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PLASMA IMMERSED ION BEAM ETCHING AND FUNCTIONALIZATION OF POLYDIMETHYLSILOXANE SURFACES

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Summary: Modification of polymer surfaces by changing the chemical structure, surface energy, and bonding characteristics is of considerable technological importance for the area of biocompatibility. In recent years, the interest was increasingly directed to plasma oxidized polydimethylsiloxane surfaces as a bioactive substrate having the capacity of interacting with a live tissue or system. New plasma immersed argon ion beam technology for controlled oxidization and mineralization of PDMS-surfaces was studied both for academic purposes and in view of its practical application. These modification techniques affected only a shallow surface region of approximate thickness $5 \div 10$ nm, while the bulk properties of the polymer were unaffected. The photoelectron spectroscopy for chemical analysis (ESCA) technique was used to characterize the surface chemistry modified by argon ion beam bombardment and atmospheric pressure air oxidation. Contact angle measurements were used to determine the polar and dispersion components, the sum of which is the surface free energy. AFM- and SEM-images provide details of surface topography.

Keywords: argon plasma etching, atomic force microscopy, contact angle measurement, oxidized polydimethylsiloxane surface, photoelectron spectroscopy for chemical analysis (ESCA), plasma immersed argon ion beam etching (PIAIBE), plasma surface engineering.

1. Introduction

Using polymers as biomaterials, i. e. as materials which are in immediate contact with tissues, proteins, foods, blood and other biological substances, requires the solution of new problems related to the biocompatibility. The development of this aspect of polymeric materials begins by creating inert biomaterials, which are characterized by low adsorption of proteins and weak interactions with blood, live tissues and cells, and are of basic importance for the production of prostheses, catheters, artificial pacemakers, etc.

The demand is being directed towards new self-biointegrating materials exhibiting active behavior with respect to the tissues by stimulating the fixture and formation of a cellular matrix that can become a prerequisite for the tissue regeneration. There are discussions even about "intelligent" materials, which are able to control the biological environment around them and cause their own integration into that environment. The initial cellular interactions depend on the properties of the polymer surface, or on the surface energy and ability of wetting; the heterogeneity, the

microrelief and surface roughness; the surface electric charges; the chemical composition and presence of certain functional groups. The problems of the interphase contact can already be solved by means of controlling the properties of thin surface nanodimensional films on the polymer surface, which are expediently created and suitable for the intended applications.

Plasma oxidizing and etching (PE) of PDMS surfaces leads to a change in the chemical composition and occurrence of oxygen containing silanol (SiOH) groups. This treatment makes the surface hydrophilic, i. e. it can be wetted by water and aqueous solutions. The oxidized surface provides possibilities for graft copolymerization of monomers, improving the interactions with cells; for creating a patterned microrelief or surface micro- and nanodimensional structures by means of electronic or ionic lithography, [1, 2, and 3].

Practices are also known, in which PDMS surfaces are subject to linear argon ion beam etching (IBE) or reactive ion beam etching (RIE) for building new

surface structures and modifying the chemical composition, [8, 9].

Here, it should be also added the practice of the plasma immersed ion implantation (PIII) that makes use of a linear ion beam, created in high-frequency

plasma, for the implantation of different ions and deposition of thin films, [4, 5, and 6].

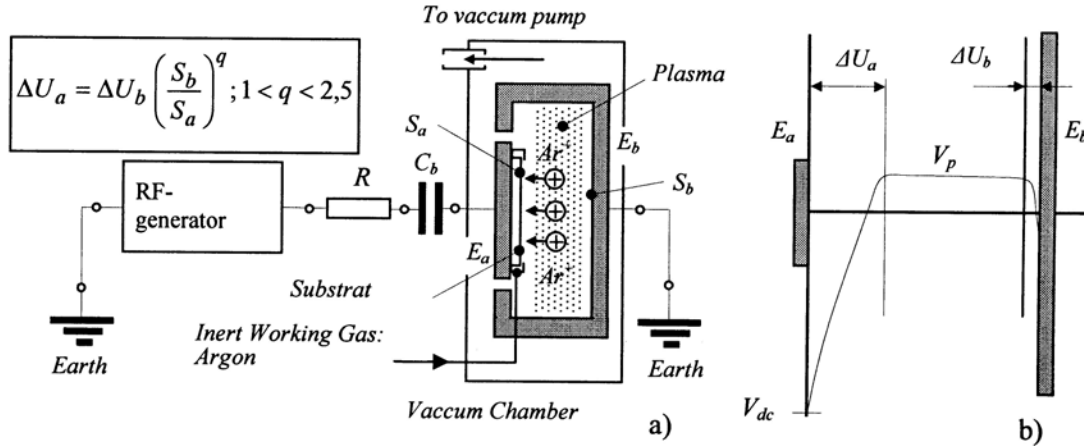


Fig. 1. Capacitive coupled radio-frequency discharge (a) in asymmetric coplanar diode ion etching configuration, [6, 7] and electric potential distribution in the air gap (b).

S_a и S_b – electrode area; ΔU_a и ΔU_b – sheath drops; q – scaling exponent, usually $q = 2$.

These existing practices define the principal concept of the present study, which consists in using a new technological tool that simultaneously or consecutively etches and chemically functionalizes the treated PDMS surface, by which it defines a greater technological effect and higher stability of the reorganized polymer surface.

