http://dx.doi.org/10.35596/1729-7648-2019-125-7-107-112

Оригинальная статья
Original paper

UDC 533.9.03

MANAGING THE SURFACE PROPERTIES OF MATERIALS OF DISPLAY TECHNOLOGY BY MEANS OF TREATMENT IN ATMOSPHERIC DISCHARGE PLASMA

YULIYA V. ZAPOROZHCHENKO, DMITRY A. KOTOV, ALEXANDER V. AKSYUCHITS, ANATOLY N. OSIPOV, SERGEI V. PACEEV

Belarusian State University of Informatics and Radioelectronics, Minsk, Republic of Belarus

Submitted 19 November 2019

Abstract. The results of research the surface of single-crystal silicon, glass, and stainless steel after processing in a plasma at atmospheric pressure are presented. It has been experimentally proved that after processing, the adhesive properties of the surface of materials are significantly improved.

Keywords: monocrystalline silicon, glass, stainless steel, processing, atmospheric plasma, surface properties.

Conflict of interests. The authors declare no conflict of interests.

For citation. Zaporozhchenko Y.V., Kotov D.A., Aksyuchits A.V., Osipov A.N., Paceev S.V. Managing the surface properties of materials of display technology by means of treatment in atmospheric discharge plasma. Doklady BGUIR. 2019; 7(125): 107-112.

Introduction

The surface cleaning and activation is of great importance before many technological processes. The cleaned surface has a higher adhesion, which allows reducing rejects. The most promising and universal method for surface modification is atmospheric plasma treatment. It has the advantages of traditional ion-plasma methods, and indeed has a lower cost.

Materials and research methods

Monocrystalline silicon, glass and stainless steel surfaces were treated in atmospheric pressure plasma. We used monocrystalline undoped silicon with orientation 111, brand glass K8 and stainless steel brand AISI-304 for plasma treatment.

The surface treatment was performed using an experimental setup, the block diagram of which is shown in the Fig. 1. The setup consists of a balloon with a working gas argon (1), a mass flow controller MFC-12 (2), a treated substrate (3), a tripod (4), a power unit (5) and a discharge system (6). There was used a coaxial type discharge system with a dielectric barrier discharge to create a diffuse atmospheric pressure plasma. This discharge system allows the formation of a plasma torch up to 3 cm long, with a treatment area of about 1 cm in diameter. Argon was used as the plasma gas [1].

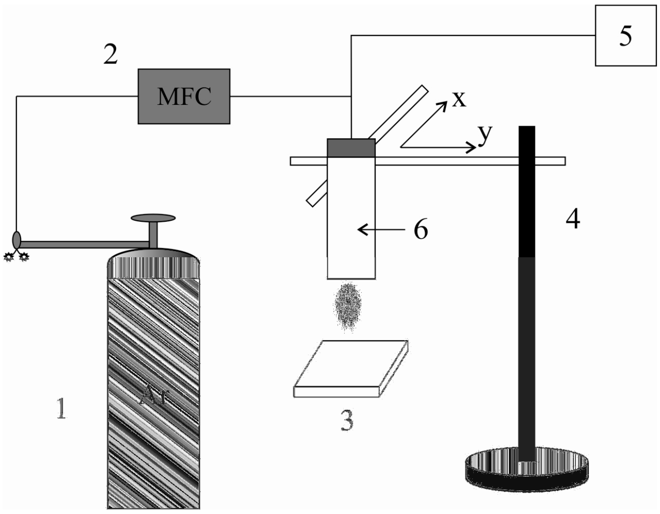

Fig. 1. The block diagram of the experimental setup

The evaluation of the monocrystalline silicon surface adhesion was carried out based on determining the coefficient of friction using an NT-206 atomic force microscope. The value of this coefficient was calculated on the basis of a measurement of the average amount of twisting of the silicon cantilever around its axis during its forward and reverse movement during scanning. When the cantilever is scanning the sample surface in the forward and reverse directions, the cantilever is twisted under the action of friction forces between it and the surface. On the untreated surface, the values of the cantilever twisting during direct and reverse movement are practically superimposed on each other [2].

