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Superior mechanical properties of hybrid organic-inorganic superhydrophilic thin film on plastic substrate

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ABSTRACT

A superior mechanical properties of bilayer thin film with anti-fogging performance for polyethylene terephthalate (PET) substrate was developed. The bottom layer, acting as a mechanical support, is a hybrid organic-inorganic thin film with interpenetrating network. Atop this layer, the superhydrophilic nanoparticles were fabricated and deposited by spray-coating to yield a layer exhibiting the superhydrophilic and anti-fogging effect. Contact angles of water were measured to examine the hydrophilicity of the hybrid organic-inorganic superhydrophilic thin film. Besides, UV/VIS spectrophotometer, atomic force microscopy (AFM) and scanning electron microscope (SEM) were carried out to characterize the optical properties and film structure of the thin film. For the actual application, variety of industrial tests such as pencil test (ASTM D 3363 standard), adhesion test (ISO 2409 standard) and steam test, were employed to evaluate the prepared hybrid organic-inorganic superhydrophilic thin film. Especially, the addition of the bottom layer results in an improvement of the adhesion between the superhydrophilic nanoparticles and PET substrate. The experimental results exhibited that the mechanical, optical, superhydrophilic and anti-fogging properties were effectively improved after applying the hybrid organic-inorganic superhydrophilic thin film on PET substrate.

1. Introduction

In recent years, polyethylene terephthalate (PET) has become a focal point of materials for a range of industrial applications such as food packaging [1,2] and flat panel display (FPD) [3]. The global PET demand amounted to 6.4 million tons in 2000, it was increasing at a compound annual growth rate of 6.9% to reach 12.6 million tons in 2010. This upward tendency is expected to continue in the near future. The global demand for PET is predicted to reach 23.4 million tons by 2020, following a forecast compound annual growth rate of 6.4% [4]. From the above, the wide-ranging applicability of PET is predictable. In particular, the advantages of PET such as low cost, low specific weight, flexible and ease of design [5–7], it is expected for near future that PET will be more applied on optical combined with surface coating technology. Nevertheless, the usage of PET is limited due to poor mechanical properties such as hardness and scratch resistance. These mechanical properties create a barrier for the adoption of PET in a wide range of industrial applications. Hence, a protective layer coated on PET substrate to improve the poor mechanical properties was necessary.

Generally, a protective layer can be fabricated by vapor deposition [8] or chemical solution process [9]. However, physical vapor deposition exhibited the coating equipment is expensive and cumbersome. Besides, the large area and different shape of PET substrate are also limited. The sol-gel process is promising to overcome such disadvantages. It provides some advantages such as low cost, simple operation, mass production and it is suitable for large-area application. There are some trials have been reported so far [10–14].

Sol-gel process is a simple and convenient method which can be applied to fabricate variety of thin film applications [15–21]. Among of the numerous applications, superhydrophilicity is a property of surface with self-cleaning and anti-fogging. At present, hydrophilic surface is usually fabricated by using TiO_2, TiO_2/SiO_2 and SiO_2 film. For example, Eshaghi et al. [22] deposited TiO_2 nanocomposite films on glass substrates by sol-gel process. After UV irradiation, the hydrophilic property was obtained by increasing the hydroxyl group density on the surface. It exhibited good photocatalytic activity leading to hydrophilic property. Fateh et al. [10] prepared a transparent hydrophilic photocatalytic TiO_2/SiO_2 thin film to endow the surfaces self-cleaning properties. The effect of the SiO_2 addition to TiO_2 films demonstrated good wettability

