[05] The object of the present application is to provide a micro-optical element having a glass substrate and a microstructure layer bonded with each other and having high stability due to tight bonding between the glass substrate and the microstructure layer.

[06] This object is solved by a glass substrate with specific glass composition and optimized geometrical, surface properties as claimed in the independent claims. Glass composition with high non-bridge oxygen (NBO) or active oxygen can generate OH^-, which can increase the bonding strength with microstructure layer. The glass substrate has suitable total thickness variation (TTV), thickness tolerance, and warp, which are benefit to get high bonding strength with a consistent microstructure layer. High TTV and warp are not benefit to get stable production process of microstructured polymer layer because the thickness of polymer is influenced by the TTV and warp of glass. On the other hand, the microstructure layer can also be influenced by glass roughness during spin coating, spray coating, deposition or imprinting process. Low glass roughness is benefit to polymer spread on glass, which is good to form consistent microstructure layer.

[06a] In accordance with an aspect of the present application, there is provided a micro-optical element comprising: a glass substrate with a thickness $t \leqslant 1500$ µm, preferably $t \leqslant 1200$ µm, more preferably $t \leqslant 1100$ µm; and a microstructure layer formed from polymer imprinted on the glass substrate. The bonding strength between microstructure layer and glass substrate is higher than 0.5MPa, preferably higher than 1MPa, more preferably higher than 1.5MPa. The glass substrate has a Total Thickness Variation TTV $\leqslant$ 40µm, preferably TTV $\leqslant$ 30 µm, more preferably TTV $\leqslant$ 20 µm, in particular preferably TTV $\leqslant$ 10 µm and most probably TTV $\leqslant$ 5 µm. The glass substrate has a thickness tolerance $\delta \leqslant$ 80 um, preferably $\delta \leqslant$ 50 µm, more preferably $\delta \leqslant$ 20 µm, further preferably $\delta \leqslant$ 10 µm, in particular preferably $\delta \leqslant$ 5 µm, and most preferably $\delta \leqslant$ 2 µm.

[07] In an embodiment, a micro-optical element comprising: a glass substrate and a microstructure layer. The glass substrate has a thickness t ≤ 1500 µm, preferably t ≤ 1200 µm, more preferably t ≤ 1100 µm; and other thickness ≤900um, 800um, 700um, 500um, 400um, 300um, 200um, 100um can also be used. But the thickness of glass in this patent does not restrict within the mentioned thickness above. The microstructure layer formed from polymer is imprinted on the glass substrate. The microstructure has an optical functions by optical design. The microstructure could be any structure (e.g., Hemisphere,

multistep, circle, square) which can generate refractive effect or diffractive effect in optics according to optical design. The glass substrate exhibits a glue contact angle θg of less than 35 °, preferably less than 25 °, more preferably less than 15 °. The bonding strength P is defined the minimum pressure than can separate microstructure layer from glass substrate. The bonding strength between the glass substrate and the microstructure layer is larger than 0.5MPa, preferably higher than 1MPa, more preferably higher than 1.5MPa The regression of bonding strength is less than 60%, preferably less than 50%, more preferably less than 40% after 1000 times of cycle at 85°C temperature and 85% humidity.

[08] In a further preferable embodiment, the glass substrate has a refractive index n_d in a range from 1.4 to 2.5, preferably in a range from 1.41 to 2.1, preferably in a range from 1.42 to 2.0,

[19] In a further preferable embodiment, the difference of the refractive index n_d between the glass substrate and the microstructure layer $\Delta n_d \leq 0.5$.

[20] In this embodiment, diffractive optical elements, DOEs, were designed for applications with lasers and high-power lasers. Used as multi-spot beam splitters, in beam shaping, and beam profile modification, such elements offer endless possibilities in different application fields. The DOE is adoptable for the application in optics, in particular diffractive optical element or refractive optical element, all these optical elements can be in the 3D imaging and sensing fields or the fields that needs the function of depth detection or recognition such as entertainment, posture recognition, tracking of hand articulations, and facial recognition system, augment reality, virtue reality.

