INCREASE IN THE SILICON SURFACE ADHESION BY TREATMENT IN ATMOSPHERIC PLASMA

D.A. Kotov, T.A. Kuznetsova, S.A. Nikitiuk, V.A. Lapitskaya,
G. B. Melnikova, S.A. Chizhik, U. V. Zaporojchenko, E. V. Yatsevich

[1]BelarusianStateUniversityofInformaticsandRadioelectronics, 220013, P.Brovky 6, Minsk, Belarus,kotov@bsuir.by
[2]A.V. Luikov institute of Heat and Mass Transfer of National Academy of Science of Belarus, 220072, Minsk, Belarus

Abstract

The silicon wafer surface was processed by atmospheric pressure plasma. Atmospheric plasma treatment resulted in a significant improvement of the surface adhesion. The adhesion was measured as a coefficient of friction. The dependence of the friction coefficient of the silicon on the treatment modes was studied by the atomic force microscope. The use of the atmospheric discharge plasma made it possible to change the surface properties rapidly and at low cost without destroying it.

Introduction

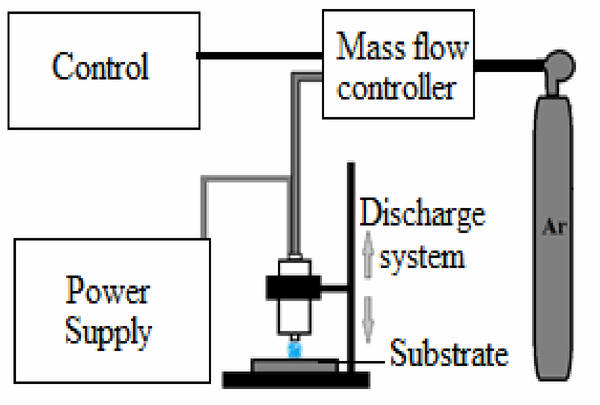
The processes of cleaning the substrate surfaces and their different nature parts, as well as their surface modification before the subsequent technological treatments play an important role in the science and technology. The plasma treatment with dielectric barrier discharge at atmospheric pressure is promising for these purposes. Its most important feature is the combination of the advantages of traditional ion-plasma treatment with a low cost of such processes, as the expensive vacuum equipment is not used in this case.

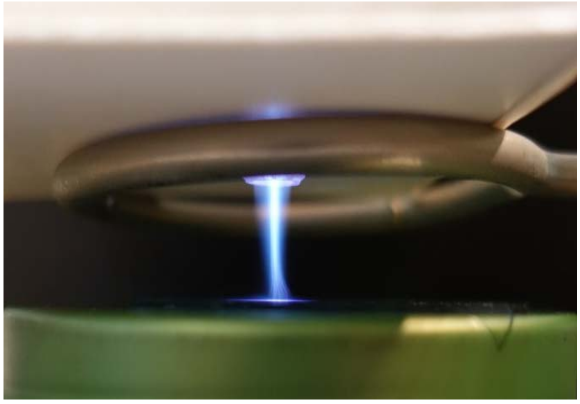
The changes in surface adhesion of silicon was estimated by the calculations of the forces acting on the cantilever of an atomic force microscope.

Materials, methods and experimental set-up

The experimental complex, which consists of a discharge system, a power supply and a work gas supply system, was used to carry out plasma treatment (Fig 1a).

The plasma stream is formed by dielectric barrier discharge that generated in a coaxial device (Fig. 1b). This discharge system allows the formation of a plasma torch up to 30 mm long, with a processing area of 10 mm in diameter. Argon is used as a plasma-forming gas.





a b

Fig. 1 – Schematic representation of the experimental complex (a) and a photo of the plasma torch (b)

The adhesion value of the surface of monocrystalline silicon was estimated by the determination of the friction coefficient using an atomic force microscope NT-206 /1/.The friction coefficient was calculated using the average value of the silicon probe torsion during its forward and reverse motion, reference probe data and Poisson coefficient. An example of the cantilever stroke for forward and reverse motion on the atom force microscopy is shown in the Fig. 2.

