CLAIMS

~~*What is claimed is:*~~

1. A method for filling an ampoule of a substrate processing apparatus, the method comprising:

(a) determining that an ampoule fill start condition for filling the ampoule with a liquid precursor is met;

(b) filling the ampoule with precursor, wherein filling the ampoule with the precursor is performed concurrent with at least one other substrate processing operation;

(c) ~~reading~~determining that a sensor level in the ampoule ~~indicating~~indicates that the ~~filling is not yet complete~~ampoule is not full, wherein a primary fill stop condition is met when the sensor level in the ampoule indicates that the ampoule is full;

(d) maintaining a cumulative time of filling the ampoule, wherein the cumulative time of filling the ampoule is all of the time that precursor is flowing to the ampoule since the cumulative time of filling the ampoule was last reset, wherein the cumulative time of filling the ampoule is reset when the sensor level in the ampoule indicates that the ampoule is full;

(~~d~~e) determining that a secondary fill stop condition is met, wherein the secondary fill stop condition comprises determining that the cumulative time of filling exceeds a threshold; and

(~~e~~f) in response to determining that the secondary fill stop condition is met and in response to determining that the sensor level in the ampoule indicates that the ampoule is not full, ceasing the filling of the ampoule with the precursor.

~~2. The method of claim 1, further comprising maintaining a cumulative time of filling starting at the end of the last time when the ampoule received the precursor, wherein the secondary fill stop condition comprises determining that the cumulative time of filling exceeds a threshold.~~

~~3~~2. The method of claim ~~2~~1, wherein the cumulative time of filling is temporarily stopped one or more times when ampoule refill temporarily ceases and deposition commences, but the cumulative time of filling restarts when filling starts again.

~~4~~3. The method of claim 1, wherein the threshold is between about 50 seconds and 90 seconds.

~~5~~4. The method of claim 1, further comprising initiating a soft shutdown when ceasing the filling in operation (e).

~~6~~5. The method of claim 1, wherein ~~the~~a sensor generating the sensor level in the ampoule is malfunctioning.

~~7~~6. The method of claim 1, wherein a system providing the liquid precursor to the ampoule is malfunctioning.

~~8~~7. The method of claim 1, wherein the ampoule fill start condition comprises determining that the substrate processing apparatus is in or is about to enter a phase during which agitation of the liquid precursor caused by filling the ampoule with the precursor would have a minimal effect on the consistency of substrates processed by the substrate processing apparatus.

~~9~~8. The method of claim 1, wherein the ampoule fill start condition comprises determining that a sequence of deposition operations has been completed on substrates contained in the substrate processing apparatus.

~~10~~9. The method of claim ~~9~~8, wherein the sequence of deposition operations are deposition operations associated with Atomic Layer Deposition.

~~11~~10. The method of claim 1, wherein the ampoule fill start condition includes determining that the precursor volume is below a threshold volume.

~~12~~11. The method of claim 1, wherein the ampoule fill start condition includes determining that setup for deposition operations is currently being performed.

~~13~~12. The method of claim 1, wherein the at least one other substrate processing operation that is performed concurrent with filling the ampoule includes a wafer indexing operation.

~~14~~13. The method of claim 1, wherein the at least one other substrate processing operation that is performed concurrent with filling the ampoule includes a temperature soak of the precursor and/or ~~the~~a substrate.

~~15~~14. The method of claim 1, wherein the at least one other substrate processing operation that is performed concurrent with filling the ampoule includes a pump to base operation.

~~16~~15. A method for controlling the filling an ampoule of a substrate processing apparatus comprising:

(a) starting a counter of the number of deposition cycles during which a precursor is delivered to a reaction chamber of the substrate processing apparatus, wherein the precursor is stored in liquid form in the ampoule;

(b) determining that an ampoule fill start condition is met;

(c) reading a sensor level in the ampoule indicating that the ampoule is sufficiently full that ~~the~~a liquid precursor should not be provided to the ampoule;

(d) determining that a number of deposition cycles counted by the counter exceeds a threshold; and

(e) in response to determining that the number of deposition cycles counted by the counter exceeds a threshold, ceasing the deposition cycles.