2. Experimental investigations

The capacitive coupled radio-frequency discharge in low pressure is widely used in industrial plasma processes. Co-planar diode configuration, Fig. 1, is the basis element of a diode plasma reactor with distance between the electrodes of 1 to 3 cm and supply voltage of 100 to 1000 V at a frequency of 13.56 MHz. The following characteristics are indicated for ion-plasma etching (IPE) in a diode reactor, which is an industrial practice in the microelectronic technology: pressure - $10^3 \div 10^4$ Pa ($10 \div 100$ mTorr), surface power density - $0.1 \div 1.0$ W/cm² (power of 50 to 2000 W), ion density - $10^9 \div 10^{11}$ cm⁻³, and ion accelerating voltage - $200 \div 1000$ V. The average electron energy is 3 to 8 eV, and electron energy distribution is Maxwellian. The diameter of the

substrates is from 10 to 50 times greater than the distance between electrodes, [6].

The assumption that the ion-plasma etching configuration of the diode plasma reactor, i. e. the connection of capacitor C_b in series to the side of the high-voltage electrode E_a defines the formation of an

ion beam directed normally towards the surface of substrate S , which is immersed in the plasma itself, characterizes the known anisotropic ion-plasma etching. The large sheath voltage S_a ($200 \div 1000$ V) accelerates and directs an argon (Ar^+) ions beam bombarding the treated substrat surface S , Fig. 1a. The reversed connection of capacitor C_b to the side of the grounded electrode E_b is related to another configuration of the radio frequency diode, which underlies the traditional isotropic surface plasma etching (PE), [7].

The inert argon-ion beam immersed in plasma (AIBIP) creates additionally active surface sputtering and reorganizing, accompanied by chemical activation and functionalization in the inert low pressure environment. This plasma-chemical processing is known as the processing of ion-plasma etching, which can be carried out either in an inert environment, or in a chemically reactive one, [10, 11].

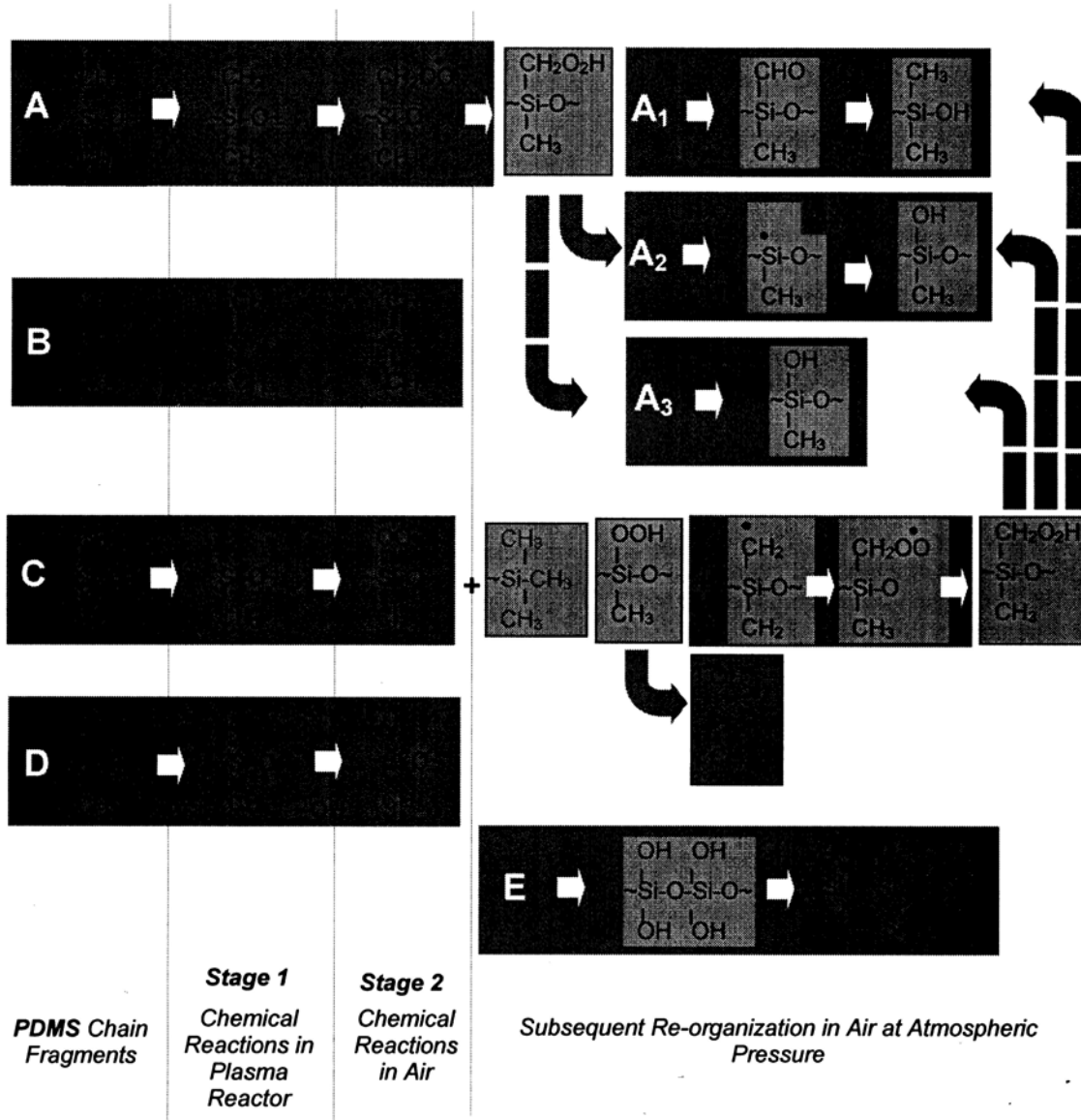
In the present work, the term of “ion-plasma etching” (IPE) was used with the additional specification that this is an ion-plasma process, evolving in inert atmosphere of argon, which is followed by air oxidization at atmospheric pressure and room temperature.

