CLAIMS

1. A drug delivery device, comprising:

a microchip element which comprises a body portion defining at least one containment reservoir therein, wherein the body portion has an exterior wall having one or more drug release apertures in fluid communication with the at least one containment reservoir, the one or more drug release apertures being closed off by one or more corresponding reservoir caps configured to be electrically activated to unclose the one or more drug release apertures;

a drug formulation, which comprise a first drug, disposed in the at least one containment reservoir; and

a drug-permeable membrane secured next to the exterior wall of the body portion of the microchip element, wherein the device is configured to operate in an aqueous environment and, upon activation of the one or more reservoir caps, release the drug by diffusion through the drug-permeable membrane and into the aqueous environment.

2. The drug delivery device of claim 1, further comprising an outer housing wall secured in a position next to, and spaced a distance from, the exterior wall of the body portion of the microchip element, the outer housing wall comprising the drug-permeable membrane, wherein a depot space is defined between the drug-permeable membrane and the exterior wall of the body portion of the microchip element.

3. The drug delivery device of claim 1, wherein the outer housing wall further comprises a rigid frame supporting the drug-permeable membrane.

4. The drug delivery device of claim 3, wherein the rigid frame defines two or more windows of the drug-permeable membrane.

5. The drug delivery device of claim 3 or 4, wherein the rigid frame is part of a shell covering at least part of the microchip element.

6. The drug delivery device of any one of claims 1 to 5, wherein the drug-permeable membrane comprises a polymeric membrane.

7. The drug delivery device of claim 5, wherein the polymeric membrane comprises silicone, polyurethane, or a combination thereof.

8. The drug delivery device of any one of claims 1 to 7, wherein the at least one containment reservoir further comprises a water swellable charge material.

9. The drug delivery device of claim 8, wherein the water swellable charge material is in the form of a charge layer adjacent to a layer of the drug formulation, the drug formulation layer being disposed between the charge layer and the one or more drug release apertures.

10. The drug delivery device of claim 8, wherein the water swellable charge material is dispersed with the drug in the drug formulation.

11. The drug delivery device of any one of claims 8 to 10, wherein the water swellable charge material comprises a hydrophilic polymer.

12. The drug delivery device of any one of claims 8 to 10, wherein the water swellable charge material comprises hyaluronic acid.

13. The drug delivery device of any one of claims 1 to 12, wherein the drug formulation is in solid form, such as a tablet.

14. The drug delivery device of any one of claims 1 to 13, wherein the drug comprises a hormone.

15. The drug delivery device of claim 14, wherein the hormone is a contraceptive hormone, such as levonorgestrel.

16. The drug delivery device of any one of claims 1 to 15, wherein the at least one containment reservoir is a microreservoir.

17. The drug delivery device of any one of claims 1 to 16, wherein reservoir caps are configured to rupture by electrothermal ablation when electrically activated.

18. The drug delivery device of claim 2, which is configured to release the drug into the depot space and subsequently diffuse through the drug-permeable membrane and into the aqueous environment.

19. The drug delivery device of any one of claims 1 to 18, wherein the drug delivery device is an implantable drug delivery device and the aqueous environment is *in vivo* in a patient.

20. The drug delivery device of any one of claims 1 to 19, further comprising:

a second microchip element which comprises a body portion defining at least one containment reservoir therein, wherein the second body portion has an exterior wall having one or more drug release apertures in fluid communication with the at least one containment reservoir, the one or more drug release apertures being closed off by one or more corresponding reservoir caps configured to be electrically activated to unclose the one or more drug release apertures;

a drug formulation, which comprise a drug, disposed in the at least one containment reservoir of the second microchip element; and

a second drug-permeable membrane secured next to the exterior wall of the body portion of the second microchip element, wherein the device is configured, upon activation of the one or more reservoir caps of the second microchip element, to release the drug therefrom by diffusion through the second drug-permeable membrane and into the aqueous environment,

wherein, optionally, a second outer housing wall, which comprises the second drug permeable membrane is secured in a position next to, and spaced a distance from, the exterior wall of the body portion of the second microchip element, to define a second depot space between the second drug-permeable membrane and the exterior wall of the body portion of the second microchip element.

21. The drug delivery device of claim 20, further comprising a hermetic enclosure disposed between the microchip element and the second microchip element.

22. The drug delivery device of claim 21, wherein the hermetic enclosure is defined in part by a pair of printed circuit boards, each comprising a ceramic substrate.

23. The drug delivery device of claim 21 or 22, wherein hermetic enclosure contains electronic components configured for electrical activation of the reservoir caps of the microchip element and the second microchip element.

