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Plasma technologies application for building materials surface modification

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Abstract. Low temperature arc plasma was used to process building surface materials, such as silicate brick, sand lime brick, concrete and wood. It was shown that building surface materials modification with low temperature plasma positively affects frost resistance, water permeability and chemical resistance with high adhesion strength. Short time plasma processing is rather economical than traditional processing thermic methods. Plasma processing makes wood surface uniquely waterproof and gives high operational properties, dimensional and geometrical stability. It also increases compression resistance and decreases inner tensions level in material.

1. Introduction

The problem of providing durability for buildings and constructions in difficult climatic conditions mostly depends on defending coating quality. Defending coatings prevent moisture penetration and protect buildings from UV, little air-bone dust particles, industrial steam, acid rains, and strengthen concrete or brick surface. Therefore structural elements of buildings and constructions are protected with special coatings.

In that reason it is necessary to find new methods of making defending coatings that meet requirements of durability and colour expression. The perspective solution of this problem lies in today’s development and production of new building materials that have qualitatively new characteristics with the use of untraditional high technologies based on application of electrochemical, plasma, laser, radiation, electro-impulse, ultrasound and other highly effective material treatment methods for significant improvement of its properties and thus providing flow of non-equilibrium processes. Of great interest are studies [1] and practical realization of building materials and products surface thermic treatment methods. The most perspective method of building materials processing is plasma method.

There are several main building materials mostly used in construction industry. They are different types of concrete (cellular, heavy), kilns materials (ceramic brick), autoclaved material (sand-lime brick). The article studies defending-decorating coatings on building materials created with low temperature plasma.

2. Experiments

Materials

Substrate materials were cellular concrete B10-B15, heavy concrete, ceramic brick and silicate sand-lime brick, № 200-250. Decorative coatings were made from pastes of different compositions of binder-liquid sodium glass and filler - fine glass, granite or quartz sand. Coatings on wood were also investigated.

Processing.

Concrete products covered by paste were dried and processed with plasma (temperature 3000 - 5000°C, at a speed of 0,045 - 0,13 m/sec, power 40 - 55 kW) [2,4] as direct surface plasma fusion of product gives high porosity and decreases coating quality. Vitreous film has thickness of 0,15 – 0,4 mm and high adhesion strength.

For making protective-decorative coating on ceramic bricks by plasma deposition method powder particles were injected into plasma jet, melted, then achieved brick surface and got fixed on it. Figure 1 shows the scheme of the research facility for protective decorative coating of wood.

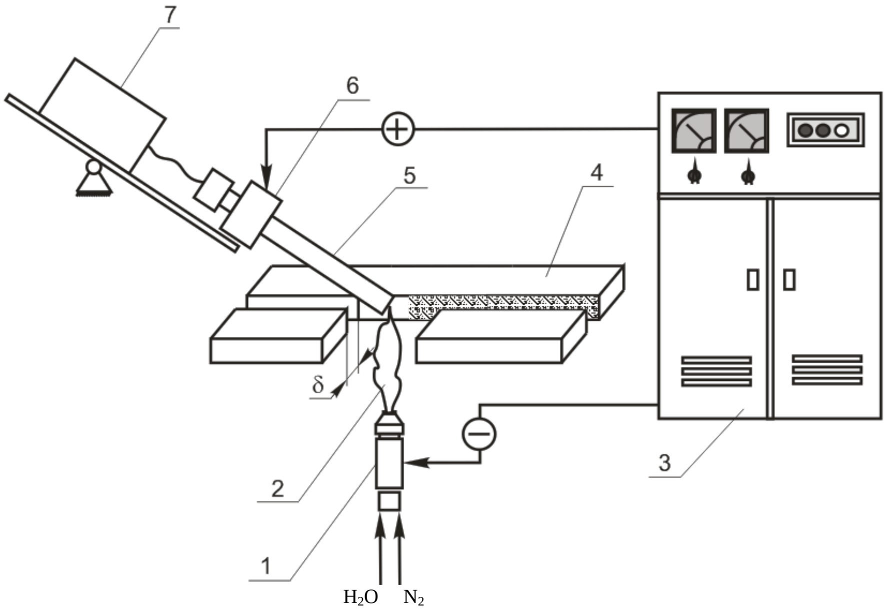


Figure 1. Facility for plasma processing of brick and wood surfaces: 1 – cathode; 2 – plasma jet; 3 – power source; 4 – sample; 5 – graphite anode; 6 – water-cooled tinsel-lead; 7 – electric drive of electrode.

The unit consists constructively of plasma generator 1, graphite anode 5 and DC power supply. Plasma generator with external anode is situated in the middle part of the conveyer, cathode is on the conveyer axis and located vertically near the table and with up oriented nozzle. External anode – graphite cylinder with diameter 70 mm, is fixed at an angle of 20° to the horizontal. Electric drive spins and moves graphite cylinder. For plasma cord generation graphite anode closes with plasmatron at a distance necessary for main plasma arc appearance. Conveyer slides provide constant gap (δ=15-20 mm) between oppositional located wood or brick samples during processing.

