layer inhomogeneous forms, which possess a gradient refractive index (GRIN) are most effective in suppressing the Fresnel reflections at an interface. They impart anti-reflective property to an interface not only over a broad spectral range but also over wider angles of incidence. Conventionally, a gradient refractive index (GRIN) has been achieved by depositing multiple layers of materials of successively reducing refractive index. However, multi-layer ARCs often deteriorate over time because of the debonding caused by thermal mismatch and poor interfacial adhesion. Incompatible mechanical and thermal properties of polymer antireflective surfaces and their durability pose major operational challenges for applications of GRIN.

There is therefore a need to provide a coating material and antireflective material comprising a substrate coated with the coating material that overcomes or at least ameliorates, one or more of the disadvantages described above.

Summary

According to the disclosure, fabrication of a highly durable and mechanically superior anti-reflective coating (ARC) by nanoimprint lithography of polyhedral oligomeric silsesquioxane-based (POSS) material on a glass substrate is demonstrated.

In the disclosure, there is provided a UV-curable coating material for a nanoimprint coating process comprising an organosilica compound having a UV-curable functional group and at least one UV-curable cross-linker.

In an aspect, there is provided a UV-curable coating material for a nanoimprint coating process comprising an organosilica compound having a UV-curable functional group and at least two UV-curable cross-linkers, wherein one UV-curable cross-linker is 1,6-hexanediol diacrylate at an amount in the range of 25 wt% to 70 wt%; and the other UV-curable cross-linker(s) is pentaerythritol tetrakis(3-mercaptopropionate) or a mixture of pentanediol tetraacrylate and pentaerythritol tetrakis(3-mercaptopropionate) at an amount in the range of 0 wt% to 30 wt%.

Advantageously, the UV-curable coating material may comprise an organosilica compound such as polyhedral oligomeric silsesquioxane (POSS). The inclusion of POSS may dramatically enhance its properties resulting in oxidation resistance, surface hardening, flammability reduction and mechanically improved hybrids. POSS may enhance the mechanical strength and stability, durability and adherence to a substrate. POSS may enhance the mechanical and chemical robustness of the coating.

Further advantageously, the coating material may comprise UV-curable cross-linking groups. The UV-curable cross-linking groups may enhance the hardness of the cured coating and reduce the brittleness of the cured coating. The UV-curable cross-linking groups may be acrylates, including diacrylates triacrylates and tetraacrylates. The hardness of the cured coating may be enhanced by the use of acrylates such as tetraacrylates. Further advantageously, the harness of the cured coating may be further increased by using mercapto reagents to reduce oxygen inhibition when being cured.

Advantageously, by having both an organosilica compound and UV-curable cross-linking groups in the coating material, the cured coating may be harder and less brittle compared to conventional ARCs.

In the disclosure, there is provided a coating comprising an organosilica compound cross-linked by at least one UV-curable cross-linker, wherein the coating comprises surface structures in the nano-sized range.

In another aspect, there is provided a coating comprising an organosilica compound cross-linked by at least two UV-curable cross-linkers, wherein the coating comprises surface structures in the nano-sized range and wherein one UV-curable cross-linker is 1,6-hexanediol diacrylate at an amount in the range of 25 wt% to 70 wt%; and the other UV-curable cross-linker(s) is pentaerythritol tetrakis(3-mercaptopropionate) or a mixture of pentanediol tetraacrylate and pentaerythritol tetrakis(3-mercaptopropionate) at an amount in the range of 0 wt% to 30 wt%.

Advantageously, the present disclosure provides a durable, chemically and thermally stable high-performance ARC on glass. Advantageously, the ARC coating may be produced by fabricating an array of topographical structures that can impart new functionalities to a material without chemically altering it. These imprinted structures may be bio-inspired and can mimic such effects as self-cleaning (lotus leaf), dry adhesion (gecko-foot), colour (butterfly wings) and anti-reflection (moth-eye).

Advantageously, the ARC may be achieved by creating gradient refractive index (GRIN) on the surface of the glass. Nanostructures emulating the moth's eye morphology may confer the advantages of GRIN such as broadband and quasi-omnidirectional antireflective properties. Moth's eye nanostructures being monolithic and comprising a single material may be robust. The graded transition in refractive index in the corneal lens of moth's eye may be attributed to the presence of hexagonally packed arrays of sub-200 nm protuberances. The individual structures may be shaped like cones and are close packed, so that they are joined at the base. Advantageously, since these subwavelength protuberances are closely packed, incident light may interact with them fully rather than resolving them structurally. Due to this interaction of light waves with what effectively appears to be a smooth transition in refractive index from air to substrate due to the moth's eye nanostructures at the interface, transmittance of incident light with wavelength larger than the spacing period may be greatly enhanced.