24. The drug delivery device of claim 2, which is an implantable drug delivery device, wherein:

the microchip element comprises a plurality of microreservoirs and the body portion has a plurality of drug release apertures in fluid communication with the microreservoirs, the plurality of drug release apertures being closed off by a plurality of corresponding reservoir caps configured to be ruptured by electrothermal ablation to open the drug release apertures;

the drug is disposed in each of the microreservoirs;

a water swellable charge material is disposed in each of the microreservoirs; and

the device is configured to operate *in vivo* by permitting interstitial fluid, following activation of one or more of the plurality of reservoir caps, to contact and be imbibed by the water swellable charge material disposed the microreservoirs corresponding to the activated reservoir cap(s), and thereby cause the charge material to swell and eject the drug out of the microreservoir(s) through the drug release apertures and into the depot space for subsequent diffusion through the drug-permeable membrane.

25. The drug delivery device of claim 24, wherein the polymeric membrane comprises silicone, polyurethane, or a combination thereof.

26. The drug delivery device of claim 24 or 25, wherein the water swellable charge material is in the form of a charge layer adjacent to a layer of the drug, the drug layer being disposed between the charge layer and the drug release apertures.

27. The drug delivery device of any one of claims 24 to 26, wherein the water swellable charge material comprises a hydrophilic polymer.

28. The drug delivery device of any one of claims 24 to 26, wherein the water swellable charge material comprises hyaluronic acid.

29. The drug delivery device of any one of claims 24 to 28, wherein the outer housing wall further comprises a rigid frame supporting the drug-permeable membrane.

30. The drug delivery device of claim 29, wherein the rigid frame defines two or more windows of the drug-permeable membrane.

31. The drug delivery device of claim 29 or 30, wherein the rigid frame is part of a shell covering at least part of the microchip element.

32. The drug delivery device of any one of claims 24 to 31, wherein the drug is in a solid form, such as a tablet.

33. The drug delivery device of any one of claims 24 to 32, wherein the drug comprises a hormone.

34. The drug delivery device of claim 33, wherein the hormone comprise a contraceptive hormone, such as levonorgestrel.

35. The drug delivery device of any one of claims 24 to 34, further comprising a hermetic enclosure fixed to the microchip element on a side opposed from the exterior wall and the depot space.

36. The drug delivery device of claim 35, wherein the hermetic enclosure is defined in part by a printed circuit board, which comprises a ceramic substrate.

37. The drug delivery device of claim 35 or 36, wherein hermetic enclosure contains electronic components configured for controlling rupture of the reservoir caps.

38. The drug delivery device of any one of claims 24 to 37, further comprising a second microchip element and a second exterior wall which comprises a second drug-permeable membrane, and which optionally defines a second drug depot space.

39. The drug delivery device of claim 1, wherein the exterior wall is in direct mechanical contact with the drug permeable membrane.

40. The drug delivery device of any one of claims 1 to 39, which is configured to release the drug from the activated at least one containment reservoir by a process comprising swelling of the drug formulation and/or by an extrusion process.

41. The drug delivery device of claim 40, wherein the at least one containment reservoir further comprises a water swellable charge material.

42. The drug delivery device of claim 41, wherein the water swellable charge material and the drug formulation in the at least one containment reservoir are combined in the form of at least one tablet.

43. The drug delivery device of claim 42, wherein the at least one tablet comprises a mixture of particles of the drug with one or more excipients comprising the water swellable charge material.

44. The drug delivery device of claim 43, wherein the drug particles have a median size from about 5 microns to about 12 microns.

45. The drug delivery device of any one of claims 42 to 44, wherein the at least one tablet is from about 10% to about 50% drug particles, by weight.

46. The drug delivery device of any one of claims 42 to 44, wherein the at least one tablet is from about 20% to about 45% drug particles, by weight.

47. The drug delivery device of any one of claims 42 to 44, wherein the at least one tablet is from about 30% to about 42% drug particles, by weight.

48. The drug delivery device of any one of claims 42 to 47, wherein the at least one tablet has a density from 1 mg/mm^3 to 1.3 mg/mm^3, a height from 0.67 mm to 0.95 mm, or both a density from 1 mg/mm^3 to 1.3 mg/mm^3 and a height from 0.67 mm to 0.95 mm.

49. The drug delivery device of any one of claims 40 to 48, wherein the drug permeable membrane has a surface area from 100 mm^2 to 200 mm^2, a thickness of from 70 µm to 75 µm, or both a surface area from 100 mm^2 to 200 mm^2 and a thickness of from 70 µm to 75 µm.

50. The drug delivery device of any one of claims 40 to 49, wherein the drug permeable membrane comprises silicone, has a surface area of about 200 mm^2, and has a thickness of about 72 µm.

51. The drug delivery device of claim 20, further comprising a hermetic enclosure, wherein (i) the hermetic enclosure is not disposed between the microchip element and the second microchip element, and (ii) the first and second microchip elements are disposed adjacent one another with their exterior walls facing in opposite directions.