Improving hydrophobicity of ZnO surfaces by combining nanoimprint lithography and sol-gel technology

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In recent years, the wetting properties of solid surfaces have attracted much attention, partly inspired by the natural lotus effect resulting from a kind of natural surface with very high water repellency. In addition to naturally occurring micro- and nanostructures, the fabrication of artificial structures on a solid surface can render the surface with tunable wetting characteristics.

The wetting property is deeply influenced by the surface free energy and the surface roughness. The preparation of hydrophobic surfaces, can then be achieved mainly by several physical and chemical methods [1]. Some typical examples of chemical methods include the surface modification by materials with low surface free energy, e.g., fluorination, the fabrication of aligned nanorods or nanowires, and the construction of hierarchical porous structure. On the other hand physical methods to increase surface roughness include mechanical abrasion, etching, anode oxidation, molding, lithography, etc. [2]

ZnO is an inexpensive material that is receiving attention because of its high conductance, chemical and thermal stability as well as its optical properties, with interesting applications such as thin film gas sensors, photo-detectors and light emitting diodes especially for UV region [3].

Most of the work focused on obtaining hydrophobic ZnO surfaces has relied upon surface roughness modification with regular patterns. This is due to the inherent hydrophilicity of ZnO surfaces that difficult to obtain surfaces with lower free surface energy.

Patterning of ZnO thin film usually requires at least three processes: deposition of ZnO layer, lithography and etching of ZnO. Compared to photolithography, nanoimprint lithography (NIL) can effectively fabricate nano-scale patterns with simple process, high throughput and relatively low cost [4]. By using the imprinting technique with the sol–gel process, the number of process steps can be decreased and the expensive processes such as photolithography and reactive ion etching steps can be skipped. Therefore, ZnO nano-patterns can be made inexpensively and various kinds of ZnO-based nano-devices can be realized using sol–gel nano-imprinting [5].

The direct patterning of gel film developed by sol-gel technology shows great advantages for cost-effective mass production [6]. There are a rich variety of techniques about the preparation of ZnO thin films including sputtering, chemical vapor deposition (CVD), spray pyrolysis, and sol–gel process [7]. The sol-gel method has some merits, such as the easy control of chemical components, good homogeneity, low processing temperature, large area coatings, good optical properties and fabrication of thin film at a low cost [8]. Particularly, the sol–gel processes are efficient in producing thin, transparent, multi-component oxide layers of many compositions on various substrates [9].

A combination of nanoimprinting of ZnO sol–gel films and thermal nanoimprint lithography technique is used to prepare nanostructured ZnO films with hydrophobic properties. This is a very simple and relatively inexpensive method to produce a high quality patterned film. . The phenomenon of the OH absorption on the surface of ZnO gel-films results in the hydrophlilicity and the nanopatterns on the surface enhance the hydrophobocity of ZnO gel film. The thermal imprint process is developed by using a poly-dimethylsiloxane (PDMS)-based polymer mold, chosen due to its capability to absorb the solvent without deformation, and when temperature is raised the organic solvent in the ZnO-sol solution is removed by diffusion through PDMS polymeric mold and the formed nanostructures of ZnO-gel are stable, thus further enhancing the hydrophobocity of ZnO gel film (Figure 1). As a result of the increased surface roughness, composite surfaces demonstrate a CA enhancement from 30º to 100º.

References

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Figures

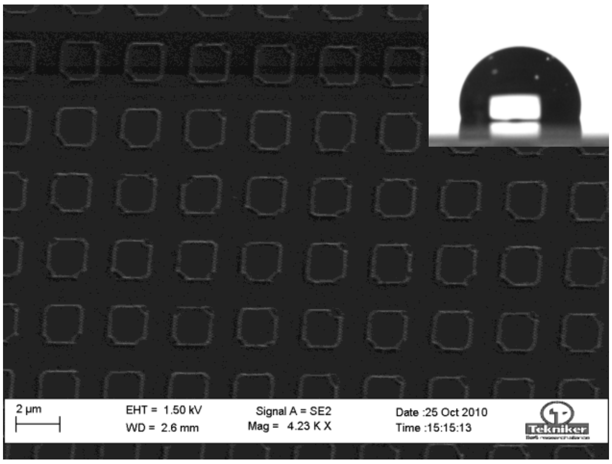

Figure 1.- SEM micrographs of ZnO-gel patterns