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Improvement of the surface state of a sandblasted glass by deposing a thin layer of SiO_2 using sol-gel technique

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1. INTRODUCTION

In Sahara, sandstorms are responsible for the surface degradation of a great number of objects in particular brittle materials such as ceramics and glasses. In the case of glass for example, impacts induced by sand particles on the surface causes a more or less severe damage. Generally, there is formation of surface microcracks, similar to those induced by Vickers indentation. When the sandstorms duration increases, it produces erosion that leads to the formation of damaged zones. This latter greatly reduces the optical transmission by scattering the incident light.

Previous works [1,2] have shown that the glass surface state plays an important role in the various uses of glass sheets (vehicles windshields, planes sensors, various glazing, . . .), because it affects their mechanical and physical properties [2]. In most applications, the glass surface is exposed to a variety of external aggressive conditions such as corrosion, chemical reactions and mechanical damage. Ruff and Wiederhorn [3], Hutchings [4] and other authors have reported that the erosion of brittle materials, such as glasses, is affected by many factors: the properties of incident particles (i.e. size, shape, density, hardness and fracture toughness); the properties of target materials (i.e. hardness, fracture toughness and surface state), and test conditions (i.e. impact velocity, impact angle and temperature). During sandstorms, all these different parameters are involved at the same time and with a very randomly manner (wide range of grains size, shape of the grains highly variable, variable velocities during the same storm, variable impact angles...). This makes the erosion process very complex. These parameters are governed by the winds turbulence recorded at ground level. Indeed, the presence of dunes with variable sizes or sometimes habitations leads to random blasts of wind.

Different techniques have been proposed to reduce the surface roughness of glasses. Among these techniques, one can include [5]: mechanical polishing, fire polishing, chemical polishing by HF acid. Coating techniques were also deposited on glass and ceramics (polymer layers, metal oxides) [6].

2. EXPERIMENTAL PROCEDURE

The adopted procedure is first to simulate in the laboratory, erosion tests by projection of sand particles on the surface of a soda-lime glass. Glass samples are tested in their as-received state, without treatments. A sand blower apparatus is used to carry out the tests. The sandblasting conditions are fixed as follow: variable projected sand masses (10–150 g), fixed impact angle (90°) and velocity of the particles flux (20 m/s). The sand used as projectiles comes from the region of Ouargla (Sahara). In order to correct the surface defects generated by sandblasting, thin transparent layers of SiO_2 were deposited for correcting surface defects and increasing the optical transmission, using sol-gel technique. For this purpose, different precursors (tetraethylorthosilicate TEOS and methyltriethoxysilane MTES) and experimental protocols were used.

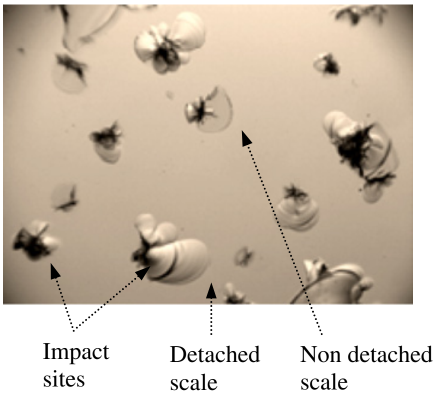

Figure 1. Micrograph showing typical defects induced by projection of 150 g of sand on glass surface (x120).

3. RESULTS

Microscopic observations of the sandblasted surfaces show that when the projected sand masses increase, the defects number increases gradually. Consequently, there is first a formation of single impacts randomly distributed on the surface. In the most cases, there is formation of impact site (crater) and around some scales. Figure 1 shows some details of defects formed on the glass surface eroded with 150 g of sand particles. It is observed that the surface defects vary in size and are randomly distributed over the entire surface. Major defects are accompanied by the formation of well developed scales. We can clearly see that the small defects contain small scales which are often not detached. In all cases, the formation of scales favors the diffusion of incident light.

