CLAIMS

1. A method for circuit fabrication, comprising:

defining a solder bump, comprising a specified solder material and having a specified bump volume, to be formed at a target location on an acceptor substrate;

positioning a transparent donor substrate having opposing first and second surfaces and a donor film comprising the specified solder material on the second surface such that the donor film is in proximity to the target location on the acceptor substrate;

directing a sequence of pulses of laser radiation to pass through the first surface of the donor substrate and impinge on the donor film so as to induce ejection from the donor film onto the target location on the acceptor substrate of a number of molten droplets of the solder material such that the droplets deposited at the target location cumulatively reach the specified bump volume; and

heating the target location so that the deposited droplets melt and reflow to form the solder bump.

2. The method according to claim 1,

wherein the droplets have respective droplet volumes that depend on an intensity of the pulses of the laser radiation, and

wherein directing the sequence of the pulses comprises setting the intensity of the pulses of laser radiation and the number of the pulses in the sequence responsively to the specified bump volume.

3. The method according to claim 2,

wherein the droplet volumes further depend on a set of pulse parameters consisting of a spot size and duration of the pulses of the laser radiation, and

wherein directing the sequence of the pulses further comprises adjusting the droplet volumes by varying one or more of the pulse parameters.

4. The method according to claim 1,

wherein defining the solder bump comprises defining first and second solder bumps, having different, respective first and second bump volumes, at different, respective first and second target locations on the same acceptor substrate, and

wherein directing the sequence of pulses comprises directing different, first and second sequences of the pulses to pass through different points on the donor substrate so that the droplets cumulatively reach each of the different first and second bump volumes at the respective first and second target locations.

5. The method according to claim 4,

wherein defining the first and second solder bumps comprises specifying different, respective first and second compositions of the first and second solder bumps, and

wherein positioning the transparent donor substrate comprises providing one or more donor films comprising a plurality of different solder materials selected so as to produce the first and second compositions.

6. The method according to claim 1,

wherein defining the solder bump comprises defining first and second solder bumps, having different, respective first and second compositions, and

wherein positioning the transparent donor substrate comprises providing one or more donor films comprising a plurality of different solder materials so as to produce the first and second compositions.

7. The method according to claim 1,

wherein defining the solder bump comprises specifying a composition of the solder bump that includes different, first and second materials,

wherein positioning the transparent donor substrate comprises providing first and second donor films comprising the first and second materials, respectively, and

wherein directing the sequence of pulses comprises directing first and second sequences of the pulses to impinge respectively on the first and second donor films so that the droplets deposited at the target location cumulatively reach the specified composition.

8. The method according to claim 7,

wherein specifying the composition comprises specifying a gradient of the materials in the composition of the solder bump, and

wherein directing the first and second sequences of the pulses comprises depositing the droplets of the first and second materials in multiple layers on the target location in accordance with the specified gradient.

9. The method according to claim 1, wherein directing the sequence of the pulses comprises depositing the droplets in multiple layers on the target location so as to reach the specified bump volume.

10. The method according to claim 9, wherein heating the target location comprises alternately depositing a layer of droplets and heating the layer to melt the droplets multiple times until the specified bump volume is reached.

11. The method according to claim 1,

wherein defining the solder bump comprises specifying a shape of the solder bump, and

wherein directing the sequence of the pulses comprises depositing the molten droplets in a pattern that conforms to the specified shape.

12. The method according to claim 1, wherein heating the target location comprises directing a laser beam to irradiate the target location with sufficient energy to cause the deposited droplets to melt and reflow.

13. The method according to claim 1, further comprising printing a conductive pad at the target location on the acceptor substrate using a process of laser-induced forward transfer (LIFT), wherein directing the sequence of the pulses comprises depositing the molten droplets of the solder material on the printed conductive pad.

14. The method according to claim 13, wherein printing the conductive pad comprises forming a concavity in the conductive pad for deposition of the molten droplets therein.

15. A system for circuit fabrication, comprising:

a controller, which is configured to receive a definition of a solder bump, comprising a specified solder material and having a specified bump volume, to be formed at a target location on an acceptor substrate;

a printing station, which comprises:

a transparent donor substrate, which has opposing first and second surfaces and has a donor film comprising the specified solder material disposed on the second surface, and which is positioned such that the donor film is in proximity to the target location on the acceptor substrate; and

a laser, which is configured to direct a sequence of pulses of laser radiation to pass through the first surface of the donor substrate and impinge on the donor film so as to induce ejection of molten droplets of the solder material from the donor film onto the target location on the acceptor substrate, wherein the controller is configured to drive the printing station to eject a number of the droplets toward the target location such that the droplets deposited at the target location cumulatively reach the specified bump volume; and

a reflow station configured to heat the target location so that the deposited droplets melt and reflow to form the solder bump.

