THIN FILM OPTICS

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. § 119 to Provisional Application No. 62/683,521 filed on June 11, 2018, in the United States Patent and Trademark Office, the entire contents of which is incorporated herein by reference for all purposes

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

TECHNICAL FIELD

[0003] This disclosure relates in general to optics and optical systems, and in particular to, for example, without limitation, thin film optics with a geometric phase to allow for high performance, and true free-form optics that can be achromatic, polarization-independent, and applies to both transmissive and reflective optics.

BACKGROUND

[0004] Conventional optics use a varying spatial profile with either distance or varying distance through a material with different index of refraction to impart a spatial profile of phase on a wavefront. This is true for both transmissive and reflective optics. While there has been much progress in improving manufacturing techniques, the same method of manufacturing optical elements employed over hundreds of years are still being used. While some newer materials allow for higher index of refraction with high transmission than was possible in the past, similar manufacturing constraints and mass production requirements remain as they have for the past several decades.

[0005] A novel and practical approach for low mass, low cost manufacturing of advanced and/or high performance optics and optical systems are desirable.

SUMMARY

[0006] In a first aspect, the present disclosure provides a method of manufacturing a thin film optical apparatus, the method comprising: providing a substrate; applying an alignment layer over the substrate, wherein the alignment layer ranges from ~~about~~ 50 to 100 ~~nm~~ nanometers in thickness; imprinting a hologram with a desired optic pattern onto the alignment layer; ~~and~~ applying at least one layer of mesogen material over the

alignment layer; and positioning a layer of reflective material between the alignment layer and the substrate. The optical apparatus may range in the order of about one-half to one wavelength thick.

[0007] In a second aspect, the present disclosure provides a method of manufacturing an optical apparatus, the method comprising: providing a substrate; applying at least one alignment layer above the substrate; writing a polarization phase hologram into the at least one alignment layer to impart the phase transform of a desired optical pattern; applying a layer of reflective material between the alignment layer and the substrate; and applying at least one layer of birefringent material over the alignment layer, wherein the at least one later of birefringent material ranges from ~~about~~ 200 nm to 2000 ~~nm~~ nanometer thick. The optical apparatus may range in the order of one-half to one wavelength in thickness.

[0008] The description in this summary section may provide some illustrative examples of the disclosure. This section is not intended to be a broad overview or to identify essential elements of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1A illustrates an exploded view of conventional or currently existing optical apparatuses (shown on the left) as compared with the thin film optical apparatus of the various embodiments of the present disclosure (shown on the right).

[0010] FIG. 1B is an illustration of a currently existing mid-wave infrared (MWIR) optical apparatus compared with a thin film mid-wave infrared MWIR optical apparatus of the various embodiments of the present disclosure.

[0011] FIG. 2 illustrates a true free-form thin film optical apparatus, including details of the structure of an achromatic, polarization-independent optical component, according to various embodiments of the present disclosure.

[0012] FIG. 3 illustrates a method of manufacturing the thin film optical apparatus in accordance with various embodiments of the present disclosure.

[0013] FIG. 4 illustrates a method and apparatus for converting a binary amplitude hologram to a phase hologram in accordance with various embodiments of the present disclosure.

[0014] FIGS. 5A and 5B illustrate methods and apparatus for rastering an incident light beam with phase control in accordance with various embodiments of the present disclosure.

[0015] FIG. 6 illustrates achromatic methods of manufacturing the thin film optical apparatus using two or more birefringent layers according to various embodiments of the present disclosure.

[0016] FIG. 7A illustrates polarization independent methods of manufacturing a thin film transmissive optical apparatus using orthogonal birefringent layers according to various embodiments of the present disclosure.

WHAT IS CLAIMED IS:

1. A method of manufacturing a thin film optical apparatus, the method comprising:

providing a substrate;

applying an alignment layer over the substrate, wherein the alignment layer ranges from ~~about~~ 50 to 100 ~~nm~~ nanometers in thickness;

imprinting a hologram with a desired optic pattern onto the alignment layer; ~~and~~

applying at least one layer of mesogen material over the alignment layer; and

positioning a layer of reflective material between the alignment layer and the substrate.

2. The method of Claim 1, further comprising curing and polymerizing the mesogen layer.

3. The method of Claim 1, wherein the applying the layer of mesogen material comprises spin coating the layer of mesogen material onto the alignment layer and aligning the layer of mesogen material over the alignment layer.

