

Supplementary Materials: Effectiveness and Compatibility of Nanoparticle Based Multifunctional Coatings on Natural and Man-Made Stones

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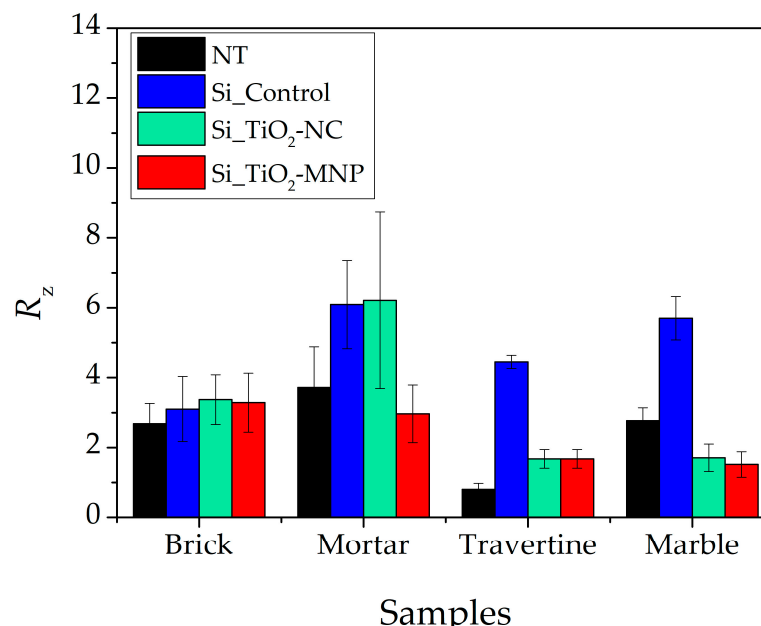


Figure S1. Comparison of average R_z measured before and after treatment for the different studied materials. NT: untreated; Si_Control: coating without nanoparticles; Si_TiO₂-NC: coating with TiO₂ nanoparticles and loaded silica nanocapsules; Si_TiO₂-MNP: coating with TiO₂ nanoparticles and loaded silica mesoporous nanoparticles.

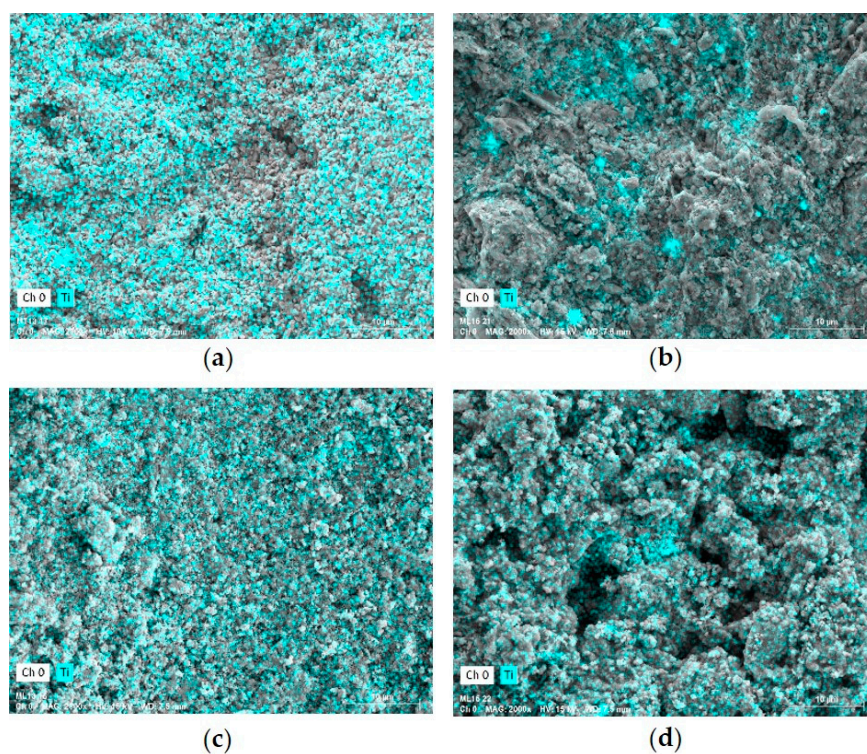


Figure S2. Ti distribution resulting from EDS-XFR mapping: (a) Si₂TiO₂-NC on brick, (b) Si₂TiO₂-MNP on brick, (c) Si₂TiO₂-NC on mortar and (d) Si-TiO₂-MNP on mortar.

