Water Repellent Treatment of Building Materials
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Strongly Adhering Ultrathin Layers on Inorganic Surfaces Obtained by Activation of Silicon-Hydrogen Bonds*

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1 Formation of a monolayer by immersion

Inorganic surfaces such as metals, metal oxides, metal alloys, glasses, silicon wafers, ceramics, rock, and artificial stone such as concrete can be modified with siloxanes by adsorption from solution [1,2]. The principle of immersion is shown in Figure 1. The adsorbed compounds, which initially contained silicon-hydrogen bonds, form strongly adhering layers on these different inorganic surfaces, in the presence of substances which activate silicon-hydrogen bonds and which transfer the activated species to the surface only [1,2]. The layer thickness is in the range of a monolayer [1,2].

*. This is a compact version of this contributon. The full length paper will be published in "Int. J. Restoration and Protection of Monuments"

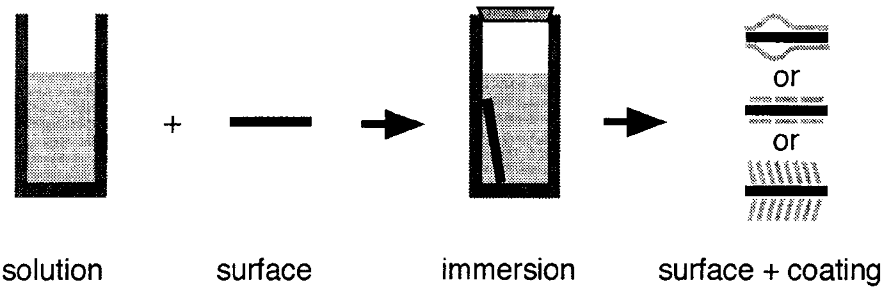

Figure 1: Fomation of ultrathin layers by adsorption from solution.

2 Contact angle measurement

PDMS(H) (see Figure 2), for example builds strongly bound polymeric sur-

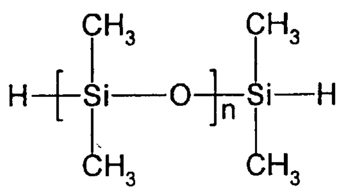

Figure 2: Structure of hydride-terminated poly(dimethylsiloxane) (PDMS(H)).

face layers on gold, aluminum, titanium, chromium, iron, copper, steel, glass, silicon wafer, aluminum oxide ceramic, clay, rock, and concrete in the presence of *cis*-dichlorobis(styrene)platinum(II). This has been made evident by contact angle measurements. A schematic representation is given in Fig. 3 and measured contact angles are given in Tab. 1 [1,2]. The strongly adhering highly water-repellent layers give hope for a new generation of hydrophobing agents, e.g., for the preservation of building materials in general and cultural heritage in particular. The water repellent treatment of concrete, as an example for a porous material, has been studied concerning penetration depth, suction profiles, and reduction of water absorption. The results will be presented in detail elsewhere.

Table 1: Advancing contact angles of water of strongly adhering monolayers of PDMS(H) on different inorganic surfaces [1,2].

Surface	Contact Angle [°]
gold[1]	115
aluminum[1]	113
titanium[2]	113
chromium[2]	113
iron[1]	108
copper[1]	115
aluminum[3]	120 - 130
iron[3]	111 - 123
copper[3]	113
V2A steel[3]	115
glass[3]	100
silicon wafer[3]	105
aluminum oxide ceramic[3]	118
clay[3]	125 -138
stone from Lecce[4]	115 - 125
sand stone from Bern[4]	108 - 131
coloured sand stone[4]	106 - 116
red sand stone[4]	115 - 127
concrete[3]	114 - 132

1:On thermally vapour-deposited metal films (silicon wafer + 6 nm chromium + 200 nm metal).
2:On thermally vapour-deposited metal films (silicon wafer + 200 nm metal).
3:On plates.
4:On stone cubes.