Properties study

Concrete quality is studied in accordance with state standard 25485-89. Coatings were tested for chemical stability, frost resistance and water permeability. Surface microstructure of fused building materials is studied with microscope JEOL JEM-2100 (Japan).

3. Results and discussions

Concretes

Test results [3] showed that plasma coating chemical resistance is significantly higher than that of base chemical resistance. Material frost resistance that mainly defines durability is satisfactory. Water permeability of plasma treated surface reduced by 1,5 – 2 times, open porosity also decreased several times. That allows apply walling from concrete with plasma coating based on pastes with different fillers for buildings that operate not only at normal temperature and humidity conditions, but also at mode of high humidity and aggressive actions.

At heavy concrete surface fusion there is no formation of uniform coating. Large fractions of gravel contained in heavy concrete and high temperature treatment causes thermal stress leading to cracking of the filler. In this regard, concrete surfaces finishing quality could be achieved by previous covering with concrete with porous aggregates. As porous aggregates in [2] expanded clay sand was used. At fusion of concrete with expanded clay sand the surface became relief and of dark green color. For decorating properties improvement of the finishing cover wastes of glass production, red and silicate brick wastes, porcelain chips were used. We found that the above mentioned additives infused into concrete surface layer defend it from calcium hydro silicates dehydration at plasma treatment and allows forming finishing layers of different textures and color on concrete. Simultaneously, there is a significant improvement of adhesion of the fused decorative layer with base. Vitreous film formed on concrete surface under plasma influence defends it from moisture, decreasing water absorption.

Bricks

At melting ceramic brick is forming finishing layer, its color being from gray to black. The surface texture depends on melting mode. Vitreous layer has high strength and high adhesion with substrate. For decorating film formation pastes deposition on brick surface is needed. Fusion begins after preliminary surface drying till residual moisture of about 10%.

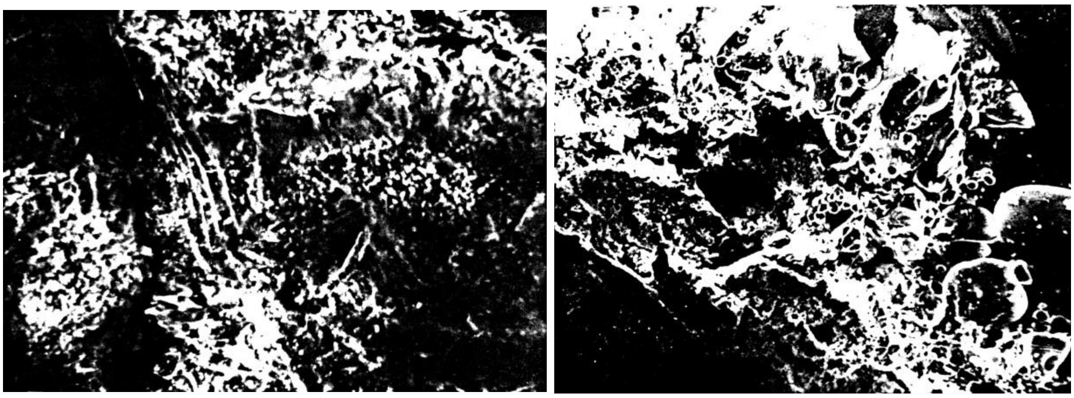
The study [2] describes the plasma treatment influence on technological parameters of exploitative properties of ceramic brick with fused surface. The fused coating adhesion and frost resistance depend on fused layer thickness. Coating thickness on the surface layer of ceramic significantly depends on plasma jet temperature and processing time. The fused coating thickness increasing leads to adhesion decreasing because of stress between glass and ceramic resulting in cracking of surface layer and decreasing of products frost resistance.

After analysis of [1-3] we can note that coating adhesion as its most important parameter and frost resistance depend on plasma torch power and treatment speed.

Studies results [1,2] show that ceramic products with surface melted by plasma jet quite satisfy the requirements for building materials and at the same time have better outward appearance, lower water absorption and higher chemical resistance in accordance with state standard 530-2012.

Plasma interaction with silicate brick surface studies [2] allow applying high concentrated thermal jets to defend decorating coatings formation on building materials. Plasma treatment of silicate products surface leads to vitreous film appearance, its color depending on substrate composition. The product surface pretreatment with different chemical compound solutions results in vitreous color films formation. At plasma treatment on products surface high temperature processes occur. As pigments only heat-resistant compounds could be used. Figure 2 shows microstructure melted silicate brick.

