Colloids and Surfaces A: Physicochem. Eng. Aspects 335 (2009) 128–132

Contents lists available at ScienceDirect

Colloids and Surfaces A: Physicochemical and Engineering Aspects

journal homepage: www.elsevier.com/locate/colsurfa

The modifications of the surface wettability of amorphous carbon films

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ARTICLE INFO

Article history:
Received 9 September 2007
Received in revised form 28 October 2008
Accepted 30 October 2008
Available online 7 November 2008

Keywords:
Wettability
Superhydrophobic
Amorphous carbon
Plasma

ABSTRACT

Stable and easily controllable wettability of a solid surface is of great significance in many applications. In the present studies, a-C films with special nano-structured surfaces were deposited on silicon and glass substrates with magnetron sputtering method. The morphologies of the surfaces vary with the deposition parameters. Therefore, these a-C surfaces can be controlled to exhibit different wettability in a wide range from the hydrophilicity to the super-hydrophobicity. The studies also prove that the CF_4 plasma treatment will remarkably enhance the hydrophobicity of the a-C films. And the fluorinated a-C surfaces show an excellent super-hydrophobic property for all the pH values of the aqueous solution. Moreover, a super-hydrophobic surface of the non-fluorinated a-C film can be reversed to being very hydrophilic by the plasma treatment of H_2 or N_2, while the fluorinated super-hydrophobic a-C films show a good stability.

1. Introduction

Super-hydrophobic surfaces have potential applications in self-cleaning [1], enhancing the cell mobility [2], and micro-fluidic devices [3,4]. Recently, for the inspirations from the nature leaves [5,6], super-hydrophobic surfaces with micro- and nano-structure are fabricated successfully by mimicking the nature's design [7–11]. Nowadays, it has been well known that the wettability of a solid surface is governed by both the chemical state and the geometry morphology of the surface [12,13].

For an actual application, usually the super-hydropobicity should be combined with some other properties such as the adequate mechanical properties, the high thermal or chemical stability, the good transparency or the other special optical and electrical properties, which might be taken into account when designing a micro fluidic chip integrated together with the optic or electronic devices, for instance.

Carbon materials have drawn much more attention for its many excellent properties. Super-hydrophobic surfaces of nanostructured carbon materials, Psuch as carbon nanotube [14,15] and nanofiber [16], have been successfully fabricated. Besides, as an environmentally benign and economically viable candidate of optic and electric device material, amorphous carbon (a-C) films are promising in various applications [17,18]. And the phenomena about the wettability on a-C surfaces has also been investigated by reseachers [19,20].

In the present work, magnetron-sputtering technique were employed to a-C films deposite for its low substrate temperature (less than 400 °C in our experiments). The a-C films had been prepared on the substrates of Si (1 0 0) and glass. The deposited processes were controlled to adjust the surface morphology of a-C films. There are several methods of discharging plasma which have been used on chemical treatments [21–23]. Here we adopted a simple technique, RF plasma. The effects of the Plasma treatments of CF_4, N_2 and H_2 on the wettability of a-C surface were also studied respectively. Different aqueous liquids, with the pH value in the range from 0 to 14, were employed to test the stability of the super-hydrophobicity on a-C surfaces.

2. Experimental methods

Amorphous carbon (a-C) films were deposited on clean Si (1 0 0) and glass substrates by a radio frequency (RF) magnetron sputtering system. A graphite plate of 99.99% purity with the diameter of 100 mm was used as the sputtering target. After pumped to a base pressure of 3×10^{-3} Pa, the working chamber was filled with Ar (99.99% purity), the work pressure was maintained at 0.5 Pa. The RF power varied from 100 W to 400 W with the same substrate temperatures in the range from room temperature to 400 °C. Then the a-C films deposited with RF power of 200 W at the substrate temperature of 400 °C were exposed to CF_4 plasma for 5 min with the pressure of 10 Pa, the RF excitation power of 100 W and the substrate temperature of 200 °C, respectively. Furthermore, N_2 and H_2 plasma were introduced for 200 s at room temperature to investigate their influences on the wettability of a-C films.

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doi:10.1016/j.colsurfa.2008.10.047

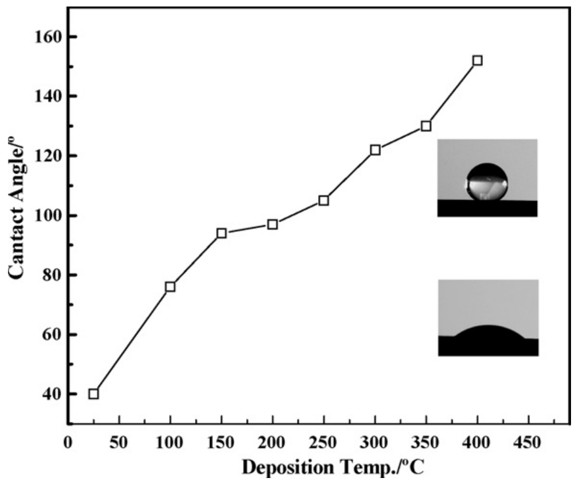

Fig. 1. Water contact angles on the surfaces of the a-C films with various deposition temperatures.