To estimate the magnitude of the glass and stainless steel surface adhesion, a sessile drop method was selected to measure the wetting angle. To determine the wetting angle, a drop of about 0.01 ml was applied to the surface, then it was photographed and the wetting angle was admeasured via the AutoCAD program. The processed image is presented in the Fig. 2 [3–5].

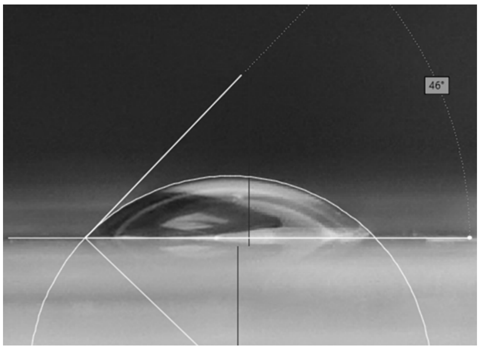

Fig. 2. Image of a sessile drop on the glass surface with a wetting angle admeasured in the AutoCAD program

Monocrystalline silicon, glass and stainless steel surface treatment was carried out at a discharge power of 25 W and a flow rate of argon of 300 l/h.

Results and discussion

To study the dependence of the friction coefficient of the silicon surface on the processing time, the processing time varied from 1 to 5 min with an interval of 1 min. The distance between the plasma source and the sample was 10 mm. Based on the obtained experimental measurements of an atomic-force microscope by averaging the values of the probe deviations when passing in the forward and reverse directions, a graph (see Fig. 3) of the friction coefficient on the processing time is plotted.

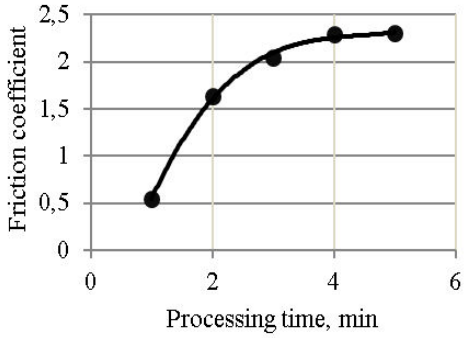

Fig. 3. The dependence of the monocrystalline silicon surface friction coefficient on the processing time

From presented in the Fig. 3 dependency, it is seen that the main effect of the treatment is achieved in 3 minutes, and then there is saturation. Therefore, it is advisable to process the surface of the silicon wafer for no more than 3–4 min.

The dependence of the friction coefficient of silicon on the distance between the plasma source end and the sample was studied during processing for 4 min. The distance varied from 5 to 35 mm. In the Fig. 4 shows the resulting relationship.

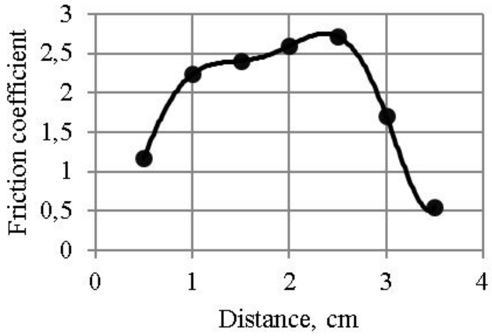

Fig. 4. The dependence of the monocrystalline silicon surface friction coefficient on the distance from the plasma source

Experimental dependence in the Fig. 4 shows the presence of extremes. This suggests different processing conditions for the plasma plume cross section. At the same time, at a distance of 20–25 mm, a change in the friction coefficient is observed. This distance corresponds to the visible length of the plasma plume. Such dependence is probably due to an increase in the number of active particles in the forming stream as the gas moves from the end discharge system.

To study the effect of processing time on the adhesive properties of glass, the processing time was increased to 1 min in increments of 5 s. The resulting dependence is shown in the Fig. 5.