At depth of 1 mm below the surface where temperature is about 600°C stable Calcium and Quartz silicates are forming. Results of electron microscopy showed identity of Calcium silicate structure in transition layer and Calcium hydro silicates. The [1] described a process of colored coatings formation by pretreatment with solutions of metal salts (i.e. cobalt, copper, iron, chromium). Pretreatment of silicate products with metal salts aqueous solutions provides not only coloring of vitreous films, but also adhesion increasing because of lower melt formation temperature and viscosity. Test results of silicate brick, ceramic brick, concretes and other products (chemical and frost resistance) showed that coating adhesion before and after test changed insignificantly, that indicates vitality and durability of products with defending decorating coating.



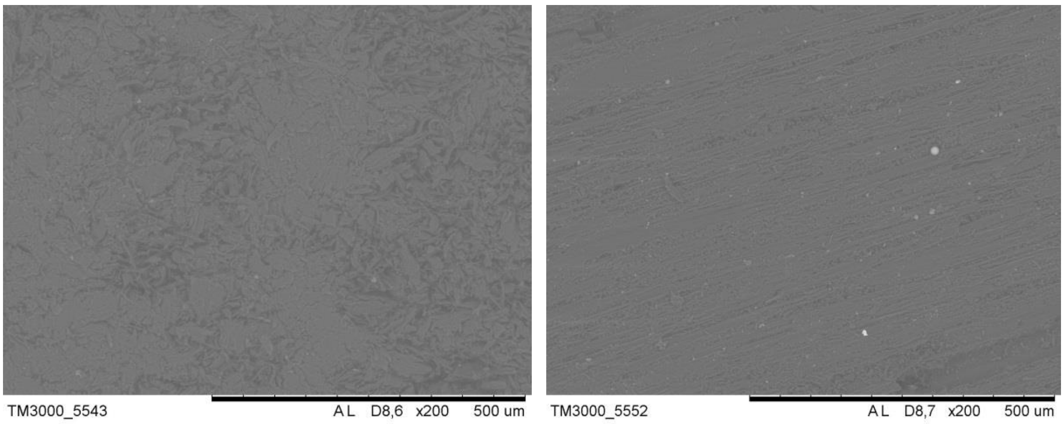
a) b)

Figure 2. Microstructure melted silicate brick: a) vitreous film; b) transition layer.

Wood

One of the priority areas of low temperature application is wood surface treatment for thick functional (hydrophobic) film formation that improves material physical properties and does not pass the liquid.

After wood plasma treatment experiments [5-7] samples surface changed colour into dark, golden brown. Wherein wood texture was clearly seen, growth rings became more visible. It is very useful at using samples in decorating. Moreover thermo treatment leads to significant changes in wood structure (Figures 3 and 4). While heating its structure evaporates resins, waxes, fats, phenols, glucose and hemicellulose components. As a result wood becomes stable to rot, mildew, defeat of various microorganisms and fungi. Material biological resistance increases. Usual drying can't achieve these effects [8].



a) b)

Figure 3. Wood surface morphology: a) before and b) after plasma processing

Influence of processing regime on colour of wood surface presented in Table 1.

Figure 4. Block-house appearance: a) before and b) after plasma processing

Table 1. Parameters of plasma processing and characteristics of wood surface

Plasmatron power, kW	I, A	U, V	Heat flux, W/m^2	Processing time, sec	Surface characteristic	Surface colour
20,8	130	160	$1{,}1 \cdot 10^6$	3,0	Incomplete combustion	Light brown
23,8	140	170	$1{,}5 \cdot 10^6$	2,0	Partly incomplete combustion	Light brown
35,2	200	176	$1{,}8 \cdot 10^6$	1,0	Uniform firing, depth 1 mm	Light brown
35,2	200	176	$1{,}8 \cdot 10^6$	2,0	Uniform firing, depth 1 mm	Golden brown
35,2	200	176	$1{,}8 \cdot 10^6$	3,0	Partly burnout	Dark brown
56	400	140	$2{,}6 \cdot 10^6$	1,0	Uniform firing, depth 2 mm	Golden brown
56	400	140	$2{,}6 \cdot 10^6$	2,0	Uniform firing, depth 2 mm	Dark brown
58,8	420	140	$2{,}8 \cdot 10^6$	1,0	Partly burnout	Dark brown
58,8	420	140	$2{,}8 \cdot 10^6$	2,0	Burnout	Black
59,4	440	135	$3{,}0 \cdot 10^6$	1,0	Burnout	Black

At the next stage of the experiments water permeability of samples before and after plasma treatment was studied. Water adsorption by wood was measured every 2 hours. Results are shown in Figure 5.

