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 pentanediol tetraacrylate and/or 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 pentanediol tetraacrylate and/or 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.

Further advantageously, UV-curing may offer increased hardness of the coating when cured, compared to resins that are thermally cured. Further advantageously, the cross-linking between the organosilica compound such as POSS having a UV-curable functional group and the UV-curable cross-linkers may facilitate covalent bond formation between the POSS monomer units thus avoiding any macrophase separation by possible agglomeration of the POSS units. 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.

Advantageously, the coating of the present disclosure may allow transmission of visible light of up to 99.4%, thereby minimising reflectance. Further advantageously, the coating may have a hardness of up to 8H on a pencil hardness test, thereby having improved anti-scratch properties. Further advantageously, the coating of the present disclosure may have higher transmission and lower reflectance measurements compared to conventional ARCs. More advantageously, the improved properties of the coating may be due to the formulation of the coating material, the imprinting process or a combination of both.

Further advantageously, the use of sub-wavelength structures instead of thin films to produce antireflective coatings may allow higher transmission of light over a broader range of incidence angles.

In another aspect, there is provided an anti-reflective material comprising a substrate coated with the coating material as defined above.

In yet another aspect, there is provided an anti-reflective material comprising a substrate coated with the coating as defined above.

Advantageously, the coating or the coating material may be coated on one side of the substrate or both sides of the substrate. Further advantageously, if the coating material or coating is coated on both sides of the substrate, then antireflective properties may be conferred in both directions of light transmission.

In the disclosure, there is provided a method of synthesizing the anti-reflective material as defined above, comprising the steps of: providing a substrate; coating the substrate with the coating material as defined above; pressing a mold against the coating material to form a nano-sized imprint thereon; and curing with UV-radiation.

In a further aspect, there is provided a method of making the anti-reflective material as defined above, comprising the steps of: providing a substrate; coating the substrate with the coating material as defined above; pressing a mold against the coating material to form a nano-sized imprint thereon; and curing with UV-radiation.

Advantageously, the method may be easy to upscale, as it may be roll-to plate processable. This may overcome the limitation of conventional methods such as when thermal curing is used, which would limit the method to relatively small substrates (less than 4 inch substrates) and only to batch style processes. Further advantageously, the use of UV-curing may enable curing of the coating within a duration of about 20 seconds to about 80 seconds, which is a significantly shorter period of time than the time it may take to cure the coating using conventional methods, for example, when thermal curing is used. This may facilitate faster manufacture of the coating and/or the antireflective material, and may enable the coating and antireflective material to be manufactured on a larger scale.