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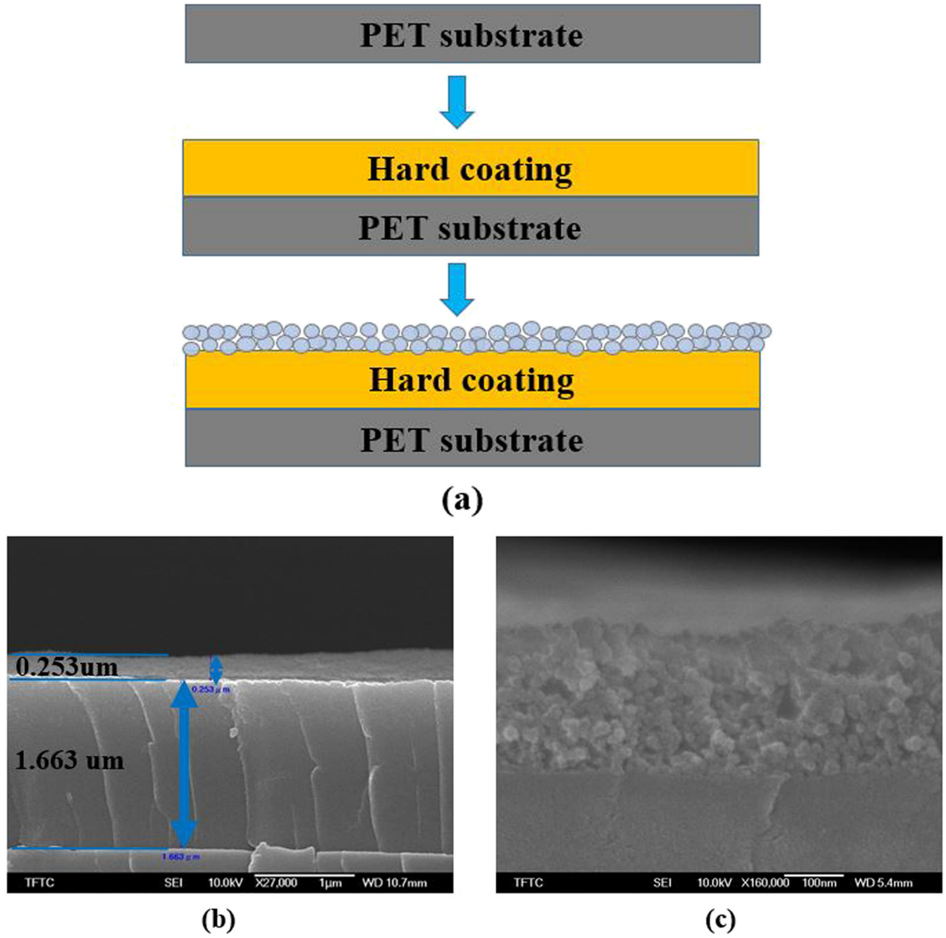

Fig. 1. (a) The illustration of the experimental flowchart, (b) SEM image of the hybrid organic-inorganic superhydrophilic thin film structure and (c) the enlarged SEM image of (b).

and photocatalytic activity. Wang et al. [23] fabricated high transmittance and superhydrophilicity of porous TiO_2/SiO_2 bi-layer films. The results of study also showed well anti-fogging property. Above researches were all showed these thin films with hydrophilic performance after UV light irradiation, but, the application would be limited. Besides, it was also seldom to discuss the durability of mechanical property. Chang et al. [11] exhibited a water resistant anti-fogging coating for PC substrates had excellent hydrophilic property. Chen et al. [24] reported that the superhydrophilic mesoporous SiO_2 thin film was fabricated by sol-gel process. It performed the superhydrophilicity and anti-fogging property in the absence of UV light irradiation. However, the mechanical properties of these thin films were also not discussed in detail.

In this work, a superior mechanical properties, hardness, adhesion and abrasion, of thin film with anti-fogging performance was designed and fabricated through modified sol-gel process, which has a special superhydrophilic/hybrid organic-inorganic bilayer structure. The hybrid organic-inorganic layer was coated on PET substrate as a mechanical supports. The superhydrophilic layer was deposited on the pre-coated PET substrate by spraying superhydrophilic nanoparticles to enhance surface energy and roughness. It exhibited the superhydrophilic nanoparticles was effectively adhesive on the pre-coated PET substrate. In addition, the thin film obtained had static water contact angle as low as 3.17° and water droplets could easily form continuous water thin film on the surface, both indicating the excellent superhydrophilic

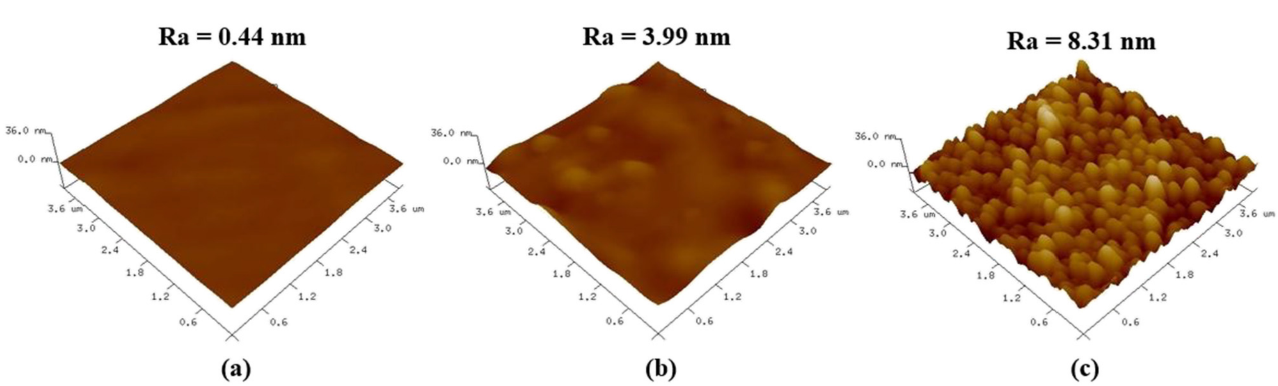

Fig. 2. AFM images of (a) PET substrate, (b) hybrid organic-inorganic thin film on PET substrate (pre-coated PET substrate) and (c) hybrid organic-inorganic superhydrophilic thin film on pre-coated PET substrate.

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