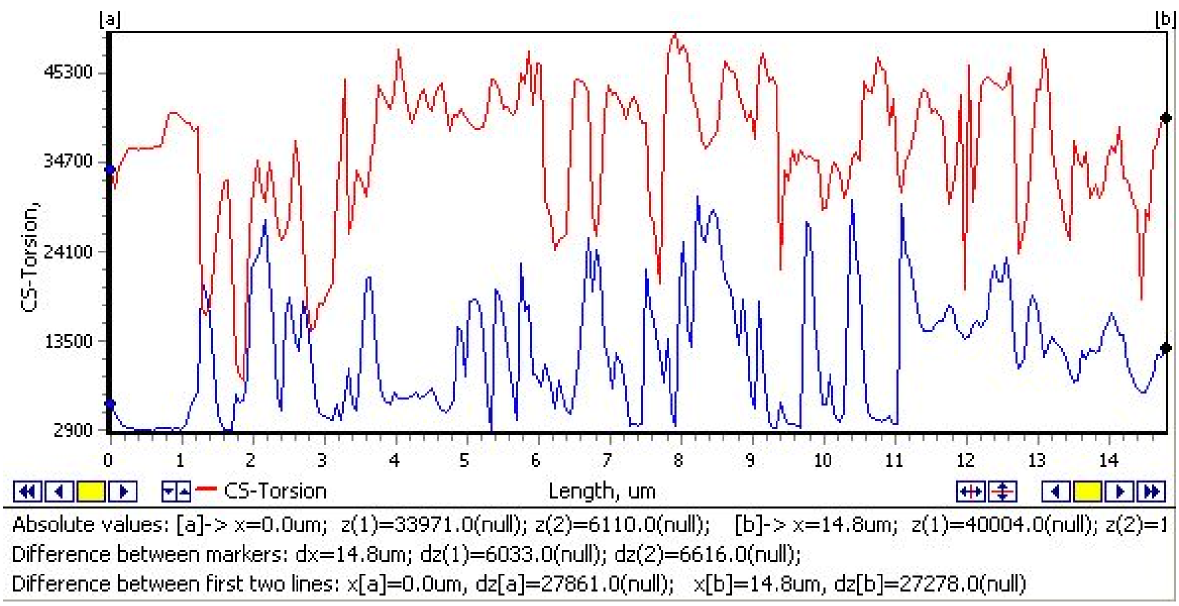


Fig. 2 – Forward and reverse stroke of the cantilever after sample treatment for 4 min

Results and discussion

Surface activation is the appearing of the defects such as the dangling bonds and another that increase a chemically active surface layer. To describe quantitatively the effect of atmospheric discharge plasma on the properties of the silicon surface, the dependence of the friction coefficient on the processing time (at a fixed distance from the plasma source) and on the distance from the plasma source to the processed surface (at a fixed processing time) was studied.

Treatment was carried out at discharge power P ≈ 25 W, plasma gas flow rate S≈300 l/h.

To study the dependence of enhancement capital effect of adhesion on the duration of treatment, the treatment time varied from 1 to 5 min with the step of 1 min. The distance between the end of the discharge system and the sample was 10 mm.

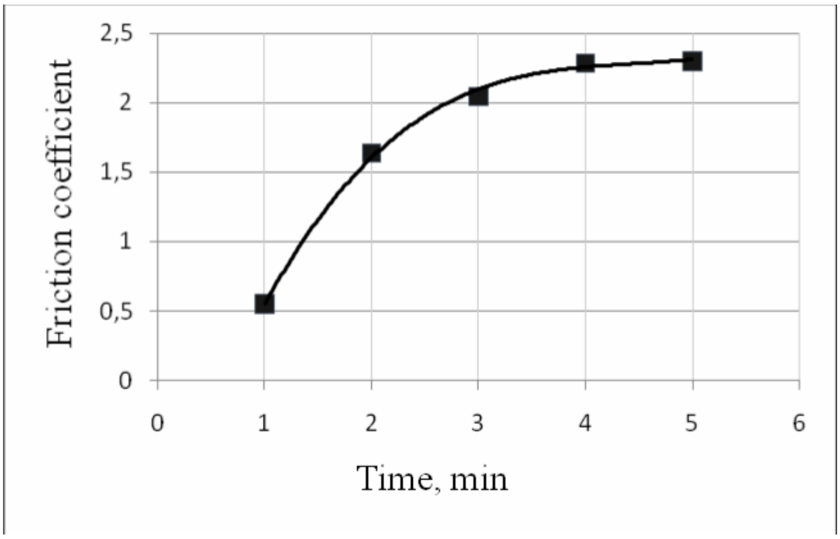


Fig. 3 – Friction coefficient depending on the processing time

As can be seen from Fig. 3 the friction coefficient increases from 0.5 to 2.0 in 3 min in plasma treatment, and then the saturation is observed. 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 on the distance between the end face of the discharge system and the sample was studied during processing for 4 min. The distance varied from 5 to 35 mm.

As can be seen from Fig. 4 on the graph there is an extremum. The friction coefficient increases stepwise from 1.2 to 2.25at the removed sample from 5 mm to 10 mm. Then it slowly increases from 2.25 to 2.65at the removed sample from 10 mm to 25 mm. The last one corresponds to the visible length of the plasma flow. After which the friction coefficient begins to decrease sharply to 1,7at the removed sample to 30 mm.

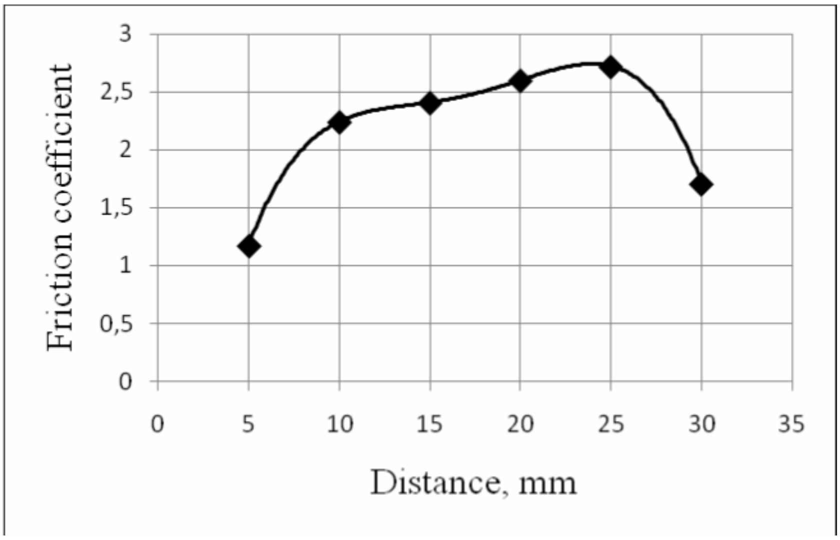


Fig. 4 – Friction coefficient depending on the distance between the sample and plasma source

This indicates different processing conditions along the cross section of the plasma flow. This dependence is probably due to the increase in the number of active particles in the formed flow when the gas-discharge plasma moves from the end of the discharge system.

From point view of maximum adhesion the effective mode of plasma treatment was achieved at the distance range 20–25 mm and processing time more than 3 min.

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