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ABSTRACT

Title	Processing and Contact Mechanics of Sol-Gel Derived Organic/Inorganic Hybrid Films for Micro/Nano-Patterning Application

(800 words)

The sol–gel process route possesses a number of advantages over conventional film formation techniques, such as low processing temperature and time, easy coating of large surface, possible formation of porous films, homogeneous multi component oxide films, and simple and cheap experimental setups. Improved mechanical and chemical resistance is in an increasing demand in a variety of coating applications. Organic–inorganic sol–gel hybrid materials are a material class which has attracted considerable attention in many research fields, because they offer a very high degree of flexibility to design their mechanical, physical and chemical properties, as a function of the application.

Hybrid films of Phenyl(Ph)$SiO_{3/2}$-Methyl(Me)$SiO_{3/2}$, and Organo(R)$SiO_{3/2}$-TiO_2 systems were prepared and studied. The final purpose of the study is elucidating the effect of molecular structures of hybrid films on their mechanical properties and founding a new thick-film technology for micro/nano-patterning. There are two ways of micro/nano-patterning hybrid films, either by heat treatment or light irradiation. These two techniques give changes to the structural of the hybrid films that will affect the mechanical properties. The rheological transition associated with the condensation reactions from the sol to the gel is elucidated in nanoindentation load tests.

In the first study, the effects of the heat-treatment-temperature and the heat-treatment-time on the process of gelation and hardening of $PhSiO_{3/2}$-$MeSiO_{3/2}$ hybrid films were studied. The results show that the partial replacement of $PhSiO_{3/2}$ by $MeSiO_{3/2}$ in the films initially increased the hardness and elastic modulus value. The changes in the mechanical properties were found to correlate with the decrease in hydroxyl content in the films and the development of Si-O-Si network structure. By utilizing the same concept, $RSiO_{3/2}$-TiO_2 hybrids were prepared. Incorporation with small amount of TiO_2 enhances the mechanical properties of the $RSiO_{3/2}$-TiO_2 films, which is essential to modify the viscoelasticity of the films. On the basis of these changes in properties, titania component is essential to give greater effects of mechanical properties of $RSiO_{3/2}$ films.

In the second study, hardening of hybrid films by light irradiation was studied. First part of this study was regarding the photocatalytic micro/nano-patternings of transparent $RSiO_{3/2}$-TiO_2 hybrid films. The hybrid films were irradiated with ultraviolet (UV) light using an ultrahigh pressure mercury lamp with different irradiation time. UV irradiation stimulated structural changes of the cleavage of Si-C bonds by photocatalytic activity of the TiO_2 component during irradiation. The observed changes in the surface profile, optical, chemical and mechanical properties of the $RSiO_{3/2}$-TiO_2 hybrid films induced by UV irradiation make them promising for micro/nano-patterning by photolithography. The influence of different UV irradiation time and intensity on $RSiO_{3/2}$ hybrid films was also studied as the second part. Results show that the exposure time and developing time are very important to fabricate the micro/nano-patterns. The UV exposure time will affect the final depth of the resultant pattern. Therefore, a high exposure UV power and the best selection of the organic group in silsesquioxane are useful to shorten the exposure time of the hybrid films. Vinyl(Vi)$SiO_{3/2}$ hybrid films was found to show rapid increases in the mechanical properties due to its feature that contain C=C bonds and shorter organic chain, in comparison with $PhSiO_{3/2}$ and $MeSiO_{3/2}$ hybrid films.

Based on all the studies, it can be concluded that embossing and photolithography using sol-gel derived hybrids are promising processes for the micro/nano-patterning application.