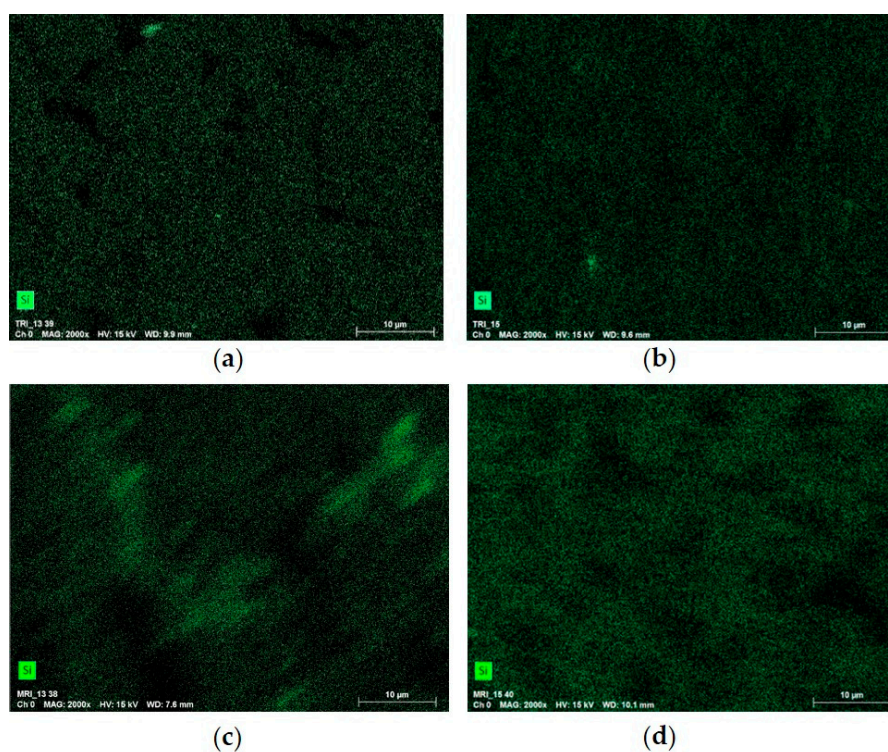


Figure S3. Si distribution resulting from EDS-XFR mapping: (a) Si₂TiO₂-NC on travertine, (b) Si₂TiO₂-MNP on travertine, (c) Si₂TiO₂-NC on Carrara marble and (d) Si-TiO₂-MNP on Carrara marble.