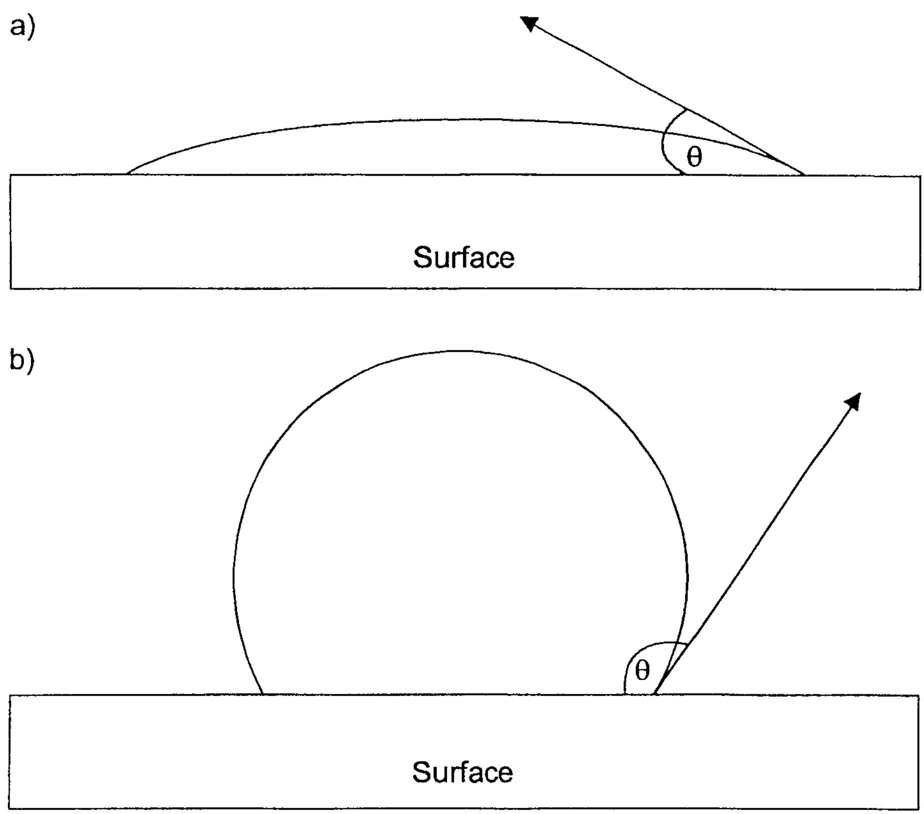

Figure 3: Advancing contact angle θ of water a) before and b) after adsorption of PDMS(H) in the presence of *cis*-dichlorobis(styrene)platinum(II)

3 Further characterization

Further characterizations of the strongly adhering highly hydrophobic layers have been performed on gold, aluminum, titanium, chromium, iron, and copper, e.g., by IR spectroscopy at grazing incidence reflection [1,2]. Signals arising from PDMS(H) are observed only in the presence of *cis*-dichlorobis(styrene)platinum(II) (see Table 2 and Figure 4) [1,2].

Table 2: Frequencies [cm^{-1}] in IR-spectra of strongly adhering monolayers of PDMS(H) on thermally evaporated metal films and of bulk PDMS(H) [1,2].

	$\nu_{as(CH3)}$	$\nu_{s(CH3)}$	$\delta_{as(CH3)}$	$\delta_{s(CH3)}$	$\nu_{as(Si\text{-}O\text{-}Si)}$		ν(Si-C)	$\rho(CH_3)$
Au	2964		1413	1266	1112		866	819
Al	2964	2907	1415	1265	1111	1034		819
Ti	2965		1415	1265	1112	1043	861	820
Cr	2964		1412	1265	1111		865	819
Fe	2957	2900	1415	1263	1107		866	816
Cu	2964	2904	1407	1264	1105	1029	865	810
PDMS(H)	2963	2905	1413	1264	1105	1029	865	801

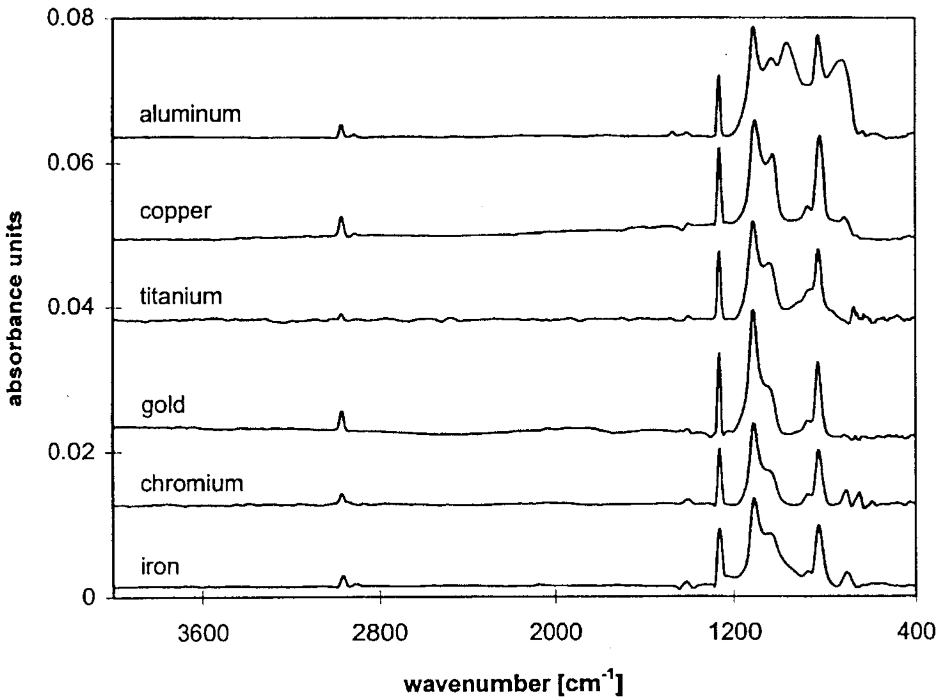

Figure 4: IR-spectra at grazing incidence reflection of strongly adhering monolayers of PDMS(H) on thermally evaporated metal surfaces [1,2]

4 Conclusions

It has been shown that inorganic surfaces can be created by ultra thin layers by immersion. The applicability of this procedure to building materials such as natural stone, clay brick or concrete is now under investigation.

References

[1] Hirayama, M.; Dissertation No. 12333, ETH Zürich, (1997)
[2] Hirayama, M.; Caseri, W.R.; Suter, U.W.; Patent Application PCT/CH 98/002200.