4. Conclusion

Analysis of the experiments allows us to make a conclusion that wood surface plasma treatment technology through little affecting time on product is rather economic as compared with traditional methods of thermal treatment. After processing the surface is more resistant to fungi, mildew and other wood defects [9]. The reason is in absence of their nutrient medium. Furthermore, wood samples after thermal treatment adsorb water several times slower than initial samples. Therefore wood threated by electro plasma technology could be used in climate with high humidity. Plasma treatment allows impart unique water resistant and exploitative properties, high dimensional stability, herewith increased wood compression stability and decreased level of internal stresses.

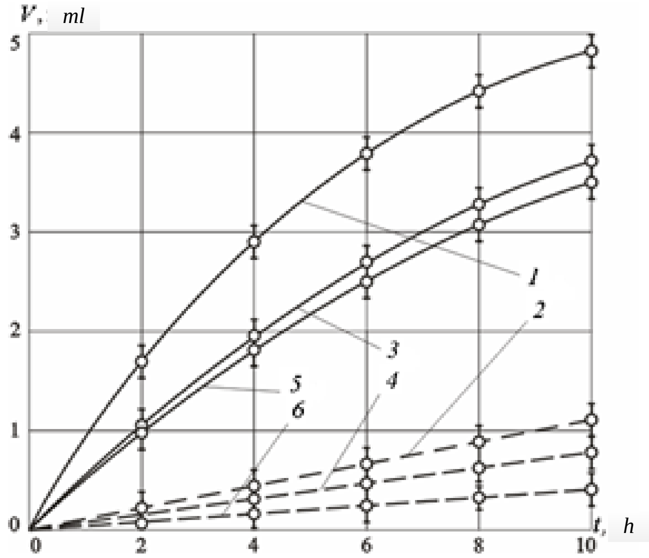


Figure 5. Water consumption (adsorption) in time. 1, 3, 5 – aspen, fir, pine before low temperature plasma treatment, 2, 4, 6 – aspen, fir, pine after low temperature plasma treatment.

References

[1] Volokitin G.G., Skripnikova N.K., Shilyayev A.M., Petrochenko V.V. Plazmennyye tekhnologii v stroitelstve [Plasma technologies in construction]. Tomsk : Vestnik of Tomsk State University of Architecture and Building. 2005. 291 p. (rus)

[2] Volokitin G.G., Lysak A.S., Anshakov A.S., Skripnikova N.K. Plazmennaya obrabotka materialov [Plasma treatment of materials]. Tomsk : Vestnik of Tomsk State University of Architecture and Building. 2009. 200 p. (rus)

[3] Anshakov A.S., Volokitin G.G., Volokitin O.G., Skripnikova N.K. Elektrotehnologicheskie ustanovki dlya plazmenno-termicheskoi obrabotki materialov [Electro-technological plants for materials plasma-thermo processing] Tomsk : Vestnik of Tomsk State University of Architecture and Building. 2014. 126 p. (rus)

[4] Bessmertnyi V.S. *Nauchnye osnovy formirovaniya potrebitelskih svoistv izdelii iz keramiki i stekla, obrabotannyh fakelom nizkotemperaturnoi plazmy [Scientific bases formation of consumer properties of ceramic and glass products processed by low temperature plasma torch]. Extended abstract of PhD dissertation*. Moscow University of Consumer Cooperatives, Moscow, 2004. (rus)

[5] Volokitin O.G., Tsvetkov N.A., Volokitin G.G. Perspektivy tekhnologii sozdaniya zashchitnodekorativnykh pokrytiy na poverkhnosti drevesiny s ispolzovaniyem plazmennoy tekhnologii [Perspectives of protective-decorative coating of wood surfaces using plasma technology]. Vestnik of Tomsk State University of Architecture and Building. 2012. No.1. Pp.112-116. (rus)

[6] Volokitin O.G. Plasma process modeling of wood surfaces / O.G. Volokitin, G.G. Volokitin, V.V. Shekhovcov, E.A. Maslov, N.V. Malyuga. // Vestnik TSUAB. 2013. p. 99-105. (rus)

[7] Volokitin O.G., Tsvetkov N.A., Volokitin G.G., Cherkashina N.A., RF Patent No. 2 484 951, Byull. Izobret., No. 10 (2002).

[8] Chukhchin D.G. *Resursosberegayushaya pererabotka drevesiny s ispolzovaniem plazmokhimicheskoi tehnologii [Resource saving wood processing using plasma chemical technology]*. PhD dissertation. Arkhangelsk State Technical University, Arkhangelsk, 1998. (rus)

[9] Onegin V.I., Udalov Y.P., Korsakov G.S., Lukin V.G. Plazmokhimicheskaya obrabotka poverkhnosti drevesiny dlya uluchsheniya ee rezonansnykh svoistv [Plasma chemical processing of wood surface for improvement its resonance properties] // Moscow: VINITI, 28.04.97, № 1414-B97, 1997, 10 p. (rus)