Advantageously, the dimensions of the structures may be less than the wavelength of light that is required to be transmitted. This may circumvent the issue that if the structures are larger than the wavelength of the incident light, the light will interact with the structures individually and a proportion of that light will be reflected and scattered. Advantageously, when the structures are smaller than the wavelength of the incident light, then the light may interact with the structures wholly, thereby treating it as a medium of gradually increasing RI. If the structured media and the substrate media are made from different materials, then it may be advantageous for the material of the structures (in bulk form) and the material of the substrate to have the same RI, so to limit the reflection at the interface between the two materials.

Further advantageously, nanoimprinting lithography (NIL) is a surface patterning technique that may offer resolutions anywhere from several hundred microns down to about 5 nm. NIL may involve transferring surface relief from a template to a thin film on a substrate by embossing onto the thin film. Advantageously, UV-assisted NIL may use UV-curable monomers. UV imprinting may utilise materials that may be cured by UV exposure. In comparison to optical lithography, NIL may be simple and economical and may offer extremely good resolution with relatively faster replication.

Claims

1. A UV-curable coating material for a nanoimprint coating process comprising an organosilica compound having a UV-curable functional group and at least two UV-curable cross-linkers, wherein one UV-curable cross-linker is 1,6-hexanediol diacrylate at an amount in the range of 25 wt% to 70 wt%; and the other UV-curable cross-linker(s) is pentaerythritol tetrakis(3-mercaptopropionate) or a mixture of pentanediol tetraacrylate and pentaerythritol tetrakis(3-mercaptopropionate) at an amount in the range of 0 wt% to 30 wt%.

2. The coating material according to claim 1, wherein the nanoimprint coating process produces surface structures that are cone shaped.

3. The coating material according to claim 2, wherein the surface structures have dimensions less than the wavelength of visible light or in the range of 100 nm to 390 nm.

4. The coating material according to claim 3, wherein the surface structures have a diameter in the range of 150 nm to 350 nm, a height in the range of 250 nm to 390 nm, and a peak-to-peak distance of 250 nm to 330 nm.

5. The coating material according to any one of the preceding claims, comprising a photoinitiator.

6. The coating material according to any one of the preceding claims, wherein the organosilica compound comprising the UV-curable functional group is present at an amount in the range of 5 to 45 wt%, the cross-linker is present in an amount in the range of 10 to 75 wt%, the photoinitiator is present at an amount in the range of 1 to 10 wt%, and wherein the total wt% of organosilica compound, cross-linker and photoinitiator is 100%.

7. The coating material according to any one of the preceding claims, wherein the organosilica compound is polyhedral oligomeric silsesquioxane (POSS) or octahedral oligomeric silsesquioxane.

8. The coating material according to claim 8, wherein the UV-curable functional group is selected from the group consisting of acrylate, alkyl methacrylate, alkyl acrylate, methacrylate, maleate, styrene, epoxy, vinyl ether, acrylopropyl, methyl methacrylate, ethyl methacrylate, propyl methacrylate, butyl methacrylate, pentyl methacrylate, methyl acrylate, ethyl acrylate, propyl acrylate, butyl acrylate, pentyl acrylate and any mixture thereof.

9. The coating material according to any one of claims 5 to 8, wherein the photoinitiator is selected from the group consisting of 2-hydroxy-2-methylpropiophenone, 1-hydroxycyclohexyl phenyl ketone, 2-methylbenzophenone, methyl benzoylformate, 3-methylbenzophenone and any mixture thereof.

10. A coating comprising an organosilica compound cross-linked by at least two UV-curable cross-linkers, wherein the coating comprises surface structures in the nano-sized range and wherein one UV-curable cross-linker is 1,6-hexanediol diacrylate at an amount in the range of 25 wt% to 70 wt%; and the other UV-curable cross-linker(s) is pentaerythritol tetrakis(3-mercaptopropionate) or a mixture of pentanediol tetraacrylate and pentaerythritol tetrakis(3-mercaptopropionate) at an amount in the range of 0 wt% to 30 wt%.

11. The coating according to claim 10, wherein the surface structures are cone shaped and have dimensions less than the wavelength of visible light or in the range of 100 nm to 390 nm.

12. The coating according to claim 10 or 11, wherein the organosilica compound is polyhedral oligomeric silsesquioxane (POSS) or octahedral oligomeric silsesquioxane.

13. An anti-reflective material comprising a substrate coated with the coating material of any one of claims 1 to 9.

14. The anti-reflective material according to claim 13, comprising an adhesion promoter or 3-(trimethoxysilyl)propyl methacrylate (TPMA) between the substrate and the coating material.

15. The anti-reflective material according to claim 13 or 14, wherein the organosilica compound having a UV-curable functional group and the at least two UV-curable cross-linkers of the coating material according to any one of claims 1 to 9 are cross-linked with covalent bonds.

16. The anti-reflective material according to any one of claims 13 to 15, wherein the substrate is a glass sheet, and the coating material of any one of claims 1 to 9 is coated on one side of the glass sheet or both sides of the glass sheet.

17. An anti-reflective material comprising a substrate coated with the coating of any one of claims 10 to 12.