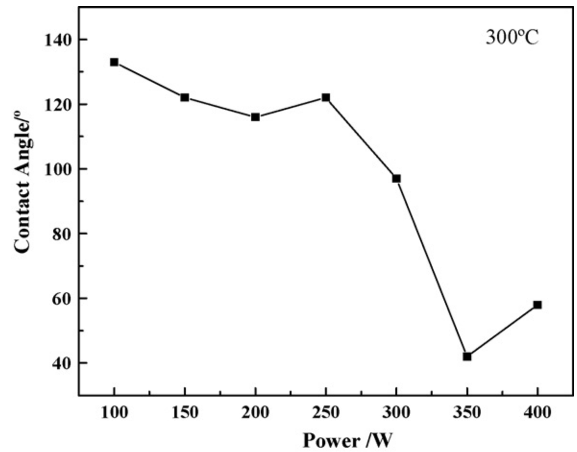

Fig. 2. Water contact angles on the surfaces of the a-C films with various sputtering powers.

The surface morphology was studied by scanning electron microscopy (SEM JEOL JSM6500) at an accelerating voltage of 30 kV. The X-ray photoelectron spectrometer (XPS) analyses were performed on a MKII with a monochromatic Al Kα source at 1486.6 eV, and the photoelectron take-off angle was 45°. The surface wettability of the a-C films were measured by a contact angle measurement system in air at ambient temperature.

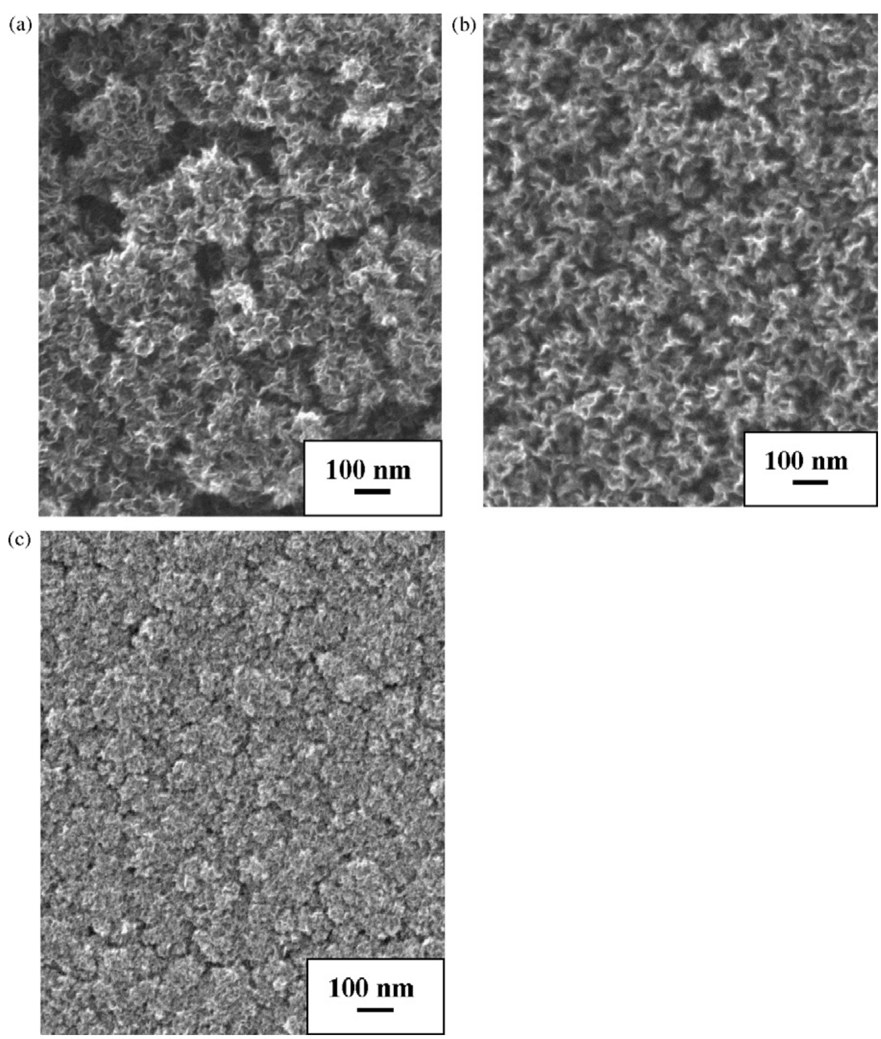

Fig. 3. SEM images of a-C films deposited with different sputtering powers. (a) 100 W, (b) 200 W, and (c) 300 W.