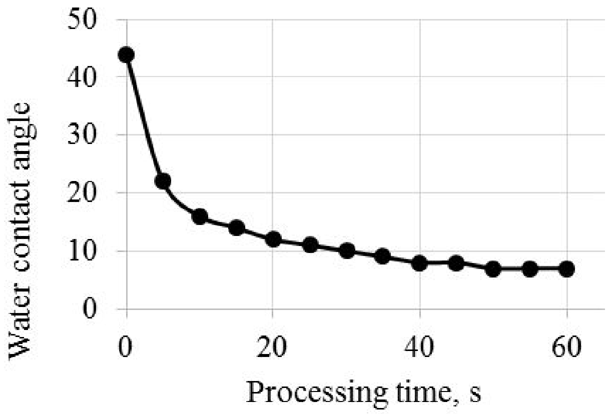

Fig. 5. Dependence of the water contact angle of the glass surface on the processing time

It is seen that the main effect of glass processing is achieved in the first 10 s, while the wetting angle decreases almost 3 times. In the first seconds of treatment, effective removal of contaminants and purification at the atomic level occurs. With further processing, the surface is activated, as a result of which the adhesion improves markedly. The most effective glass processing time is 40–50 s.

The study of the dependence of the wetting angle of glass on the distance from the plasma source was carried out for 30 s (Fig. 6).

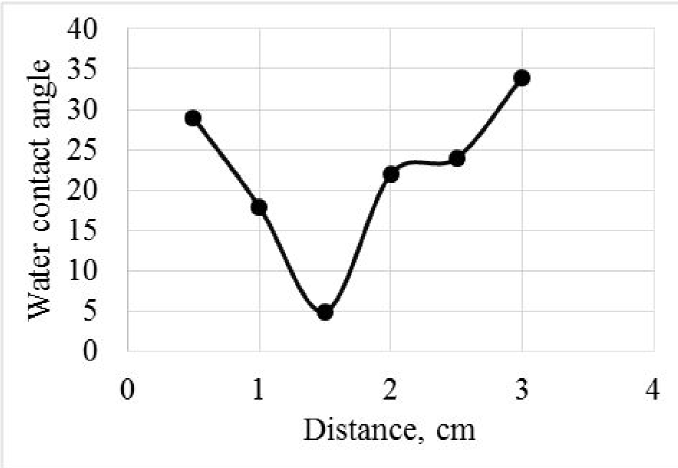

Fig. 6. Dependence of the water contact angle of the glass surface on the distance from the plasma source

In Fig. 6, the minimum wetting angle is clearly visible at a distance of 15 mm from the discharge system. At this distance, the drop almost completely spreads. With a plasma torch length of 2,2 cm, the largest treatment area is achieved at this distance.

The dependence of the processing time on the wettability of stainless steel is shown in the Fig. 7.

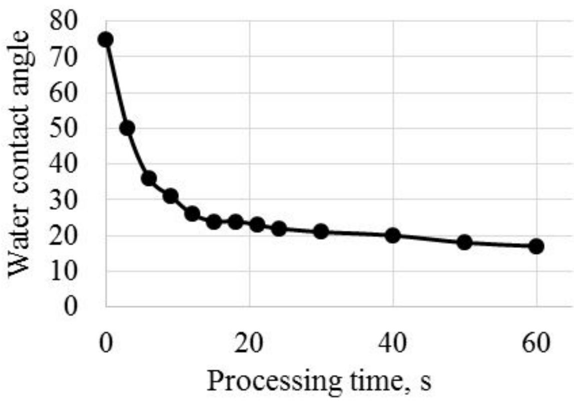

Fig. 7. Dependence of the water contact angle of the stainless steel surface on the processing time

The main effect of processing was achieved in the first 15 s. In 50 s of processing, the wetting angle decreased from 75 ° to 18 °. Stainless steel is not a hydrophilic substance, as the wetting angle of the untreated surface is 75 °. During processing, atomic cleaning of the surface occurs. The processing time of stainless steel in the range of 30 – 50 s is enough to achieve a minimum wetting angle.

The results of the study of the effect of the distance from the plasma source on the wettability of the stainless steel surface are presented in Fig. 8. The study was conducted at a processing time of 30 s.

