanoMOF-B (middle), and nanoMOF-C (bottom) measured by TEM.
Figure S2. SEM images of nanoMOF-A (A), nanoMOF-B (B), nanoMOF-C (C), and polydisperse cubic nanoparticles of MOF-525 (D).

Scanning electron microscopy (SEM) was performed on a FEI Nova NanoSEM with a Through Lens detector in the secondary electrons mode at an accelerating voltage 5-10 kV. The samples for SEM were prepared by the deposition of dispersed nanoparticles in ethanol onto a silicon wafer chip. Prior the deposition, the nanoparticles were well dispersed using an ultrasonic bath.
Figure S3. Powder XRD patterns of nanoMOF-A (a) and nanoMOF-C (b) compared with the theoretical XRD pattern of PCN-222 (CCDC 893545; black bars).
Powder XRD was recorded using a PANalytical X’Pert PRO diffractometer in the transmission setup equipped with a conventional Cu X-ray tube (40 kV, 30 mA).

![Figure S3. Powder XRD patterns of nanoMOF-A (a) and nanoMOF-C (b) compared with the theoretical XRD pattern of PCN-222 (CCDC 893545; black bars). Powder XRD was recorded using a PANalytical X’Pert PRO diffractometer in the transmission setup equipped with a conventional Cu X-ray tube (40 kV, 30 mA).](image)

Figure S4. DLS size distribution of nanoMOF-A (top) and nanoMOF-C (bottom) in water dispersions at room temperature.

![Figure S4. DLS size distribution of nanoMOF-A (top) and nanoMOF-C (bottom) in water dispersions at room temperature.](image)
Figure S5: a) Liquid-state $^{13}$C NMR spectrum of 5,10,15,20-tetrakis(4-carboxyphenyl)porphyrin (TPPC) in DMSO-$d_6$ at room temperature. The lines were assigned to the corresponding carbon atoms as labeled in the schematic representation of TPPC molecule (b). The assignment of the $^{13}$C NMR spectrum was achieved by means of HSQC and HMBC $^1$H-$^{13}$C spectra. The peaks corresponding to the pyrrole carbons are broadened considerably probably as a result of the tautomeric proton exchange: the $\beta$ carbon atoms are located at 132 ppm and $\alpha$ carbon atoms are expected to resonate at around 150 ppm.

$^{13}$C NMR cross-polarization spectra under the magic angle spinning conditions (Figure 1B) were recorded using a Bruker Avance III HD spectrometer (Bruker BioSpin GmbH) operating at magnetic field of 11.75 T (500.5 MHz and 125.8 MHz for the $^1$H and $^{13}$C basic Larmor frequency, respectively). The sample diameter was 2.5 mm and the sample spinning frequency was 20 kHz. $^1$H 90 deg excitation pulse duration was 1.95 $\mu$s, the Hartmann-Hahn condition for $^1$H and $^{13}$C was matched at the amplitude of the transverse magnetic field of $\omega/2\pi = 78$ kHz, the optimal cross-polarization period was found to be 10 ms. SPINAL-64 was used for $^1$H decoupling during acquisition at the power level corresponding to the transverse field amplitude of 128 kHz. The recycle delay was set to 5 s, and about 40,000 transients were accumulated for each sample.
Figure S6. Nitrogen adsorption isotherms of nanoMOFs and microcrystalline PCN-222 at 77 K.

Figure S7. Pore size distribution calculated from nitrogen adsorption isotherms of nanoMOFs and microcrystalline PCN-222 presented in Figure S6.
Figure S8. Normalized UV-vis spectra of nanoMOF dispersions compared with the corresponding spectrum of monomeric TPPC, all in absolute ethanol.

![Normalized UV-vis spectra of nanoMOF dispersions compared with the corresponding spectrum of monomeric TPPC](image)

Figure S9. Normalized fluorescence emission spectra of nanoMOF dispersions and TPPC in ethanol. Excitation wavelength was 520 nm.

![Normalized fluorescence emission spectra of nanoMOF dispersions and TPPC in ethanol](image)
Figure S10. Kinetics of the triplet states of nanoMOF-A (top) and 5,10,15,20-tetrakis(4-sulfonatophenyl)porphyrin (middle) in oxygen-, air, and argon-saturated D$_2$O. Red lines are exponential fits to the experimental data. The Stern-Volmer plots of the triplet states quenching of 5,10,15,20-tetrakis(4-sulfonatophenyl)porphyrin (a) and nanoMOF-A (b) in D$_2$O (bottom). Excitation wavelength was 308 nm.

