CLAIMS

1. A method of forming a blind via in a substrate, comprising:

conveying the substrate to a scanning chamber, the substrate comprising a conductive layer, a dielectric layer disposed on at least a portion of the conductive layer, and a mask layer disposed on at least a portion of the dielectric layer, the mask layer providing a substrate surface;

determining one or more properties of the blind via, the one or more properties comprising:

a top diameter of the blind via and a bottom diameter of the blind via, the blind via having a height from the top diameter to bottom diameter, the top diameter being greater than the bottom diameter;

a volume of the blind via, the volume corresponding to the top diameter, the bottom diameter, and the height; or

a taper angle of about 80 degrees or more;

focusing a laser beam emitted from a laser source, under laser process parameters, at the substrate surface to remove at least a portion of the mask layer;

adjusting the laser process parameters based on the one or more properties; and

focusing the laser beam, under the adjusted laser process parameters, to remove at least a portion of the dielectric layer within the volume to form the blind via.

2. The method of claim 1, wherein the laser process parameters include a laser power, a laser energy in a burst, a focal beam diameter, a focus height, a burst energy, a pulse energy, a number of pulses in a burst, a pulse frequency, a burst frequency, a beam spot size, an M2 value, an offset of beam focusing from substrate surface, or a combination thereof.

3. The method of claim 1, wherein the laser process parameters comprise:

an amount of laser energy in a burst of about 5 μJ or more;

a focal beam diameter that is from about 2 μm to about 10 μm for drilling 5 μm diameter vias;

a focal beam diameter that is from about 7 μm to about 12 μm for drilling 10 μm diameter vias;

a focus height that is from about 0 μm to about 50 μm;

a pulse frequency that is about 500 MHz or more;

a number of pulses in a burst that is about 2 or more;

a number of bursts of about 2 or more;

a burst frequency of about 100 kHz or more; or

a combination thereof.

4. The method of claim 1, wherein the top diameter is about 10 μm or less.

5. The method of claim 1 further comprising removing the mask layer from the substrate.

6. The method of claim 1, wherein:

the mask layer comprises Al, Cu, W, Mo, Cr, or a combination thereof;

the mask layer has a height of about 2 μm or less; or

a combination thereof.

7. The method of claim 6, wherein when the mask layer comprises Mo or W, the method further comprises depositing a layer of copper on the mask layer.

8. The method of claim 1, wherein the laser source is a femtosecond ultraviolet laser with a wavelength of about 400 nm or shorter.

9. A method of forming a blind via in a substrate, comprising:

conveying the substrate to a scanning chamber, the substrate comprising a conductive layer of about 2 um or more in height, a dielectric layer disposed on at least a portion of the conductive layer, and a pre-etched mask layer disposed on at least a portion

of the dielectric layer, the pre-etched mask layer having blind via openings to expose at least a portion of the dielectric layer and the dielectric layer providing a substrate surface;

determining one or more properties of the blind via, the one or more properties comprising:

a top diameter of the blind via and a bottom diameter of the blind via, the blind via having a height from the top diameter to bottom diameter, the top diameter being greater than the bottom diameter, and the top diameter corresponding to the blind via openings;

a volume of the blind via, the volume corresponding to the top diameter, the bottom diameter, and the height; or

a taper angle of 80 degrees or more;

focusing a laser beam emitted from a laser source, under laser process parameters, at the substrate surface to remove a first portion of the dielectric layer within the volume without causing more than half-of-the thickness of mask layer damage to the pre-etched mask layer;

adjusting laser process parameters based on the one or more properties; and

focusing the laser beam, under the adjusted laser process parameters, to remove a second portion of the dielectric layer within the volume to form the blind via.

10. The method of claim 9, wherein the laser process parameters include a laser power, a laser energy in a burst, a focal beam diameter, a focus height, a burst energy, a pulse energy, a number of pulses in a burst, a pulse frequency, a burst frequency, a beam spot size, an M2 value, an offset of beam focusing from substrate surface, or a combination thereof.

11. The method of claim 9, wherein the laser process parameters comprise:

an amount of laser energy in a burst of about 5 μJ or more;

a focal beam diameter that is from about 2 μm to about 10 μm for drilling 5 μm diameter vias;

a focal beam diameter that is from about 7 μm to about 12 μm for drilling 10 μm diameter vias;

a focus height that is from about 0 μm to about 50 μm;

a pulse frequency that is about 500 MHz or more;

a number of pulses in a burst that is about 2 or more;

a number of bursts of about 2 or more;

a burst frequency of about 100 kHz or more; or

a combination thereof.

12. The method of claim 9, wherein the top diameter is about 10 μm or less.

13. The method of claim 9 further comprising removing the pre-etched mask layer from the substrate.

14. The method of claim 9, wherein:

the pre-etched mask layer comprises Al, Cu, W, Mo, Cr, or a combination thereof;

the pre-etched mask layer has a height of 3 μm or less; or

a combination thereof.

15. The method of claim 14, wherein when the pre-etched mask layer comprises Mo or W, the method further comprises depositing a layer of copper on the pre-etched mask layer.

16. The method of claim 9, wherein the laser source is a femtosecond ultraviolet laser.

17. An apparatus for forming a blind via in a substrate, comprising:

an optical device comprising:

a galvanometer scanner having a plurality of reflecting facets and an axis of rotation; and

a beam expander and collimator;

a femtosecond laser beam source configured to direct electromagnetic radiation to the beam expander;

a transport assembly configured to position the substrate to receive the electromagnetic radiation reflected from at least one of the reflecting facets of the galvanometer scanner;

a height sensor configured to detect a height of one or more layers of the substrate; and

a controller configured to:

receive signals from the height sensor; and

control the femtosecond beam laser source and the transport assembly based on signals received from the height sensor.

18. The apparatus of claim 17, wherein the femtosecond laser beam source is configured to emit a Gaussian laser beam profile.

19. The apparatus of claim 17, further comprising a positioning sensor configured to detect a leading edge of the substrate.

20. The apparatus of claim 19, wherein the controller is further configured to:

receive signals from the positioning sensor; and

control the control the femtosecond beam laser source and the transport assembly based on signals received from the positioning sensor.

21. The method of claim 1, wherein the mask layer comprises Cr.

22. The method of claim 9, wherein the mask layer comprises Cr.