

CLAIMS:

1 1. A method for introducing a customized variation of a geometric parameter in a nanoscale
2 pattern on a substrate, the method comprising:

3 conducting a nanoscale precision programmable profiling process on one or more regions
4 of said substrate with said nanoscale pattern, wherein said nanoscale precision programmable
5 profiling process is used to deposit a profiling film with a thickness profile that is a function of
6 said customized variation of said geometric parameter in said nanoscale pattern; and

7 conducting a plasma etch process of said profiling film and material of said nanoscale
8 pattern that converts said thickness profile of said profiling film into said customized variation of
9 said geometric parameter in said nanoscale pattern, wherein said customized variation is a
10 function of said thickness profile of said profiling film.

1 2. The method as recited in claim 1, wherein said nanoscale pattern is one or more of the
2 following: a 1D diffraction grating, a 2D diffraction grating, a multilevel grating, a slanted
3 grating, a surface relief gratings, a Bragg grating, a volume hologram, and a photonic crystal.

1 3. The method as recited in claim 1, wherein said substrate is a high-index waveguide
2 substrate, wherein said method is executed on a patterned side of said high-index waveguide
3 substrate, and wherein said nanoscale pattern comprises a diffractive optical element.

1 4. The method as recited in claim 1, wherein said geometric parameter comprises one or
2 more of the following: a depth or a height of a feature, a lateral width of a feature, and an angle
3 of one dimension with respect to a horizontal plane.

1 5. The method as recited in claim 1, wherein one or more properties of said customized
2 variation is different for different regions of said nanoscale pattern on said substrate.

1 6. The method as recited in claim 1, wherein said conducting of said nanoscale precision
2 programmable profiling process and said conducting of said plasma etch process are carried out
3 simultaneously across a plurality of regions of said nanoscale pattern on said substrate.

1 7. The method as recited in claim 1, wherein said customized variation is achieved in
2 multiple iterations of said conducting of said nanoscale precision programmable profiling
3 process and said conducting of said plasma etch process.

1 8. The method as recited in claim 1, wherein an average surface roughness of said nanoscale
2 pattern with said customized variation is substantially equivalent to an average surface roughness
3 of said nanoscale pattern without said customized variation.

1 9. The method as recited in claim 1, wherein a ratio of etch rates of said profiling film and
2 said nanoscale pattern material is substantially matched.

1 10. The method as recited in claim 1, wherein a ratio of etch rates of said profiling film and
2 said nanoscale pattern material is tunable between 0.05 and 20.

1 11. The method as recited in claim 1, wherein a customized spatial variation is accomplished
2 in said profiling film using one or more of the following: an inkjet, differential heating with a
3 superstrate, and differential heating without a superstrate.

1 12. The method as recited in claim 1, wherein said profiling film has an optical property that
2 is substantially matched with said nanoscale pattern.

1 13. A method for correcting one or more aberrations in a waveguide substrate, the method
2 comprising:

3 performing a nanoscale precision programmable profiling process on an unpatterned
4 portion of said waveguide substrate by depositing a profiling film on said unpatterned portion of
5 said waveguide substrate with a customized variation to correct for said one or more aberrations
6 in said waveguide substrate.

1 14. The method as recited in claim 13 further comprising:

2 performing a plasma etch of said profiling film to transfer a desired profile to an
3 underlying material of said profiling film.

1 15. The method as recited in claim 13, wherein said unpatterned portion of said waveguide
2 substrate lies on a surface of said waveguide substrate that does not contain diffractive optical
3 elements.

1 16. The method as recited in claim 13, wherein said unpatterned portion of said waveguide
2 substrate has a nanoscale texture.

1 17. The method as recited in claim 13, wherein said one or more aberrations result from one
2 or more of the following: substrate total thickness variation (TTV) errors and deposition of films.

1 18. An apparatus for introducing a customized variation of a geometric parameter in a
2 nanoscale pattern on a substrate, the apparatus comprising:

3 a profiling module, wherein said profiling module has an inkjet for depositing a profiling
4 film on a substrate with a thickness profile that is a function of said customized variation of said
5 geometric parameter in said nanoscale pattern on said substrate, wherein a plasma etch process is
6 conducted on said profiling film and material of said nanoscale pattern that converts said
7 thickness profile of said profiling film into said customized variation of said geometric parameter
8 in said nanoscale pattern on said substrate, wherein said customized variation is a function of
9 said thickness profile of said profiling film.

1 19. The apparatus as recited in claim 18, wherein said substrate comprises a waveguide
2 substrate, wherein said substrate has a region with an optical element with said customized
3 variation of said geometric parameter in said nanoscale pattern on said substrate.

1 20. An XR device, the device comprising:
2 a waveguide that is fabricated using nanoscale precision programmable profiling for one
3 or more of the following: introducing a customized variation in a geometric parameter of a
4 nanoscale pattern on said waveguide, correction of substrate flatness or total thickness variation
5 errors, and correction of image distortions or optical aberrations.