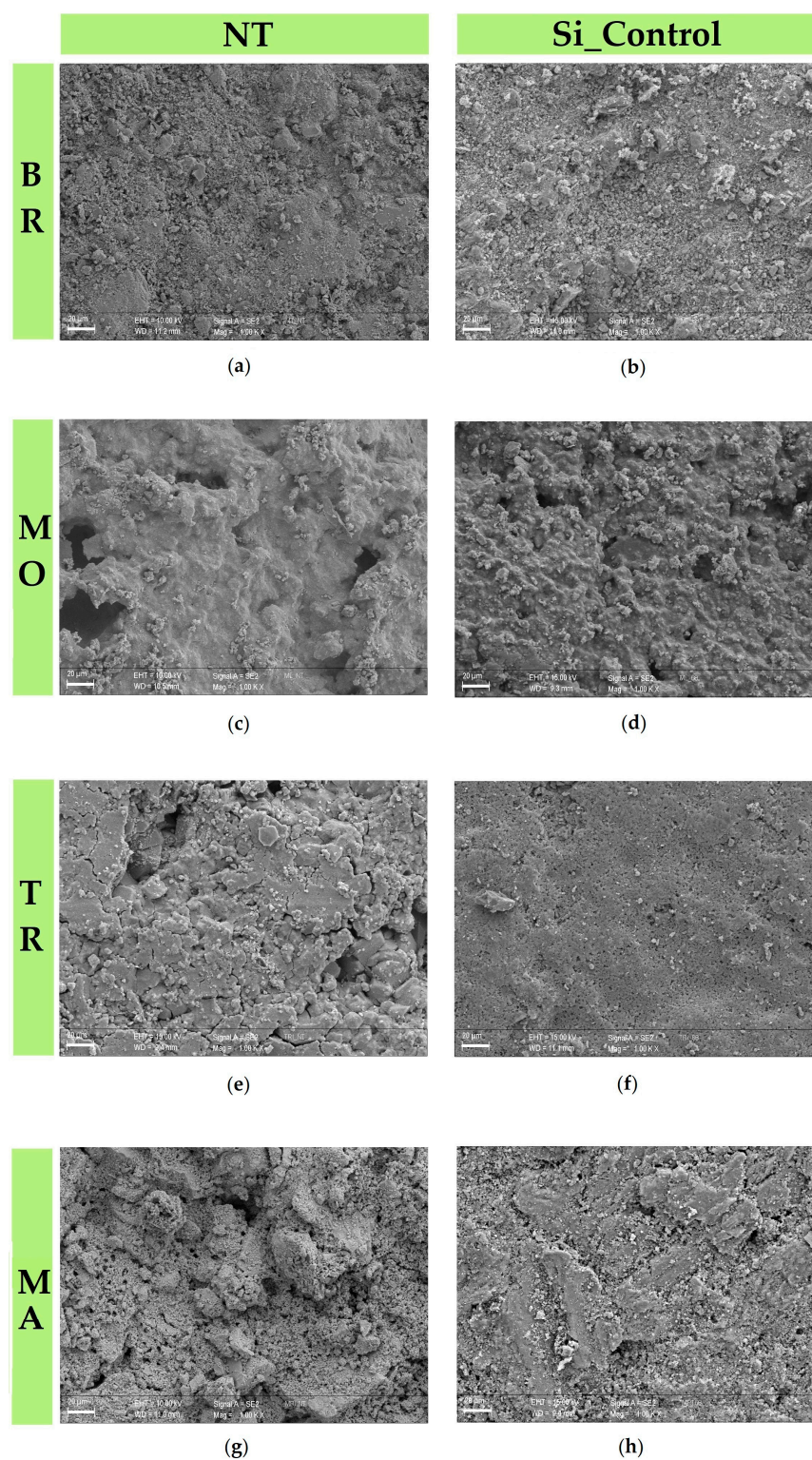


Figure S4. SEM micrographs (1000×) of: Brick (BR) (a,b), mortar (MO) (c,d), travertine (TR) (e,f) and Carrara marble (MA) (g,h). NT: untreated; Si_Control, coating without nanoparticles.

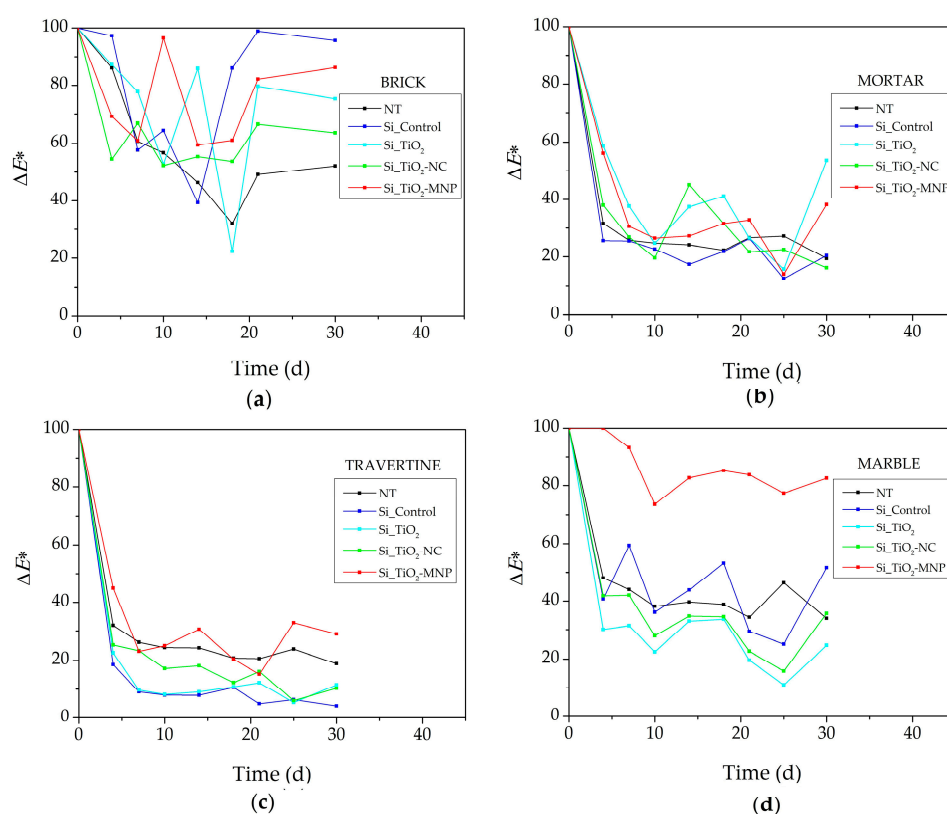


Figure S5. Evolution of total colour difference (ΔE^*) for samples irradiated in-situ with natural solar light: (a) brick, (b) mortar, (c) travertine and (d) Carrara marble. NT: untreated; Si_Control: coating without nanoparticles; Si_TiO₂: coating with TiO₂ nanoparticles; Si_TiO₂-NC: coating with TiO₂ nanoparticles and loaded silica nanocapsules; Si_TiO₂-MNP: coating with TiO₂ nanoparticles and loaded silica mesoporous nanoparticles.