Two variants for the ion-plasma oxidation of PDMS surfaces exist: (i) an oxidization is being leded in parallel to the ion-plasma treatment inside the vacuum chamber in chemically reactive atmosphere either in pure form (oxygen), or in a reactive (oxygen) and inert (argon) gas mixture; (ii) an oxidization consecutive to the ion-plasma treatment, outside the vacuum

chamber, the ion-plasma treatment being wholly carried out in chemically inert environment at low pressure – which corresponds to etching with plasma immersed argon ion beam, and the chemical oxidation is conducted after that outside the vacuum chamber in a reactive atmosphere – an air at atmospheric pressure and room temperature.

The two-stages *PDMS* surfaces oxidation was considered more suitable for an initial processing study because of the complexity and multiplicity of the chemical transformations. The simultaneous conduct-

ing processings of physical and chemical destruction and oxidation create a picture which is much more complex for studying than the case of successive realization of the *PDMS* surface oxidation immediately after the ion-plasma treatment. The consecutive or two-stages processing of chemical and physical inert surface destruction and its following oxidation in air, outside the vacuum chamber at atmospheric pressure and room temperature, becomes the subject of investigation.



Фиг. 2. Two stages ion-plasma oxidation of *PDMS* surfaces: *first stage* – ion-plasma etching in inert gas (argon); *second stage* – oxidation in reactive air at atmospheric pressure and room temperature.

As a result of the ion-plasma treatment at low pressure, it is expected that a plurality of radicals will be obtained on the *PDMS*-substrate surface in one of the following three ways: (i) by means of bond scissing ($\text{CH}_2\text{-CH}_2\text{-}$) and extracting a hydrogen atom from methyl ($-\text{CH}_3$) groups (case A, Fig. 2); (ii) by means of bond scissing from the main ($-\text{Si-O-}$) chain (case B,

Fig. 2); (iii) by means of eliminating methyl ($-\text{CH}_3$) and methylene ($-\text{CH}_2$) groups (cases C and D, Fig. 2). Of course, some of the radicals are going to be immediately re-combined in the vacuum chamber and form chemically unactive particles and new radicals.

It is expected that as early as in the first minutes after the *PDMS*-substrates have been taken out into the air,

a great part of the newly formed radicals will be rapidly oxidized to peroxides and hydroperoxides (the fragments in rectangles, cases A and C, Fig. 2), which are easily dissociated when heated, as well as that a lot of silanol groups will be produced (cases B and D, Fig. 2).

The subsequent chemical re-organization of the plasma treated surface will take place after that and in most cases it will terminate with the formation of new silanol groups (SiOH) - cases A₁, A₂ and A₃, C-A₁, C-A₂ and C-A₃; (-Si-O-Si-) and (-Si-O-C-) bonds.

The silanol groups on the polymer surface are of great practical interest for the fact that together with the mineralized surface layer formed with their participation (case E, Fig. 2) they can define durable hydrophilicizing of the whole PDMS surface, Fig. 2.

Ion-plasma etching was performed at pressure of 26.7 kPa (200 mTorr) in an inert argon environment, the discharge power was changed on three levels – 100, 1200 and 2500 W, to which correspond the surface power density – 0.1, 1.2, and 2.2 W/cm². The plasma treatment duration was changed on three levels, too: 60, 300 and 600 sek. Previous investigations indicate that a minimal treatment duration of the order of 60 sek was sufficient.

The chemical composition of the PDMS surface and its ion-plasma treatment and oxidization have been followed by means of electronic spectroscopy for chemical analysis (ESCA, or XPS). The binding energy is a characteristic of the surface atoms (to a depth of 5 nm). The ESCA-analysis has been realized with the photoelectronic spectrometer VGS ESCALAB Mk II having a monochromatic radiation source AlK_α (FWHM = 0.5 eV). Comparative investigations on the surface topography and roughness have been conducted by means of scanning atomic force microscopy (SFM) on an apparatus of the firm Anfattec Instruments AG, Germany, having vertical resolution of up to 0.2 nm. The surfaces have also been investigated comparatively by means of scanning electronic spectroscopy (SEM) on an apparatus Jeol Super Probe

733. The hydrophilic/hydrophobic surface balance, the surface energy and its components, the polarity of the PDMS-surface were defined by measuring the equilibrium contact angle in accordance with the two-liquid method by using distilled water (H₂O) and methylene iodide (CH₂I₂). The durability of the performed PDMS-surface re-organization was determined on the basis of the change in the boundary contact angle after the samples staying at normal atmospheric pressure and room temperature for up to 720 h (30 d).

3. Experimental results and discussion

3.1. Change in the modified surface chemical composition

The surface chemical composition after the ion-plasma oxidizing of PDMS, determined by means of the total ESCA-spectrum, is represented in Table 1. It was observed the abrupt decrease in the surface content of carbon (C_{1s}), which is characteristic for plasma, oxidized PDMS surfaces and accompanied by considerable increase in the content of oxygen (O_{1s}) and silicon (Si_{2p}). These modification effects are obviously a result of physical sputtering and chemical extracting of carbon, accompanied by forming of volatile products after oxidization. According to many authors, the re-organization of the PDMS surface leads to forming a mineralized (SiO₂-like) surface layer, which contains a small quantity of oxidized carbon particles and silanol (SiOH).

It is also noticed that increasing the surface power density above 1.2 W/cm² and the ion-plasma treatment duration above 60 s does not bring along essential new change in chemical composition. This fact defines the choice of an operational mode for the ion-plasma treatment (1.2 W/cm², 60 s), which is considered to be effective as regards the pursued maximal changes in the chemical composition of the PDMS surface.

