Regulating the wettability properties of Polytetrafluoroethylene (PTFE) via oxygen plasma treatment: influence of the operating pressure and examining the ageing behaviour

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Polytetrafluoroethylene (PTFE) is a fluoropolymer that consists of a repeating molecular structure of (-CF2-CF2-)n and possesses a hydrophobic surface that has a surface-free energy of 18.6 mJ/m^2. This feature allows it to endure extreme circumstances, offering excellent thermal stability, resistance to wear, chemical inertness, and low friction. The hydrophobic nature of PTFE makes it extensively utilised in the fields of electronics, medical, home products, and environmental protection[1]. However, the high static voltage limits its lifespan. In recent years, there has been a significant study focusing on the surface modification of PTFE to enhance its application in various industries, improve its lifespan and maintain its unique properties. Teflon can undergo surface modification by physical means as well as chemical approaches. Non-thermal plasma technology offers a dry, clean, and safe approach to alter the surface of many materials without changing their fundamental qualities[2]. This is especially advantageous for heat-sensitive polymers often used in textiles, as non-thermal plasmas may be applied without causing thermal damage to the materials[3]. Various plasma processing techniques can be tailored to modify polymeric surfaces through engineering[4][[5]. Plasma treatment can alter a material's chemical composition, physical structure, and surface properties[6][7].

In this work, we enhanced the wettability of PTFE and studied the ageing effect of plasma-treated PTFE to notice the structural and chemical changes on the surface over time. We used oxygen plasma treatment on the PTFE material due to its unique properties. The changes in the PTFE surface were observed using different characterization techniques. Scanning electron microscopy was used to study the structural changes on the surface while the chemical behaviour of the PTFE surface was characterised by Fourier transform infrared spectroscopy (FTIR). Mass spectroscopy was also performed to detect the gas-phase composition of the PTFE sample.

Experimental Setup

Firstly, the PTFE samples were cut into 6 × 6 cm^2 and washed three times to remove the dust particles from the surface. The oxygen plasma treatment was used in this experiment. The gas was supplied to the cylindrical vacuum chamber through the upper electrode which is directly connected to the RF power supply. The power supply provided the voltage to the lower chamber. Before starting, the chamber was vacuumed by a rotary pump. The plasma treatment on the PTFE sample was operated at 6 × 10^{-2} mbar pressure and 150W power. This treatment was carried out for 30 minutes. After the treatment, the sample was covered with aluminium foil and placed in a desiccator to avoid any exposure of the surface to the environment.

Results

The water contact angles (WCAs) were measured before and after the oxygen plasma treatment and continued to measure the WCAs after several days to observe the ageing effect of the oxygen plasma on the PTFE surfaces. The WCA before the treatment was measured 104˚. It can be seen that after the treatment the WCA was increased to 130˚and PET became a superhydrophobic surface. After a few days, it went towards the hydrophilic surface lowering the WCA gradually. We observed this sample was treated at the lowest pressure and its ageing effect is also slow towards hydrophilicity. Within 21 days it maintained its hydrophobic behaviour and became hydrophilic after 40 days with 85˚WCA.

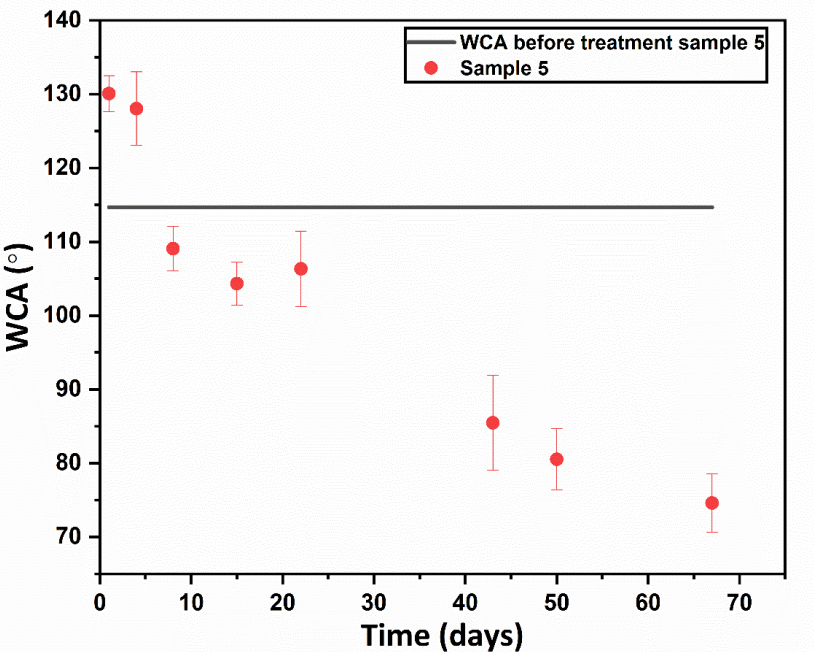

Figure 2. Water contact angles of sample 5 (6 at 6 × 10^{-2} mbar) as a function of ageing time (T) days