16. The system according to claim 15,

wherein the droplets have respective droplet volumes that depend on an intensity of the pulses of the laser radiation and on a set of pulse parameters consisting of a spot size and duration of the pulses of the laser radiation,

wherein the controller is configured to set the intensity of the pulses of laser radiation and the number of the pulses in the sequence responsively to the specified bump volume, and

wherein the controller is configured to adjust the droplet volumes by varying one or more of the pulse parameters.

17. The system according to claim 15,

wherein the controller is configured to receive definitions of first and second solder bumps, having different, respective first and second bump volumes, at different, respective first and second target locations on the same acceptor substrate,

wherein the controller is configured to drive the laser to direct different, first and second sequences of the pulses to pass through different points on the donor substrate so that the droplets cumulatively reach each of the different first and second bump volumes at the respective first and second target locations,

wherein the definitions of the first and second solder bumps specify different, respective first and second compositions of the first and second solder bumps,

wherein one or more donor films comprising a plurality of different solder materials are disposed on the second surface of the donor substrate, and

wherein the solder materials are selected so as to produce the first and second compositions.

18. The system according to claim 15,

wherein the controller is configured to receive definitions of first and second solder bumps, having different, respective first and second compositions, and

wherein one or more donor films comprising a plurality of different solder materials are disposed on the second surface of the donor substrate, wherein the solder materials are selected so as to produce the first and second compositions.

19. The system according to claim 15,

wherein the definition specifies a composition of the solder bump that includes different, first and second materials,

wherein the transparent donor substrate comprises first and second donor films comprising the first and second materials, respectively,

wherein the controller is configured to drive the printing station to direct first and second sequences of the pulses to impinge respectively on the first and second donor films so that the droplets deposited at the target location cumulatively reach the specified composition,

wherein the definition specifies a gradient of the materials in the composition of the solder bump, and

wherein the controller is configured to drive the printing station to deposit the droplets of the first and second materials in multiple layers on the target location in accordance with the specified gradient.

20. The system according to claim 15, wherein the controller is configured to drive the printing station to deposit the droplets in multiple layers on the target location so as to reach the specified bump volume.

21. The system according to claim 20, wherein the controller is configured to drive the printing station and the reflow station to alternately deposit a layer of droplets and heat the layer to melt the droplets multiple times until the specified bump volume is reached.

22. The system according to claim 15,

wherein the definition specifies a shape of the solder bump, and

wherein the controller is configured to drive the printing station to direct the sequence of the pulses so as to deposit the molten droplets in a pattern that conforms to the specified shape.

23. The system according to claim 15, wherein the printing station is configured to:

print a conductive pad at the target location on the acceptor substrate using a process of laser-induced forward transfer (LIFT), and

deposit the molten droplets of the solder material on the printed conductive pad.

24. The system according to claim 23, wherein the printing station is configured to print the conductive pad with a concavity for deposition of the molten droplets therein.

25. A method for circuit fabrication, comprising, for each of one or more target locations:

positioning a transparent donor substrate having opposing first and second surfaces and a donor film comprising a specified solder material on the second surface such that the donor film is in proximity to the target location on the acceptor substrate;

ejecting molten droplets of the solder material toward the target location by directing a sequence of pulses of laser radiation to pass through the first surface of the donor substrate and impinge on the donor film so as to induce ejection from the donor film onto the target location on the acceptor substrate of the molten droplets of the solder material such that the droplets deposited at the target location cumulatively reach the specified bump volume; and

focusing one or more pulses of a laser beam onto the target location with sufficient energy to cause the deposited droplets to melt and reflow so as to form solder bumps.

26. The method according to claim 25, wherein the pulses have a pulse duration no greater than 1 ms.

27. The method according to claim 26, wherein the pulses have a pulse duration less than 100 μs.

28. The method according to claim 25, wherein the pulses have a pulse energy no greater than 3 mJ.

29. The method according to claim 25, wherein focusing the one or more pulses comprises focusing a single, respective pulse of the laser beam onto the target location.