The transient absorption of the porphyrin triplet states was recorded on a laser kinetic spectrometer LKS 20 (Applied Photophysics, U.K.) equipped with a 150 W Xe lamp (Phillips) and R928 photomultiplier (Hamamatsu). The rate constants $k_{O2}$ of the triplet state quenching by oxygen were calculated using the Stern-Volmer equation: $1/\tau_T = 1/\tau_T^{Ar} + k_{O2} [O_2]$, where $\tau_T$ is the triplet state lifetime in oxygen- or air-saturated D$_2$O and $\tau_T^{Ar}$ is the lifetime in argon-saturated D$_2$O. The concentration of molecular oxygen is 0.28 mM in air-saturated water.
Figure S11. Kinetics of $O_2(^1\Delta_g)$ decay after excitation of nanoMOF-A by a 308 nm laser pulse in oxygen-saturated acetonitrile. Red line is the corresponding single exponential fit. Singlet oxygen has a long lifetime in acetonitrile, making the detection of $O_2(^1\Delta_g)$ more sensitive in this solvent than in ethanol or aqueous dispersions.

Figure S12. Comparison of $O_2(^1\Delta_g)$ luminescence intensities photogenerated by 5,10,15,20-tetrakis(4-sulfonatophenyl)porphyrin (a) and nanoMOF-A (b) adjusted to the same absorbance at the excitation wavelength of 308 nm in oxygen saturated D$_2$O.
Figure S13. Confocal microscopy analysis of nanoMOF-A (A, B, C), nanoMOF-B (D, E, F), nanoMOF-C (G, H, I) localization in HeLa cells after 4 h incubation; A, D, G) Confocal sections stained with membrane marker FITC-WGA (green); B, E, H) Fluorescence of nanoMOFs; C, F, I) Merging of the two panels on the left. Scale bars: 10 µm.
Figure S14. Flow cytometry histograms: A) HeLa cells incubated with nanoMOF-A for 10, 30, 60, and 120 min (from light green to dark green; red is the control), porphyrin concentration is 2 µM; B) HeLa cells incubated with 1, 2, or 4 µM nanoMOF-A for 120 min (from grey to green, dark grey color is the control).
Figure S15. Flow cytometry histograms: HeLa cells were incubated with nanoMOF-A (red), nanoMOF-B (green), and nanoMOF-C (blue) for 60 min (the control is in shadow color), porphyrin concentration is 2 µM.

Figure S16. Viability of HeLa cells treated with nanoMOF-B for various time intervals followed by 15 min irradiation (> 600 nm) and measured after next 24 h.
Figure S17. Stability of nanoMOF-C (left) and PCN-224 nanoparticles (average size = 55 nm, right) in the EMEM medium: Powder XRD patterns before (a) and after 4 h treatment (b).
Figure S18. Stability of nanoMOFs and PCN-224 in the EMEM medium: TEM micrographs of nanoMOF-A (top), nanoMOF-C (middle), and PCN-224 (bottom) before (left) and after 4 h treatment (right).
Figure S19. Flow cytometry histograms document the production of intracellular reactive oxygen species in the presence of nanoMOFs. HeLa cells were treated with nanoMOFs (2 μM) for 2 h, loaded with 10 μM 2’,7’-dichlorodihydrofluorescein diacetate for 10 min, followed by either incubation in dark (top) or 15 min irradiation with a 630 nm LED source at a power density of 9 J cm\(^{-2}\) (bottom). Fluorescein fluorescence was measured immediately after irradiation using fluorescence-assisted cell sorting analysis.

Dark experiment: Control (black), nanoMOF-A (red), nanoMOF-B (green), nanoMOF-C (blue).

After irradiation: Control (black), nanoMOF-A (red), nanoMOF-B (green), nanoMOF-C (blue).
Figure S20. Immediate phototoxicity of nanoMOF-A, nanoMOF-B, 5,10,15,20-tetrakis(4-carboxyphenyl)porphyrin (TPPC), and PCN-224 nanoparticles (average size = 55 nm) for HeLa cells. 2 h incubation, 15 min irradiation (> 600 nm).

![Figure S20](image1.png)

Figure S21. Phototoxicity of 4 µM nanoMOF-A and 5,10,15,20-tetrakis(4-carboxyphenyl)porphyrin (TPPC) for HeLa cells based on flow cytometry analysis: the percentage of apoptotic, necrotic, and normal cells 1 h after 15 min irradiation (> 600 nm).

![Figure S21](image2.png)