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Hydrophile regression phenomenon of a silicone polymer plate surface treated with an inverter plasma

インバータープラズマで表面処理したシリコーンポリマー板の親水性の退行現象

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The Surface of a silicone polymer material after a plasma exposure treatment has been investigated and two additional treatment methods have been attempted for improving the treatment effect. The pulsed plasma was generated from a low-pressure oxygen gas using an inverter plasma apparatus developed in Osaka university. The surface characteristics was estimated from measured water wettability after the elapsed time. In the experimental results, it was confirmed that the treatment effect, that is, the surface's good wettability decreased in only a few hours after the plasma exposure. Then, it was also found that the additional treatment methods were useful to keep the good wettability surface for a longer time.

1. Introduction

Silicone polymers are very important materials for industrial fields of food, medicine, and bioscience etc. It is because they are a kind of useful heat-stable elastomers, and contain little harmful chemicals. The surface of silicone polymer materials, however, is water repellent i.e. good hydrophobic and has severe adhesive difficulties. Then, some surface treatment methods especially by plasma exposure have been employed to offer a hydrophile surface property to silicone polymers like other various polymers. The treatment effect, however, decreases in only a few hours after the plasma exposure. So, we have attempted an improved treatment method for keeping hydrophile surface of a silicone polymer for a longer duration time [1-3].

This study aims to observe the behavior of the silicone polymer surface after a plasma exposure and to suppress the above regression process of the hydrophile surface. In the presented article, we will describe two adopted additional treatment methods and demonstrate experimental results.

2. Experimental

We have adopted two improving methods for treating silicone polymer plate samples. They were a low-temperature preserving method and an aging preprocess method. The former was preserving the samples in a constant lower temperature than the room one after the plasma exposure process. In this experiment, the samples were preserved at three different temperatures of 3, 20, and 40 ℃.

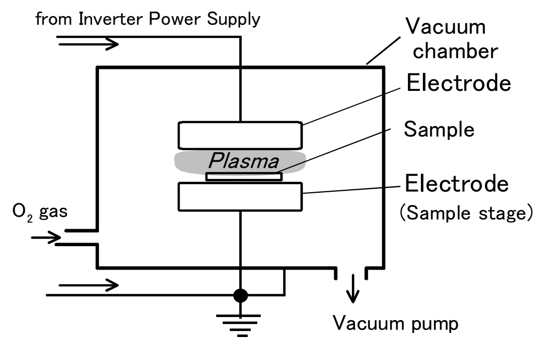

Fig.1 Inverter plasma surface treatment apparatus [4]
Gas: Oxygen 200 Pa. Discharge power from an inverter power supply: about 20 W. Waveform of discharge power: 5 kHz repeated bipolar pulse with 1.5 kV pp.

The latter was aging the samples at a high temperature for a long time in an oven before the plasma exposure treatment. The selected conditions were the aging temperature of

130 ℃ and the aging time of 30, 60, 90h.

We performed a hydrophile treatment of silicone polymer film samples using a plasma treatment apparatus composed of an inverter power supply and a pair of parallel electrodes in a low-pressure oxygen gas filled chamber as shown in fig. 1 [4-5]. The inverter plasma was generated by bipolar high-voltage pulses repeated in a low frequency. It is thought that the inverter plasma is appropiate to surface trreatment of delicate materials such as polymers [5], because the observed plasma was stable and the plasma generation power was considerably low with a pulse timing control technique.

The plate samples with a 30 mm-diameter circular form were made of a commercially prepared a silicone polymer plate with a thickness of 1 mm. Each sample plate was set on a discharge electrode in the inverter plasma apparatus, and irradiated with the oxygen gas plasma in duration of 300 seconds. In order to analysis of the treated silicone polymer surface, contact angles of water of each sample were measured from just after the plasma exposure till the elapsed time became to 10 days.

3. Conclusions and summary

First, it was confirmed that the contact angles of the all sample plates changed from the pristine angle of 110° to a well hydrophile surface of about 10 ~ 20° just after the inverter oxygen plasma exposure. Next, fig. 2 shows the measured contact angles after the plasma treatment at deferent preserving temperatures. A PET film sample was also tested for comparison.

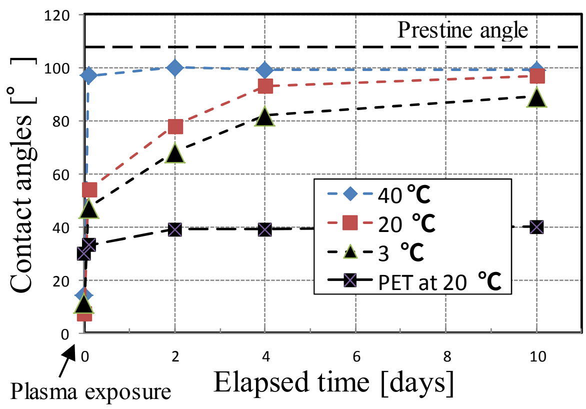

Fig.2 Measured contact angles of treated silicone polymer plate samples (no aged). Each sample was preserved in constant temperature vessels at 3 - 40 ℃. A PET film sample was also tested for comparison.

As shown in fig.2, it is found that the sample preserved at 3 °C kept the lowest contact angles of the samples preserved at 20 °C or higher. This is because the sample surface was seemed to be covered with hydrophobic silicone oil components that were diffused from the bulk region and the diffusion velocity may be in proportion to the preserving temperature.

Then, we have tried the aging preprocess method to reduce the silicone oil component in the bulk region. After this preprocessing, the samples were surface-treated with the plasma exposure and preserved at a room temperature of about 20°C. The measured contact angles are shown in Fig.3. In this result, it was found that the lower contact angles were kept by performing the longer time aging.

In future, we would like to research the optimum conditions for the low-temperature preserving method and the ageing preprocess method to control the surface wettability of silicone polymers.

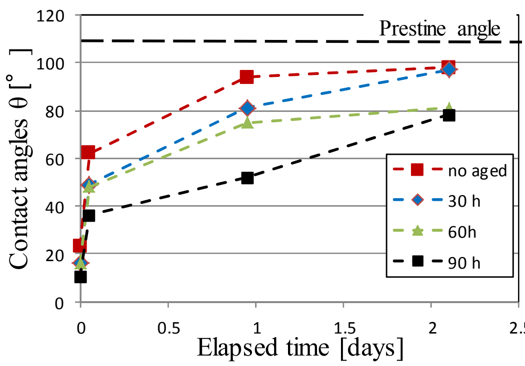

Fig.3 Measured contact angles vs. elapsed time after plasma exposure for silicone polymer plate samples (no aged sample and aged at 130 ℃ in different days). Each sample was preserved in the room temperature.

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