By increasing the sand masses, there is interaction between single defects which leads to local damaged

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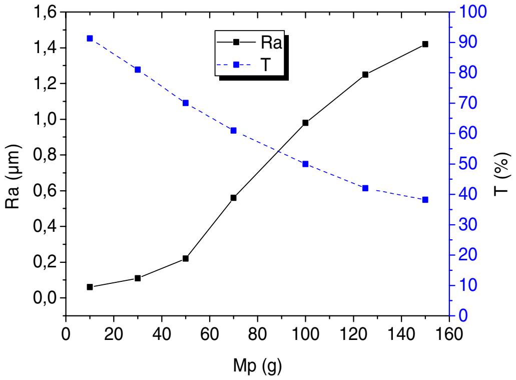

Figure 2. Variations Ra and T versus sand masses.

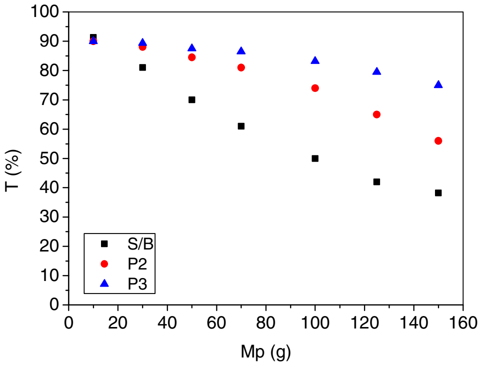

Figure 3. Variation of the transmission versus the sand masses for sandblasted and covered samples using different protocols.

zones. For large sand masses (150 g and more), these damaged zones tend to cover the entire surface exposed to sandblasting. It is evident that the optical transmission will be reduced strongly by these defects, in particular by light scattering.

Figure 2 shows the variations of optical transmission (T) and roughness (R_a^{max}) versus the projected sand masses. The measured optical transmission of as-received samples (without sandblasting) is 91.3%. After projection of 150 g of sand, it drops regularly to 38.2%. At the same time, the roughness increases sharply up to 1.42 μm.

To cover the sandblasting defects and then to restore the optical transmission, transparent layers of SiO_2 were deposited by sol-gel method using dip-coating technique [7]. Initially, the molar ratio between the precursor TEOS (tetraethylorthosilicate) and isopropanol alcohol was successively chosen equal to 1/5, 1/10 and 1/20. This protocol (called **P1**) gives films too thin, of about 280–300 nm. This thickness is not sufficient to cover the defects of the sandblasted samples whose maximum roughness R_a^{max} reaches 1.42 μm. Subsequently, we changed the first solution by adding a second precursor which is methyltriethoxysilane (MTES). This protocol (named **P2**) allowed increasing the thickness of the deposited layer up to 1.71 μm. Thus, a significant improvement in transmission is observed. For example in the case of the most unfavorable sandblasting ($\alpha = 90°$ and Mp = 150 g), transmission is T = 38.2%, whereas with a deposition of one layer of SiO_2 using the second protocol, the transmission reaches a value of 55%. We consider that this improvement is still insufficient. To further improve the transmission, we have added to the initial precursors (TEOS and MTES) a colloidal suspension of SiO_2 nanoparticles (Ludox 40%) in order to increase the thickness of the deposited layer. This third protocol is named **P3**. The mean thickness measured has reached the value of 2.32 μm. A remarkable improvement was observed on the transmission spectra of all sandblasted and recovered samples. The optical transmission was significantly increased compared to the previous cases (figure 3). It changes from 38.2% for the sandblasted state ($\alpha = 90°$, Mp = 150 g) to 57.4% using protocol P1, to 66.2% using protocol P2, to 73.6% using protocol P3.

Table 1. Some characteristics of SiO_2 layers for Mp = 150 g.

State	As-R	S/B	P1	P2	P3
x (μm)	–	–	0.28	1.71	2.31
I_R	1.48	–	–	1.43	1.46
T (%)	91.3	38.2	57.4	66.2	73.6
HV (GPa)	5.65	–	–	6.11	6.25

All coated samples were subjected to annealing at 500 °C for one hour in order to densify SiO_2 layers.

Some characteristics of SiO_2 layers are summarized in table 1 for as-received state (As-R), sandblasted (S/B) and covered using different protocols (P1, P2, P3). (x = layer thickness; I_R = refractive index, T = Transmittance).

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