[21] In a further preferable embodiment, the glass substrate is made of a glass selected from the group consisting of silicate glasses, borosilicate glass, aluminosilicate glasses, aluminum borosilicate glass, soda lime glass and lithium aluminum silicate glass (LAS).

[22] In a further preferably embodiment, the microstructure layer consists of a polymer selected from the group consisting of epoxy resins and acrylic resins. Polymer may contain some inorganic material, e.g. SiO_2, to increase refractive index of the polymer. But the polymer is not limited to the above mentioned polymers. Any polymer that can form the desired microstructure can be used to make the microstructure layer.

[22a] In accordance with another aspect of the present application, there is provided a method for manufacturing the micro-optical element as described herein. The method includes the following steps: providing a glass substrate with a thickness $t \leqslant 1500$ µm, preferably $t \leqslant 1200$ µm, more preferably $t \leqslant 1100$ µm, and wherein the glass substrate has a Total Thickness Variation TTV $\leqslant$ 40µm, preferably TTV $\leqslant$ 30 µm, more preferably TTV $\leqslant$ 20 µm, in particular preferably TTV $\leqslant$ 10 µm and most probably TTV $\leqslant$ 5 µm; the glass substrate has a thickness tolerance $\delta \leqslant 80$ um, preferably $\delta \leqslant 50$ µm, more preferably $\delta \leqslant 20$ µm, further preferably $\delta \leqslant 10$ µm, in particular preferably $\delta \leqslant 5$ µm and most preferably $\delta \leqslant 2$ µm; and applying a microstructured polymer layer to the glass substrate to form a microstructure layer.

[23] In another embodiment, a method for manufacturing the micro-optical element mentioned above is provided. The method includes the following steps:

- providing a glass substrate with a thickness t ≤ 1500 µm, preferably t ≤ 1200 µm, more preferably t ≤ 1100 µm, and wherein the glass substrate has a Total Thickness Variation TTV ≤ 40µm, preferably TTV ≤ 30 µm, more preferably TTV ≤ 20 µm, in particular preferably TTV ≤ 10 µm and most probably TTV ≤ 5 µm; the glass substrate has a thickness tolerance δ ≤ 80 um, preferably δ ≤ 50 µm, more preferably δ ≤ 20 µm, further preferably δ ≤ 10 µm, in particular preferably δ ≤ 5 µm and most preferably δ ≤ 2 µm,

– applying a microstructured polymer layer to the glass substrate, wherein the microstructure profile can be periodic structure of pyramid, circle, triangle, square, jagged, diffraction grating comprising a metasurface having 2-phase level, asymmetric geometric phase optical elements and other unlimited optical elements according to the optical design.

[24] The application of the microstructured polymer layer to the glass substrate consists of the three major process steps: origination, replication, and pattern transfer, namely:

(a) polymer is deposited onto a substrate, and a UV-transparent template is positioned above;

(b) the template is pressed into the polymer and UV light or heat is shone through the template to cure the polymer; and

(c) the template is released leaving the cured polymer with the imprinted features, to form a microstructure layer, wherein the template can be made from metal, quartz or other suitable materials and the polymer can be cured by heating, UV flash or other suitable methods.

[25] In a further preferable embodiment, the microstructure layer can be alternatively applied by imprinting, spin coating, spray coating or deposition and not limited methods

[26] In a further preferable embodiment, the microstructure layer can be alternatively cured by thermal heating or similar method.

[27] In a further preferable embodiment, the microstructure layer can be applied onto two side surfaces of the glass substrate.

[28] In the present invention, the glass shows a high NBO number, and thus, the glass has more oxygen with negative charge (so called “active oxygen”). It is founded that higher NBO number or more active oxygen can generate a high active glass surface which can increase the wettability of the glass surface and reduce the water/glue contact angle. The good glass surface wettability and low water/glue contact angle is good to the bonding strength of glass and the glue, i.e., adhesive layer, which increases the stability.

[29] In accordance with yet another aspect, there is provided a use of the micro-optical element as described herein as a diffractive optical element, refractive lens, mirror, prism, GRIN len, hybrid element, diffuser in 3D imaging/sensor, augmented reality, Virtual reality, cameras, automated manufacturing systems, mobile communications.

Brief Introduction of Drawings