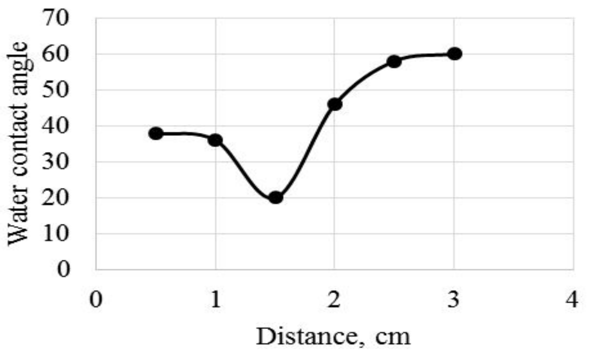

Fig. 8. Dependence of the water contact angle of the stainless steel surface on the distance from the plasma source

On the presented graph, the minimum wetting angle is clearly visible at a distance of 1,5 cm to the plasma source. With an increase in the distance to the discharge system from 0,5 cm to 1,5 cm, a smooth decrease in the wetting angle from 38 ° to 31 ° occurs. At a distance of more than 1,5 cm, a rather sharp increase in the wetting angle to 60 ° occurs.

Conclusion

During processing in atmospheric pressure plasma, it is possible to achieve a significant improvement in the monocrystalline silicon, glass and stainless steel surface adhesion. In the research process, the friction coefficient of the monocrystalline silicon surface increased 5 times. The wetting angle of the glass surface decreased from 44 ° to 5 °, and that of stainless steel from 75 ° to 18 °. This proves that atmospheric plasma is useful for practical application.

References

1. Kotov, D. Izuchenie parametrov plazmennoj strui generiruemoj diehlektricheskim barernym razryadom / Kotov D., Shukevich Ya., Sigay O. Proceedings of the international conference "Youth in science – 2016", Minsk, Belaruskaya navuka 2017; 348-356 (In Russ).
2. Metodicheskoe posobie po vypolneniyu laboratornoj raboty "Opredelenie koehfficienta treniya razlichnyh poverhnostej MEMS-akselerometra proizvodstva NII radiomaterialov". – Minsk: BNTU, 2017; 12 (In Russ).
3. Adamson, A. W. Physical Chemistry of Surfaces. – New York: Wiley-Interscience, 1976; 698 p.
4. Metod lezhashchej kapli [Electronic resource]. -URL:https://tirit.org/articles/surface_theory_sessile.php (In Russ.).
5. Urazaev, V. Gidrofilnost i gidrofobnost / V. Urazaev // Tekhnologii v ehlektronnoj promyshlennosti. 2006; 3: 33-36 (In Russ).

Authors contribution

Zaporozhchenko Y.V. conducted the research and developed the measurement methods.

Kotov D.A. realized the development of atmospheric pressure plasma generation system and the research methodology.

Aksyuchits A.V. developed the atmospheric pressure plasma generation system.

Osipov A.N. analysed the results.

Paceev S.V. analysed the results.

Information about the authors

Zaporozhchenko Y.V., Master Student of the Department of Micro- and Nanoelectronics of Belarusian State University of Informatics and Radioelectronics.

Kotov D.A., PhD, Associate Professor, Associate Professor of the Department of Micro- and Nanoelectronics of Belarusian State University of Informatics and Radioelectronics.

Aksyuchits A.V., Master Student of the Department of Micro- and Nanoelectronics of Belarusian State University of Informatics and Radioelectronics.

Osipov A.N., PhD, Associate Professor, Academician of the Belarusian Engineering Academy, Vice-Rector for Scientific Work of Belarusian State University of Informatics and Radioelectronics.

Paceev S.V., Doctor of the 1st Clinical Hospital at Minsk.

Address for correspondence

220013, Republic of Belarus,
Minsk, P. Brovki st., 6,
Belarusian State University of Informatics and Radioelectronics
tel. +375-29-629-59-34
e-mail: yliyazaporozchenko@gmail.com
Zaporozhchenko Yuliya Vladimirovna