4. The method of Claim 1, wherein ~~the alignment layer comprises a thin layer having a magnitude of one half of a wavelength or less~~ imprinting the hologram comprises writing a polarization phase hologram into the alignment layer to impart a phase transform of the desired optical pattern, and wherein the method further comprises applying at least one layer of birefringent material over the alignment layer.

5. The method of Claim 1, wherein the imprinting the hologram onto the alignment layer comprises producing a hologram with a desired optic pattern by setting up a desired wavefront in a holographic interferometer.

6. The method of Claim 5, wherein producing the hologram with a desired optic pattern comprises imparting a geometric phase utilizing a polarization based holographic interferometer.

7. The method of Claim 6, wherein imparting the geometric phase comprises converting a binary amplitude hologram to a phase hologram.

8. The method of Claim 6, wherein the polarization based holographic interferometer comprises a Mach-Zehnder interferometer.

9. The method of Claim 5, wherein producing the hologram with a desired optic pattern comprises rastering an incident light beam with phase control.

10. The method of Claim 9, wherein rastering the incident light beam with phase control comprises:

moving the substrate along the Z-axis in order to accurately position the substrate within focus;

controlling polarization of the incident light beam; and

moving the substrate along X- and Y-axes of motion to yield the hologram with the desired optic pattern.

11. The method of Claim ~~9~~1, further comprising positioning a retarder between the layer of reflective material and the substrate~~wherein rastering the incident light beam with phase control comprises:~~

~~controlling polarization of the incident light beam; and~~

~~performing X-Y angle control of the incident light beam to accurately position the substrate within focus.~~

12. The method of Claim 1, wherein the applying at least one layer of mesogen material comprises applying at least two orthogonally oriented layers of mesogen material over the alignment layer.

13. A method of manufacturing an optical apparatus, the method comprising:

providing a substrate;

applying at least one alignment layer above the substrate;

writing a polarization phase hologram into the at least one alignment layer to impart the phase transform of a desired optical pattern; ~~and~~

applying a layer of reflective material between the alignment layer and the substrate; and

applying at least one layer of birefringent material over the alignment layer,

wherein the at least one layer of birefringent material ranges from ~~about~~ 200 nm to 2000 ~~nm~~ nanometers thick.

14. The method of Claim 13, further comprising positioning ~~a layer of reflective material and~~ a retarder between the ~~alignment~~ layer of reflective material and the substrate.

15. The method of Claim 14, wherein the applying at least one alignment layer and the applying at least one layer of birefringent material comprise:

applying a first alignment layer over the retarder;

applying a first layer of birefringent material over the first alignment layer;

applying a buffer layer over the first layer of birefringent material;

applying a second alignment layer over the buffer layer; and

applying a second layer of birefringent material over the second alignment layer, the second layer of birefringent material being oriented orthogonally relative to the first layer of birefringent material.

16. The method of Claim 15, further comprising:

annealing the first and second alignment layers and the first and second layers of birefringent material; and

curing the first and second alignment layers and the first and second layers of birefringent material with ultraviolet (UV) radiation in an oxygen free environment.

17. The method of Claim 13, wherein the applying at least one alignment layer and the applying at least one layer of birefringent material comprise:

applying a first alignment layer over the substrate;

applying a first layer of birefringent material over the first alignment layer;

applying a second alignment layer over the first layer of birefringent material; and

applying a second layer of birefringent material over the second alignment layer, the second layer of birefringent material being oriented orthogonally relative to the first layer of birefringent material.

18. The method of Claim 17, further comprising positioning a buffer layer between the first layer of birefringent material and the second alignment layer.

19. The method of Claim 18, further comprising:

applying a third alignment layer over the second layer of birefringent material;

applying a third layer of birefringent material over the third alignment layer;

applying a fourth alignment layer above the third layer of birefringent material; and

applying a fourth layer of birefringent material over the fourth alignment layer, the third layer of birefringent material being oriented orthogonally relative to the fourth layer of birefringent material.

20. The method of Claim 19, further comprising:

positioning a first buffer layer between the first layer of birefringent material and the second alignment layer; and

positioning a second buffer layer between the third layer of birefringent material and the fourth alignment layer.