Table 1. Surface elemental composition of PDMS.

| № | Samples | Surface elemental composition, at. % | | | | | |
|---|---------------------|--------------------------------------|-----------------|------------------|--------|--------|------|
| | | C _{1s} | O _{1s} | Si _{2p} | nC/nSi | nO/nSi | |
| 1 | non-treated PDMS | 49.7 | 24.5 | 25.8 | 1.93 | 0.95 | |
| 2 | PDMS plasma treated | 0.1 W/cm ² ; 60 s | 37.9 | 35.0 | 27.1 | 1.39 | 1.29 |
| 3 | | 1.2 W/cm ² ; 60 s | 18.6 | 49.4 | 31.0 | 0.60 | 1.60 |
| 4 | | 2.2 W/cm ² ; 60 s | 18.8 | 49.2 | 31.0 | 0.63 | 1.59 |
| 5 | | 1.2 W/cm ² ; 300 s | 18.5 | 49.4 | 29.9 | 0.62 | 1.65 |
| 6 | | 1.2 W/cm ² ; 600 s | 18.0 | 49.9 | 31.1 | 0.58 | 1.60 |

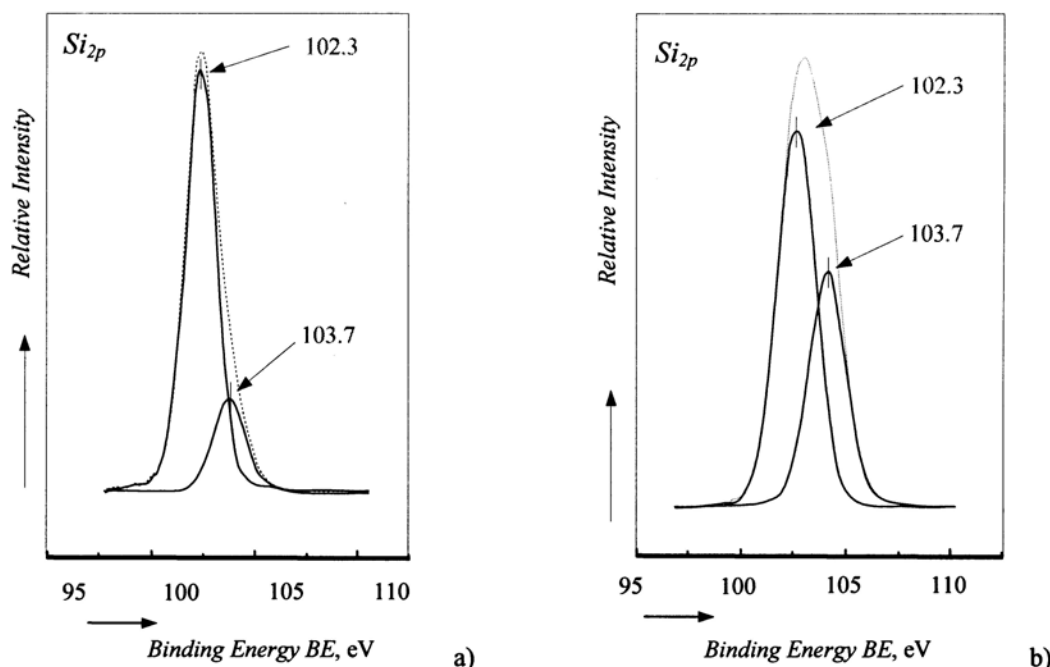


Fig. 3. High resolution ESCA spectrum of Si_{2p} peak and composing peaks of PDMS: a – initial PDMS surface; b – ion-plasma treated and oxidized PDMS surface at RF surface power density of 0.1 W/cm^2 and duration time of 60 sek.

The hypothesis of partial PDMS-surface mineralization, being a result of surface ion-plasma etching, oxidizing and re-organizing, finds confirmation in the results from the ESCA-analysis of the detailed Si_{2p} maximum. Observing the ESCA maximum at 103.7 eV (for SiO_x) has shown that after

modification the relative intensity of this peak increases sharply even at lowest intensity of the ion-plasma treatment (0.1 W/cm^2), depending on the operation conditions – the duration of surface treatment and the surface power density.

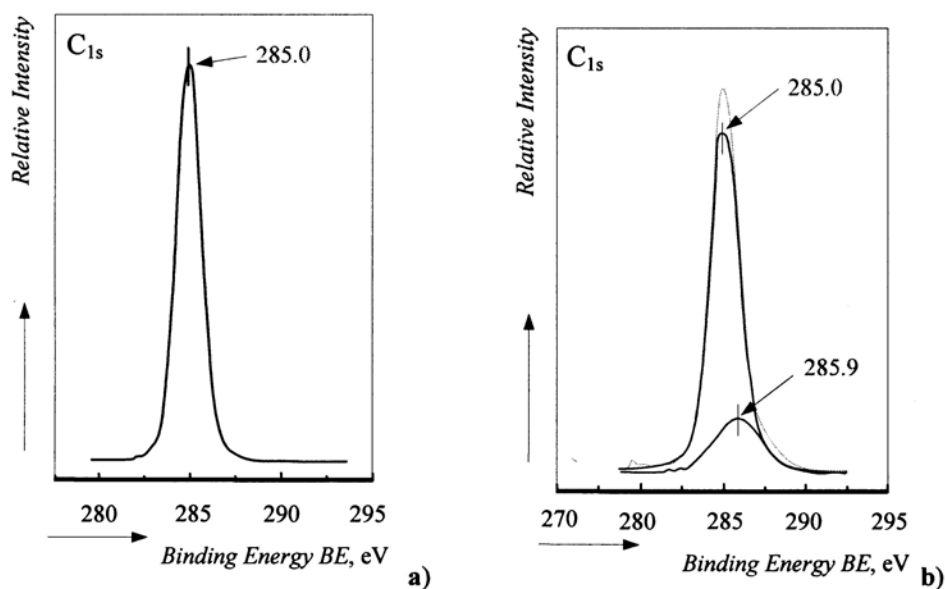


Fig. 4. High resolution ESCA spectrum of C_{1s} peak and composing peaks of PDMS: a – initial PDMS surface; b – ion-plasma treated and oxidized PDMS surface at RF surface power density of 2.2 W/cm^2 and duration time of 60 sek.

