Development of a Roll-to-roll Ultraviolet Imprint Lithography Equipment for Superhydrophobic Film Fabrication

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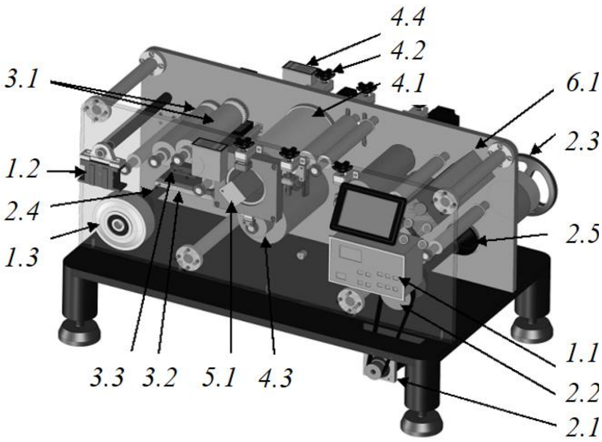
Superhydrophobic surface has been widely investigated by researchers in these years for its self-clean characteristics which can be used in various fields such as transport, medical treatment, energy and environment protection [1]. Although there are several methods to obtain the superhydrophobic surface, including etching, electrospinning, sol-gel method and template transfer etc, the fabrication process requires either expensive materials or equipment, complex manipulations or rigorous processing requirement [2][3].As a result, a large-area superhydrophobic surface could not be simply fabricated by these process. On the other hand, roll-to-roll ultraviolet nano-imprint (RtR UV NIL) technology has been developed over the past years as a promising candidate for the large area fabrication, especially for the grating structures and solar cell films [4].In this paper, we proposed an equipment for fabrication of large area superhydrophobic materials based on RtR UV NIL and fast UV curing technology. Micro patterns could be transferred to a flexible substrate without complicated fabrication process in a clean room, and large area superhydrophobic film can be fabricated rapidly and efficiently.

The proposed RtR UV NIL equipment is composed of six parts: tension control part, film transmitting part, photoresist coating part, structure transferring part, curing part and surface treatment part. The RtR UV NIL equipment and its 3D structure modelare showed in Figure 1 and Figure 2, respectively. The whole fabrication process will be presented as following.

Firstly, the PDMS mold was obtained against the Si master fabricated via UV lithography (EVG 610, Austria) and deep reactive ion etching (DRIE) [5]. Then the UV resist (four types used are shown in Table 1) was coated on the polyethylene terephtalate (PET) substrate. After that, the microstructures on the PDMS mold were transferred to the UV resist using the RtR UV NIL equipment. After the UV exposure, the resist was cured and the film with the same micropillar pattern was obtained after demolding. At last, the fluoride treatment of the film was carried out with fumigation of trimethylsilyl chloride, decreasing the surface energy. Also, it was found that it is possible to manufacture superhydrophobic microstructure arrays free of bubble defects using R2R UV imprinting technique through selecting processing parameters within the process window: the web speed between 0.5 and 0.7m/min, the pressure between 4 and 5kg/cm^2, the UV light lamp has a power of 7kW, its lamp watts is 260W/cm, and its wavelength range is 250–450nm, and the mold temperature between 57 and 65° C.

After process and recipe optimization, a typical micro structure array (20 μm-diameter, 40 μm-pitch,17 μm-height) was successfully transferred by using a customized UV resist (80% UA-232P, Shin-nakamura Chemical), as shown in Figure 3. The de-ionized water contact angle was measured up to 150° after fluorinated treatment as shown in Figure 4. For the future study, we will try more complicated T-type microstructure array using this equipment aiming at large-area superlyophobic film.

Fig.1 RtR UV IL equipment.



1.1 tension controller 1.2 tension sensor 1.3 magnetic controller
2.1 rewinding drive motor 2.2 rewinding roller 2.3 film substrate loading control handwheel 2.4 unwinding roller
2.5 rewinding tension head
3.1 roller coating 3.2 glue groove3.3 glue box
4.1embossing roller 4.2 adjusting screw 4.3 impression roller
4.4 pressure control instrument
5.1 UV lamp source bracket
6.1 film surface fumigation chamber

Fig. 2 3D modeling effect of RtR UV IL equipment.

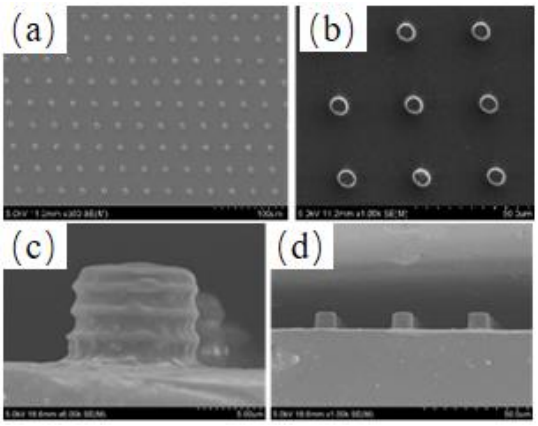


Fig.3 SEM image of the transferred structure by using 80% UA-232P curing resist. (a)-(b) Microscope image of tooth cylindrical structures.(c)-(d) enlarged view of tooth cylindrical structure.

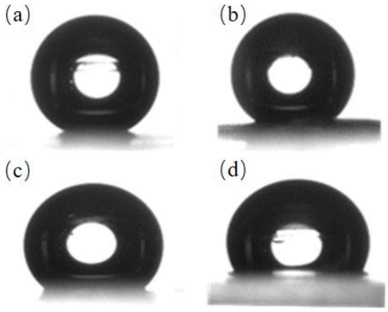


Fig.4Water contact angle of the film -by using different UV curing resist. (a)Formula1 151.71°. (b)Formula2 142.42°. (c)Formula3 137.76°. (d) Formula4 122.67°.

Table 1. Four types of UV curing resist

formula	Acrylate oligomer and its mass fraction	Types and mass fraction of active diluents	Photoinitiator and its mass fraction
1	80% UA-232P（Shin-nakamura Chemical）	12%M2101+4.8% M220（Miwon Specialty Chemical）	3.2% 1173 Photoinitiator (Nanjing JiaZhong chemical industry)
2	80% SC4240（Miwon Specialty Chemical）		
3	80% EBECRYL 8807（Allnex Belgium SA/NV）		
4	80% 4 Aliphatic polyurethane acrylate（JiaZhong chemical industry）		

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