~~17~~16. The method of claim ~~16~~15, wherein the threshold comprises between about 3000 and 6000 deposition cycles.

~~18~~17. The method of claim ~~16~~15, wherein starting the counter in (a) occurs when the liquid precursor is delivered to the ampoule, and wherein the counter continues to count until liquid precursor is again delivered to the ampoule.

~~19~~18. The method of claim ~~16~~15, further comprising initiating a soft shutdown when ceasing the deposition cycles in operation (e).

~~20~~19. The method of claim ~~16~~15, wherein ~~the~~a sensor generating the sensor level in the ampoule is malfunctioning.

~~21~~20. The method of claim ~~16~~15, wherein the ampoule fill start condition comprises determining that the substrate processing apparatus is in or is about to enter a phase during which agitation of the liquid precursor caused by filling the ampoule with the precursor would have a minimal effect on the consistency of substrates processed by the substrate processing apparatus.

~~22~~21. The method of claim ~~16~~15, wherein the ampoule fill start condition comprises determining that a sequence of deposition operations has been completed on substrates contained in the substrate processing apparatus.

~~23~~22. The method of claim ~~22~~21, wherein ~~the~~a sequence of deposition operations are deposition operations associated with Atomic Layer Deposition.

~~24~~23. The method of claim ~~16~~15, wherein the ampoule fill start condition includes determining that setup for deposition operations is currently being performed.

~~25~~24. The method of claim ~~16~~15, wherein the ampoule fill start condition comprises one other substrate processing operation that is performed concurrent with filling the ampoule selected from the group consisting of a wafer indexing operation, a temperature soak of the precursor and/or the substrate, a pump to base operation.

~~26~~25. A precursor refill system comprising:

an ampoule configured to be fluidically connected to a precursor delivery system and a precursor source and configured to contain liquid precursor; and

one or more controllers configured to:

(a) start a counter of the number of deposition cycles during which a precursor is delivered to a reaction chamber of the substrate processing apparatus, wherein the precursor is stored in liquid form in the ampoule;

(b) determine that an ampoule fill start condition is met;

(c) read a sensor level in the ampoule indicating that the ampoule is sufficiently full that the liquid precursor should not be provided to the ampoule;

(d) determine that a number of deposition cycles counted by the counter exceeds a threshold; and

(e) in response to determining that the number of deposition cycles counted by the counter exceeds a threshold, cease the deposition cycles.

~~27~~26. The precursor refill system of claim ~~26~~25, wherein the threshold comprises between about 3000 and 6000 deposition cycles.

~~28~~27. The precursor refill system of claim ~~26~~25, wherein the one or more controllers are further configured to start the counter in (a) when the liquid precursor is delivered to the ampoule, and continue to count until liquid precursor is again delivered to the ampoule.

~~29~~28. The precursor refill system of claim ~~26~~25, wherein the one or more controllers are further configured to initiate a soft shutdown when ceasing the deposition cycles in operation (e).

~~30~~29. The precursor refill system of claim ~~26~~25, wherein the ampoule fill start condition comprises determining that the substrate processing apparatus is in or is about to enter a phase during which agitation of the liquid precursor caused by filling the ampoule with the precursor would have a minimal effect on the consistency of substrates processed by the substrate processing apparatus.

~~31~~30. The precursor refill system of claim ~~26~~25, wherein the ampoule fill start condition comprises determining that a sequence of deposition operations has been completed on substrates contained in the substrate processing apparatus.

~~32~~31. The precursor refill system of claim ~~26~~25, wherein the ampoule fill condition comprises one other substrate processing operation that is performed concurrent with filling the ampoule selected from the group consisting of a wafer indexing operation, a temperature soak of the precursor and/or the substrate, a pump to base operation.

~~33~~32. The ~~substrate processing apparatus~~precursor refill system of claim ~~26~~25, further comprising:

a deposition chamber; and

a substrate processing station contained within the deposition chamber, wherein the substrate processing station includes a substrate holder configured to receive a substrate and the precursor delivery system is configured to deliver precursor during processing of the substrate received by the substrate processing station.