These results confirm that the modification undertaken leads to obtaining a partially mineralized surface layer, similar to the layer which is obtained after argon linear ion beam bombardment (ALIBB), i.e. for these

conditions of ion-plasma treatment and oxidation the results obtained are analogous to those of the treatment with a linear ion beam.

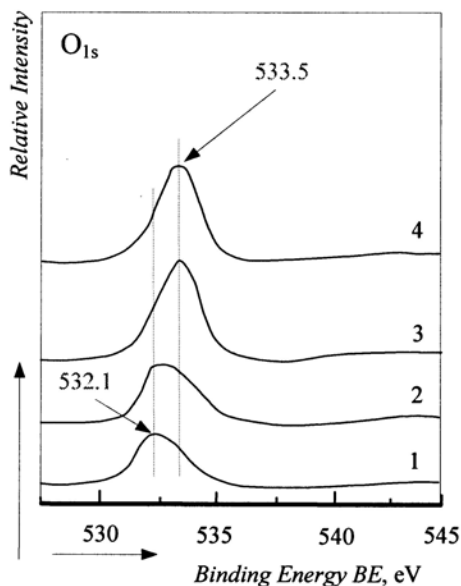


Fig. 5. High resolution ESCA spectrum of O_{1s} peak and composing peaks of PDMS: 1 – initial PDMS surface; 2, 3 and 4 – ion-plasma treated and oxidized PDMS surface at RF surface power density of 0.1, 1.2 and 2.2 W/cm^2 respectively and duration time of 60 sek.

This result is obtained by eliminating the $-CH_2$ or $-CH_3$ groups from the initial polymer and forming new Si-O-Si and Si-O-C links. It should be also emphasized that many of the paths leading to forming silanol groups on the PDMS-surface, Fig. 2, and they also lead to forming a $-Si-O-Si-$ network (chemical re-organization of type E, Fig. 2).

The so modified chemical composition is preserved durably, probably due to the formation of a complex reinforcing network of $SiO_xC_yH_z$, which helps avoiding an eventual subsequent re-organization of the modified PDMS surface during the staying period. The detailed C_{1s} spectrum of the unmodified PDMS contains a single component centered at 285.0 eV, which corresponds to $-CH_2$ and $-CH_3$ groups linked to a silicon (Si) atom, Fig. 3a. All ion-plasma treated and oxidized substrates contain one more characteristic maximum at 285.9 eV, shifted towards higher binding energies in the region of oxygen links, which reveals the occurrence of oxidized carbon atoms on the PDMS-surface, Fig. 3b.

The formation of oxygen containing groups with carbon atoms as a result of the undertaken ion-plasma surface oxidation is also confirmed by the high resolution ESCA spectra of O_{1s} , Fig. 5: only one peak at 532.1 eV (for oxygen linked to silicon: Si-O) corresponds to the untrated PDMS-surface. A second peak at 533.5 eV occurs in the ESCA spectrum after the

ion-plasma modification and oxidization, which is a result of the formation of oxygen bonds with the carbon atoms $-C-O$. This occurs for the lowest surface power density (0.1 W/cm^2) and is already well manifested at 1.2 W/cm^2 (and 2.2 W/cm^2). These processes also lead to the formation of a more complex network of $SiO_xC_yH_z$ on the PDMS surfaces.

3.2. Change in the topography and roughness of the modified surfaces

The scanning atom force microscope (SFM) is one of the most powerful tools for revealing the plasma modifications in the surface topography with sub-nanometric resolution (Müller et al., 1995; Schabert et al., 1995, Shao et al., 1996). The topography and microrelief of the polymer surface exert an essential impact upon the contact angle and upon initial interactions with cells. This fact as well as the expected modifications of PDMS surfaces as a result of the ion-plasma oxidization provide a reason for performing comparative electronic microscope observations of the examined PDMS-surfaces. The unmodified PDMS surface is characterized by a fine-grained surface structure and the following roughness parameters: an average value $R_a = 1.59$ nm and effective value $R_{RMS} = 2.01$ nm, Fig. 6.

