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Influence of plasma treatment on polyetheretherketone (PEEK) surface properties

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Abstract: The aim of the study was to determine the wettability and energetic properties of polyetheretherketone (PEEK) before and after activation by air plasma. PEEK plates were treated by air plasma for 25, 60 and 180 seconds. After the plasma surface modification contact angles have a much lower value in comparison to that measured on the original surface.

Keywords: polyetheretherketone, plasma, contact angle, surface free energy

1. Polyetheretherketone (PEEK)

From a medical point of view very important polymer is polyetheretherketone (PEEK), which is used as implants for the cervical, thoracic and lumbar spine. PEEK has excellent physical and chemical properties, including high strength and stiffness, good fracture toughness and compatibility with all common sterilization methods, resistance to corrosion, ease of forming by molding or machining and a density comparable to human tissue [1, 2]. However, its relatively low adhesion to the bone tissue has limited its more common application [3].

2. Plasma treatment

Hydrophilic-hydrophobic properties of the solids can be modified in several different ways of which plasma surface treatment has become very popular recently [4]. Plasma technique allows obtaining various materials with different surface properties from the initial polymer. By using reactive gases in the plasma like O_2 or Ar the surface becomes more hydrophilic with formation of new groups which can interact specifically with other groups [5, 6]. Plasma surface modification is an effective and economical surface treatment technique for many polymers and of growing interests in biomedical engineering. This technique provides an alternative to traditional methods of surface modification by wet chemical cleaning, etching, cross-linking and functionalization. However, appropriate plasma choice, its duration and temperature allow to increase hydrophobicity or hydrophilicity, depending on the modified material.

3. The aim of the study

The aim of the study was to determine the wettability and surface energy properties of PEEK before and after activation by air plasma. PEEK plates were treated by air plasma for 25, 60 and 180 seconds. The contact angles (advancing and receding) were measured for water, formamide and diiodomethane using the sessile droplet method.

Then the surface free energy and its components were calculated using the values of the measured contact angles and applying the Owens-Wendt approach [7], acid-base approach proposed by van Oss, Good and Chaudhury [8] as well that based on the contact angle hysteresis (Chibowski approach) [9, 10]. The values of the acid-base dispersion and polar interactions allowed the estimation of the hydrophilic-hydrophobic modified PEEK surface changes before and after plasma activation.

Furthermore, the chemical changes on the polyetheretherketone surface were also reflected in the IR spectra – after the plasma surface treatment new functional groups appear.

4. Results and short discussion

The studies show that after plasma treatment wettability and surface free energy are changed, which results from an increase in polar, more hydrophilic nature of the surface.

After the plasma surface modification contact angles have a much lower value compared to that of the original surface (Fig. 1). The lowest values of the contact angle were observed for plates treated with plasma for 180 seconds. The reduced water contact angle was observed from 107° to less than 35° with only 25 s plasma treatment.

As it can be seen in Fig. 2 surface free energy calculated from the CAH and LWAB approaches gives comparable results. The surface free energy value estimated from O-W approach is higher because it is calculated in based on water and diiodomethane contact angles without formamide interaction. Even short activation of surface with plasma results in significant increase in surface free energy. Longer surface activation does not affect significantly on the value of total surface free energy.

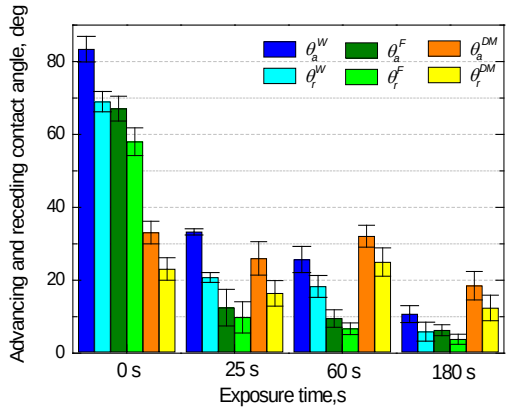

Fig. 1. Changes of values of advancing (θ_A) and receding (θ_R) contact angle for water (W), formamide (F) and diiodomethane (D), depending on time of action (t) on PEEK plates with air plasma.

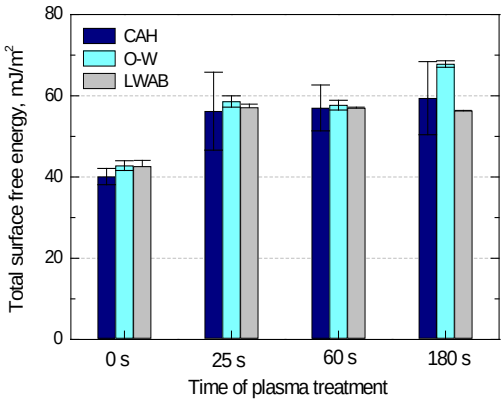

Fig. 2. Total surface free energy of untreated and plasma-treated PEEK surface calculated from contact angle hysteresis approach (CAH), Owens and Wendt theory (O-W) and Lifshitz-van der Waals acid-base approach (LWAB).

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