~~34~~33. A ~~precursor refill system~~substrate processing apparatus comprising:

an ampoule configured to be fluidically connected to a precursor delivery system and a precursor source and configured to contain liquid precursor; and

one or more controllers configured to:

(a) determine that an ampoule fill start condition for filling the ampoule with a liquid precursor is met;

(b) fill the ampoule with precursor, wherein filling the ampoule with the precursor is performed concurrent with at least one other substrate processing operation;

(c) ~~read~~determine that a sensor level in the ampoule ~~indicating~~indicates that the ~~filling is not yet complete~~ampoule is not full, wherein a primary fill stop condition is met when the sensor level in the ampoule indicates that the ampoule is full;

(d) maintain a cumulative time of filling the ampoule, wherein the cumulative time of filling the ampoule is all of the time that precursor is flowing to the ampoule since the cumulative time of filling the ampoule was last reset, wherein the cumulative time of filling the ampoule is reset when the sensor level in the ampoule indicates that the ampoule is full;

(~~d~~e) determine that a secondary fill stop condition is met, wherein the secondary fill stop condition comprises determining that the cumulative time of filling exceeds a threshold; and

(~~e~~f) in response to determining that the secondary fill stop condition is met and in response to determining that the sensor level in the ampoule indicates that the ampoule is not full, cease the filling of the ampoule with the precursor.

~~35. The substrate processing apparatus of claim 34, wherein the one or more controllers are further configured to maintain a cumulative time of filling starting at the end of the last time when the ampoule received the precursor,~~
~~wherein the secondary fill stop condition comprises determining that the cumulative time of filling exceeds a threshold.~~

~~36~~34. The substrate processing apparatus of claim ~~35~~33, wherein the one or more controllers are further configured to temporarily stop the cumulative time of filling one or more times when ampoule refill temporarily ceases and deposition commences.

~~37~~35. The substrate processing apparatus of claim ~~34~~33, wherein the threshold is between about 50 seconds and 90 seconds.

~~38~~36. The substrate processing apparatus of claim ~~34~~33, wherein the one or more controllers are further configured to initiate a soft shutdown when ceasing the filling in operation (e).

~~39~~37. The substrate processing apparatus of claim ~~34~~33, wherein the ampoule fill start condition comprises determining that the substrate processing apparatus is in or is about to enter a phase during which agitation of the liquid precursor caused by filling the ampoule with the precursor would have a minimal effect on the consistency of substrates processed by the substrate processing apparatus.

~~40~~38. The substrate processing apparatus of claim ~~34~~33, wherein the ampoule fill start condition includes determining that the precursor volume is below a threshold volume.

~~41~~39. The substrate processing apparatus of claim ~~34~~33, wherein the at least one other substrate processing operation that is performed concurrent with filling the ampoule includes a temperature soak of the precursor and/or ~~the~~a substrate.

~~42~~40. The substrate processing apparatus of claim ~~34~~33, further comprising:

a deposition chamber; and

a substrate processing station contained within the deposition chamber, wherein the substrate processing station includes a substrate holder configured to receive a substrate and the precursor delivery system is configured to deliver precursor during processing of the substrate received by the substrate processing station.

41. The method of claim 1, wherein the ampoule fill start condition comprises determining that the substrate processing apparatus is in or is about to enter a phase after one or more substrates have been loaded into a substrate processing chamber of the substrate processing apparatus, before any of the one or more substrates have been unloaded from the substrate processing chamber, and while deposition is not occurring in the substrate processing chamber.

42. The substrate processing apparatus of claim 33, wherein the ampoule fill start condition comprises determining that a sequence of deposition operations has been completed on substrates contained in the substrate processing apparatus.

43. The substrate processing apparatus of claim 33, wherein the ampoule fill start condition includes determining that setup for deposition operations is currently being performed.

44. The substrate processing apparatus of claim 33, wherein the at least one other substrate processing operation that is performed concurrent with filling the ampoule includes a wafer indexing operation.

45. The substrate processing apparatus of claim 33, wherein the at least one other substrate processing operation that is performed concurrent with filling the ampoule includes a pump to base operation.