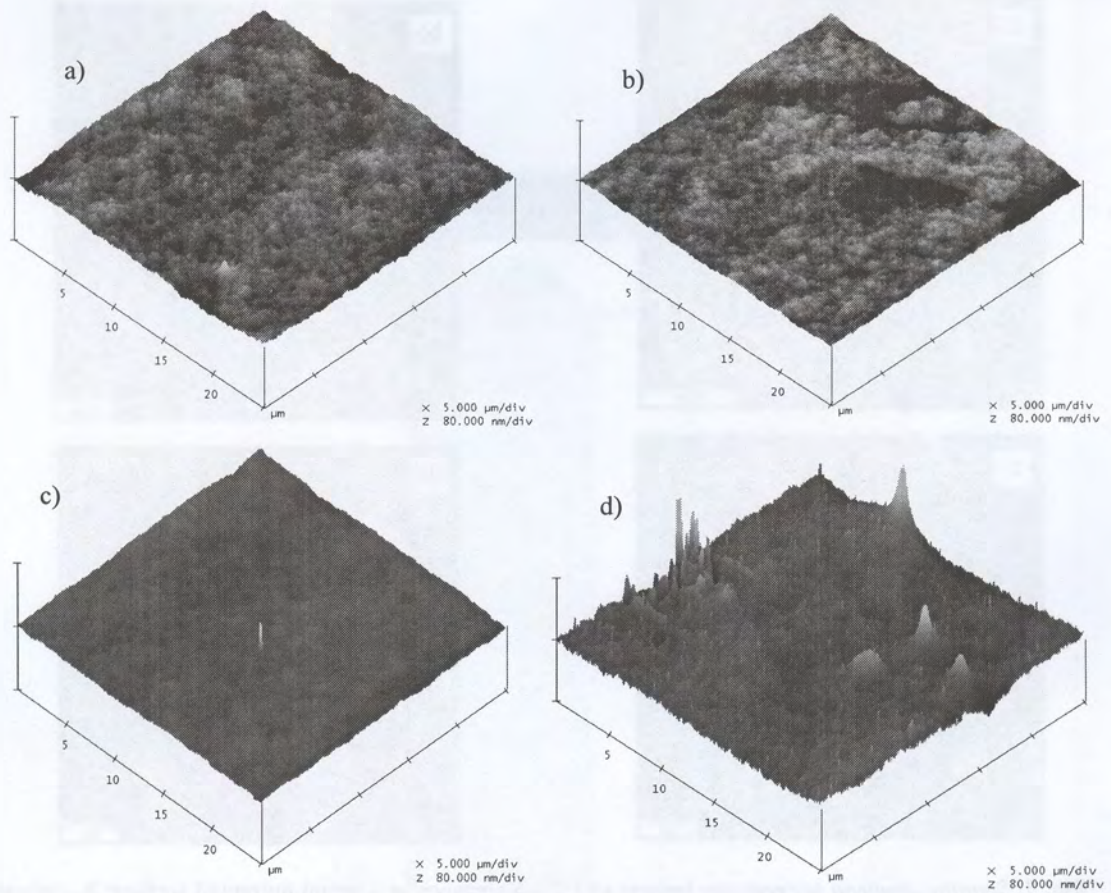


Fig. 6. Three dimensional scanning atom force microscopy images of PDMS surfaces: **a** – initial untreated surface: $R_a = 1,59$ nm; $R_{RMS} = 2,01$ nm; **b** – plasma treated ($0,1$ W/cm²; 60 sek): $R_a = 1,36$ nm; $R_{RMS} = 1,60$ nm; **c** – plasma treated ($1,2$ W/cm²; 60 sek): $R_a = 1,06$ nm; $R_{RMS} = 1,20$ nm and **d** – plasma treated ($2,2$ W/cm²; 60 sek): $R_a = 3,87$ nm; $R_{RMS} = 5,81$ nm.

However, the results after ion-plasma treatment and consecutive oxidizing at atmospheric pressure are of interest because the modifications evolve in two opposite directions depending on the values of the surface power density of the capacitive coupled high-frequency (RF-) discharge: (i) twenty four hours after surface plasma treatment for 60 sek at 1.2 W/cm² and oxidization in air at atmospheric pressure, the surface morphology of the PDMS is characterized by even more fine-grained structure and lower-value roughness parameters – an average value $R_a = 1.06$ nm and effective value $R_{RMS} = 1.20$ nm, Fig. 8, i. e. smoothing or polishing of the polymer surface was observed; (ii) twenty four hours after the ion-plasma treatment at considerably higher power – 2.2 W/cm² (for 60 sek) and oxidizing in air, the

surface morphology of the PDMS is characterized by multiple high and low local peaks on the background of the characteristic fine-grained structure and increased roughness parameters – the average value increases to $R_a = 3.87$ nm, and the effective value to $R_{RMS} = 5.81$ nm, Fig. 9, i.e. the mode of surface etching, characteristic for this technology, is observed.

These observations indicate that the ion-plasma treatment, combined with oxidization of the PDMS in air at atmospheric pressure, represents a powerful tool for controlling the topology and microrelief of the polymer surface, and as a consequence also its interaction with live cells. In such a way the natural biological inertness of the PDMS is overcome and the door is open for subsequent chemical modification