Table S1. Amount of applied product calculated by weighting the specimens before and after the application of coatings.

Sample	Amount of applied product (kg/m ²)		
	Si_Control	Si_TiO ₂ -NC	Si_TiO ₂ -MNP
Brick	0.62 ± 0.03	0.56 ± 0.09	0.61 ± 0.01
Mortar	0.70 ± 0.12	0.95 ± 0.12	1.02 ± 0.14
Travertine	0.06 ± 0.02	0.18 ± 0.03	0.13 ± 0.04
Carrara Marble	0.11 ± 0.03	0.23 ± 0.02	0.23 ± 0.03

Si_Control: coating without nanoparticles; Si_TiO₂-NC: coating with TiO₂ nanoparticles and loaded silica nanocapsules; Si_TiO₂-MNP: coating with TiO₂ nanoparticles and loaded silica mesoporous nanoparticles.

Table S2. Amount of dry matter retained after one week from the application for all samples treated with all coatings.

Sample	Quantity of dry matter retained (kg/m ²)		
	Si_Control	Si_TiO ₂ -NC	Si_TiO ₂ -MNP
Brick	0.017 ± 0.001	0.033 ± 0.006	0.011 ± 0.000
Mortar	0.005 ± 0.001	0.020 ± 0.002	0.117 ± 0.005
Travertine	0.003 ± 0.002	0.005 ± 0.001	0.002 ± 0.001
Carrara Marble	0.003 ± 0.001	0.002 ± 0.001	0.001 ± 0.002

Table S3. Colorimetric Coordinates L^* , a^* and b^* generated by all coatings on all stone samples.

Sample	Colour data	Treatment					
		NT	Si_Control	NT	Si_TiO ₂ -NC	NT	Si_TiO ₂ -MNP
BR	L^*	59.8 ± 2.1	59.7 ± 1.9	59.3 ± 0.9	60.1 ± 1.1	59.6 ± 1.5	60.2 ± 1.5
	a^*	14.4 ± 0.9	14.3 ± 0.5	14.9 ± 0.5	14.0 ± 0.5	14.9 ± 0.4	14.3 ± 0.3
	b^*	25.3 ± 0.8	24.9 ± 0.7	25.5 ± 0.6	22.8 ± 0.6	25.2 ± 0.6	22.9 ± 0.6
MO	L^*	74.2 ± 2.7	73.3 ± 2.6	73.5 ± 0.9	73.5 ± 1.2	73.8 ± 0.9	73.1 ± 1.6
	a^*	-0.2 ± 0.2	-0.7 ± 0.2	0.1 ± 0.2	0.2 ± 0.2	-0.1 ± 0.1	0.2 ± 0.1
	b^*	11.1 ± 0.8	11.4 ± 0.6	10.2 ± 0.5	10.5 ± 0.5	9.9 ± 0.4	10.3 ± 0.4
TR	L^*	85.0 ± 2.8	85.3 ± 2.4	86.2 ± 1.8	86.4 ± 2.0	86.4 ± 4.0	85.8 ± 3.6
	a^*	-0.9 ± 0.2	-0.8 ± 0.18	-0.3 ± 0.1	-0.4 ± 0.2	-0.4 ± 0.2	-0.4 ± 0.2
	b^*	2.2 ± 0.7	1.9 ± 0.6	1.3 ± 0.8	1.5 ± 0.7	1.5 ± 1.3	1.7 ± 1.2
MA	L^*	91.8 ± 0.7	92.3 ± 0.8	91.6 ± 1.3	93.9 ± 1.2	91.4 ± 0.9	93.7 ± 0.9
	a^*	-0.8 ± 0.01	-0.7 ± 0.01	-0.3 ± 1.4	-0.3 ± 0.1	-0.3 ± 0.1	-0.2 ± 0.1
	b^*	2.4 ± 0.4	2.3 ± 0.4	1.4 ± 0.5	1.3 ± 0.6	1.5 ± 0.3	1.3 ± 0.2

BR: brick; MO: mortar; TR: travertine; MA: Carrara marble; NT: untreated; Si_Control: coating without nanoparticles; Si_TiO₂-NC: coating with TiO₂ nanoparticles and loaded silica nanocapsules; Si_TiO₂-MNP: coating with TiO₂ nanoparticles and loaded silica mesoporous nanoparticles.