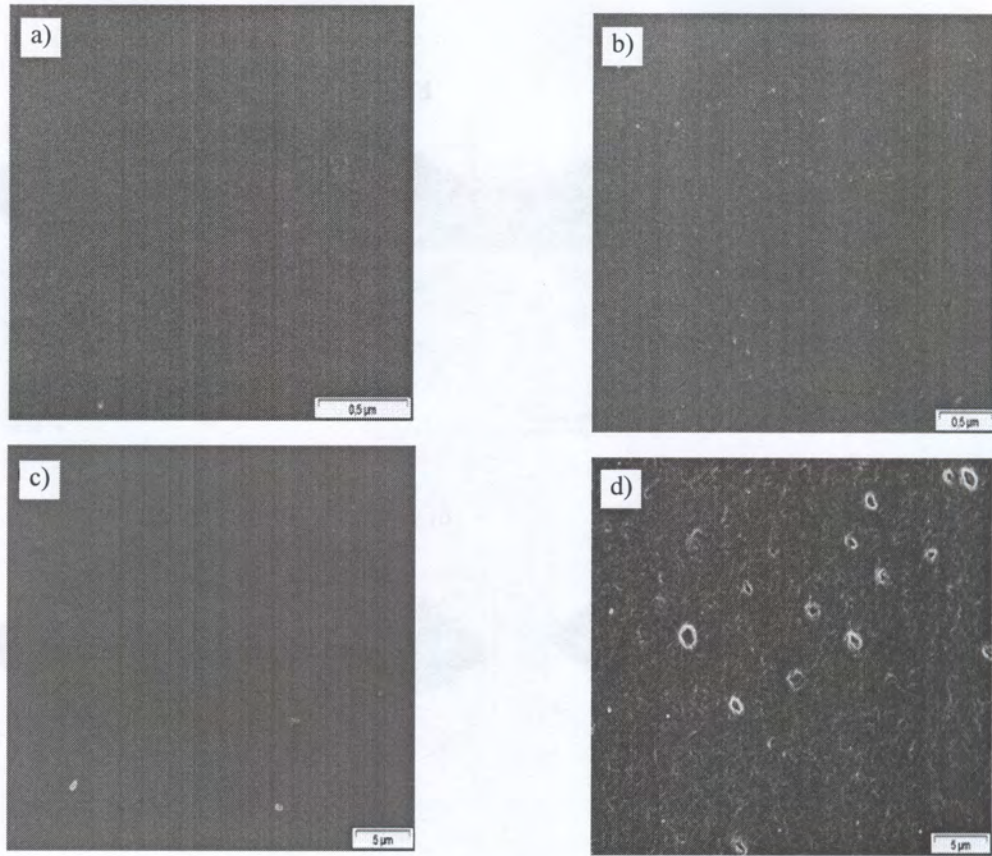


Fig. 7. Scanning electron microscopy images of PDMS surfaces: **a** – initial untreated surface; **b** – plasma treated (0.1 W/cm^2 ; 60 sek); **c** – plasma treated (1.2 W/cm^2 ; 60 sek); **d** – plasma treated (2.2 W/cm^2 ; 60 sek).

3.3. Change in the hydrophilic/hydrophobic balance of the modified surfaces

It is well known that the initial cellular interactions are better when the surface is of expressed hydrophilicity, and for this reason the surface modifications are very often directed towards modifying the hydrophilic/hydrophobic balance in that direction. The PDMS surfaces are of strong hydrophobicity, which makes difficult (even impossible) their initial interaction with cells. The expressed modifications in the surface chemical composition of the of PDMS,

including the observed mineralization with building of a complex $\text{SiO}_x\text{C}_y\text{H}_z$ network and multiple silanol (SiOH) groups, Fig. 2, presuppose a shift of this balance towards its hydrophilicizing. Many authors indicate the plasma oxidization of the PDMS as a reason for hydrophilicizing even after modes of plasma treatment, [1, 2, 3, 5, 6, and 7]. The change in the hydrophilic/hydrophobic balance is defined not only by the modified chemical composition, but also by the modified topology (morphology) and microrelief (roughness) of the surface.

Table 2. Equilibrium contact angle θ of untreated and plasma treated PDMS surfaces with water (H_2O) and methylene iodide (CH_2I_2), surface energy γ_s and its components polar γ_s^p and disperse γ_s^d , and polarity p

| № | Samples | | $\theta(\text{H}_2\text{O})$ | $\theta(\text{CH}_2\text{I}_2)$ | γ_s | γ_s^d | γ_s^p | p |
|---|----------------------------|----------------------|------------------------------|---------------------------------|-----------------|-----------------|-----------------|------|
| | | | | | mJ/m^2 | mJ/m^2 | mJ/m^2 | - |
| 1 | PDMS untreated | | 101.9^0 | 70.2^0 | 22.9 | 21.8 | 1.1 | 0.05 |
| 2 | PDMS plasma treated 60 sek | 0.1 W/cm^2 | 87.9^0 | 66.7^0 | 26.8 | 21.9 | 5.0 | 0.18 |
| 3 | | 1.2 W/cm^2 | 60.8^0 | 49.5^0 | 45.6 | 28.1 | 1.5 | 0.38 |
| 4 | | 2.2 W/cm^2 | 39.4^0 | 61.8^0 | 57.1 | 18.5 | 38.7 | 0.68 |

The results of the investigation undertaken for the equilibrium contact angle θ by using two liquids – a polar (H_2O , water) and non-polar (CH_2I_2 , methylene iodide) ones – are measured, calculated, and shown in Table 2.

The assumption for strong hydrophilicization of the *PDMS*-surface after ion-plasma chemical treatment was confirmed by the obtained – a surface of strong hydrophobicity of the initial *PDMS* with equilibrium contact angle $\theta(\text{H}_2\text{O}) = 101.9^\circ$; $\theta(\text{CH}_2\text{I}_2) = 70.2^\circ$; was hydrophilicized. After the ion-plasma treatment and oxidization in air, it was transformed in a hydrophilic surface with strongly increased polarity – the polarity was increased from 0.05 to 0.18, 0.38, and 0.68, depending on the mode of ion-plasma treatment, Table 2.

Increasing of polarity p was mainly due to the rapid increase in the polar component of the surface energy γ_s^p . The accumulation of oxygen

containing polar groups on the *PDMS* surface at increasing the surface power density of the *RF*-discharge from 0.1 to 2.2 W/cm^2 , Fig. 2, defines the observed decrease in the equilibrium contact angle θ – very significant for the polar liquid (H_2O) and considerably less significant for the non-polar liquid (CH_2I_2), Table 2.

However, it should be noted immediately that, irrespective of the similar nature of the chemical composition of *PDMS* surfaces, Table 1, the modified substrates are of rather differing hydrophilicities, Table 2. This imposes the idea that the topology and microrelief also perform an essential role in shifting the hydrophobic/hydrophilic balance.

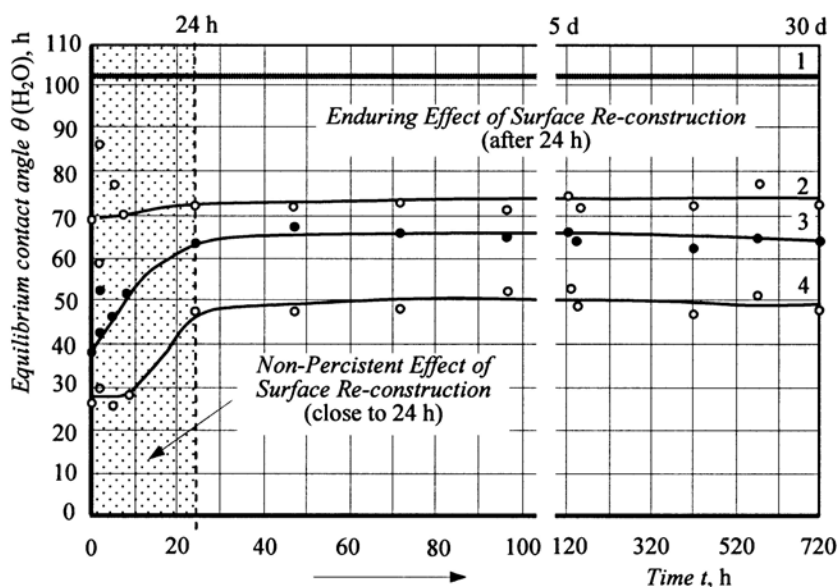


Fig. 8. Plots of equilibrium contact angle of the *PDMS* surfaces with water $\theta(\text{H}_2\text{O})$ versus time of stying at atmospheric pressure and room temperature for different *PDMS* samples: 1 – initial untreated surface; 2, 3 and 4 – ion-plasma treated and oxidized *PDMS* surfaces at *RF* surface power density of 0.1, 1.2 and 2.2 W/cm^2 respectively and duration time of 60 sek.

The issue of the durability of the re-organization performed and the surface modification duration effect is always of practical interest for the surface plasma-chemical modification, which imposes the need of tracking the equilibrium contact angle θ for a continuous time interval – from 0.5 to 720 h (30 d), Fig. 8.

A lot of new questions are posed by the continuing reconstruction of the surface of the *PDMS* substrates, which formulates the observed characteristic dispersion in the values of the equilibrium contact angle θ for the first 24 h. The surface modifications are durably settled no earlier than after the end of this period

and only after that moment it can be assumed there is a durable result from the ion-plasma treatment and oxidization of the *PDMS*. This result is present after staying in normal conditions - the equilibrium contact angle with a polar liquid (water) decreases from $\theta = 101.9^\circ$ with about 27 % for 0.10 W/cm^2 , 36 % for 1.20 W/cm^2 , and 52 % for 2.2 W/cm^2 , Fig. 8.

The surface reconstruction is also related to the occurrence of an electric charge - most probably a homocharge, on the ion-plasma treated *PDMS* surface, which is most probably consequence of the bombardment, implantation and capture of argon ions (Ar^+) in so called potential traps on the surface. Depending on the humidity, temperature, pressure, and

presence of negative ions in the air, this electrical charge is neutralized in a faster or slower manner, the polarized state being disturbed. The electric polarization or the electret state of the polymer essentially influences the performed investigations for the equilibrium contact angle, which is weakened after its neutralization or destruction. The observed large dispersions in measuring the equilibrium contact angle, Fig. 8, are most probably due to the electric polarization of the surface as a result of its ion-plasma treatment.

Conclusion

The investigated modifications in polydimethylsiloxane surfaces after various operational modes of ion-plasma treatment - polishing or etching, and oxidization in air environment allow making the following basic conclusions:

- the ion-plasma treatment of PDMS in an inert gas (argon) and the oxidization that follows after it can be considered a tool, which, depending on the selected process mode, can polish and/or etch the surface treated, modify its chemical composition to a different extent by means of oxidization, and implant positive ions by electrically charging the surface layer, i. e. bring it into an electrically polarized state;
- the ion-plasma treatment of PDMS allows obtaining results, which are characteristic for the modification of the surface with a linear ion (Ar^+) beam, by using an apparatus simplified to a very great extent, in this case it being possible to use even the industrial RIE-reactors, which have long been considered "dinosaurs" from the era of initial development of the microelectronic manufacturing;
- the plasma immersed ion beam makes it possible to perform anisotropic etching not only on plane objects, but also on objects having a complex and unfolded surface, a practice that exists in implanting by a plasma immersed ion beam (PIII) – in this way it is possible to treat and functionalize complex 3D-surfaces;
- at this stage it can be assumed that the ion-plasma technology for the preparation and oxidization of PDMS represents an efficient tool, which modifies the chemical composition and topology of the surface by preparing it for its successful interaction with cells, [12, 13];
- the ion-plasma oxidized PDMS surfaces (at 2.20 W/cm², 60 s) are characterized by improved initial cellular interactions, [12];
- the ion-plasma oxidized PDMS surfaces can be additionally activated chemically by means of a successful graft copolymerization with acrylic acid (CH₂=CH-COOH), the entire surface being subject to reconstruction and carboxyl groups (-COOH) emerg-

ing, which enable, for their part, the subsequent bio-functionalization of the surface, [12];

- new data are obtained for controlling the oxidizing processes on PDMS surfaces by means of a preliminary ion-plasma treatment (bombardment), which has clearly expressed advantages in comparison to the classic plasma treatment and the treatment with a linear ion beam.

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