CLAIMS

1. A reactor for coating particles, comprising:

(a) a stationary vacuum chamber to hold a bed of particles to be coated, the chamber including:

(i) a lower portion in fluid connection with a first channel portion,

(1) wherein the first channel portion extends at a shallow angle toward a curved inner surface of a half-cylinder formed by the lower portion of the chamber; and

(2) wherein the first channel portion opens to the chamber at a plurality of apertures; and

(ii) an upper portion;

(b) a vacuum port in the upper portion of the chamber;

(c) a motor to rotate a rotatable drive shaft;

(d) a paddle assembly including:

(i) the rotatable drive shaft, the rotatable drive shaft extending through the chamber along an axial axis of the half cylinder; and

(ii) a plurality of paddles extending radially from the drive shaft such that rotation of the drive shaft by the motor orbits the plurality of paddles about the drive shaft; and

(e) a first gas injection assembly configured to:

(i) receive a first fluid from a chemical delivery system; and

(ii) inject a first reactant or precursor gas into the lower portion of the chamber through the apertures substantially tangent to the curved inner surface of the half-cylinder.

2. The reactor of claim 1, wherein the first gas injection assembly is configured to inject the reactant or precursor gas in a direction perpendicular to the axial axis.

3. The reactor of claim 1, wherein the first gas injection assembly comprises a first plurality of apertures extending in a first row parallel to the axial axis, and wherein the first gas injection assembly is configured to inject the reactant or precursor gas through the first plurality of apertures.

4. The reactor of claim 3, wherein the first plurality of apertures are positioned in a lower quarter of the lower portion of the chamber.

5. The reactor of claim 3, wherein the chemical delivery system is configured to deliver a second fluid, and further comprising a second gas injection assembly to receive the second fluid from the chemical delivery system and having apertures configured to inject a second reactant or precursor gas into the lower portion of the chamber and such that the second reactant or precursor gas flows substantially tangent to a curved inner surface of the half-cylinder.

6. The reactor of claim 5, wherein the second gas injection assembly comprises second plurality of apertures extending in a second row parallel to the axial axis, and wherein the second gas injection assembly is configured to inject the second reactant or precursor gas through the second plurality of apertures.

7. The reactor of claim 3, wherein the first gas injection assembly include a manifold and a plurality of channels extending from the manifold to a first plurality of nozzles, and comprising a restriction between the manifold and the plurality of channels.

8. A reactor for coating particles, comprising:

a stationary vacuum chamber to hold a bed of particles to be coated, the chamber having a lower portion that forms a half-cylinder and an upper portion;

a vacuum port in the upper portion of the chamber;

a motor to rotate a rotatable drive shaft;

a paddle assembly including:

the rotatable drive shaft, the rotatable drive shaft extending through the chamber along an axial axis of the half cylinder,

a plurality of paddles extending radially from the drive shaft such that rotation of the drive shaft by the motor orbits the plurality of paddles about the drive shaft; and

a chemical delivery system to deliver a plurality of fluids including at least a first liquid; and

a first gas injection assembly to receive the first liquid from the chemical delivery system, the first gas injection assembly including a vaporizer to convert the first liquid to a first reactant or precursor gas, a manifold to receive the first reactant or precursor gas from the vaporizer, and a plurality of channels leading from the manifold to a plurality of apertures located in the lower portion of the chamber.

9. The reactor of claim 8, wherein the vaporizer, the manifold, and a plurality of passages are formed in a unitary body.

10. The reactor of claim 8, comprising a passage connecting the chemical delivery system to deliver an inert gas from the chemical delivery system to the manifold.

11. The reactor of claim 8, wherein the vaporizer includes a cavity, a heater to heat walls of the cavity, and a nozzle to aerosolize the first liquid as the first liquid passes into cavity.

12. A method of coating particles, comprising:

dispensing particles into a vacuum chamber to fill at least a lower portion of the chamber that forms a half-cylinder;

evacuating the chamber through a vacuum port in an upper portion of the chamber;

rotating a paddle assembly such that a plurality of paddles orbit a drive shaft; and

injecting a reactant or precursor gas into the lower portion of the chamber as the paddle assembly rotates such that a first reactant or precursor gas flows substantially tangent to a curved inner surface of the half-cylinder.

13. A method of coating particles, comprising:

dispensing particles into a vacuum chamber to fill at least a lower portion of the chamber that forms a half-cylinder;

evacuating the chamber through a vacuum port in an upper portion of the chamber;

rotating a paddle assembly such that a plurality of paddles orbit a drive shaft;

flowing a reactant or precursor from a chemical delivery system to a vaporizer;

converting a first liquid to a first reactant or precursor gas in the vaporizer; and

passing the gas from the vaporizer through a manifold and a plurality of channels to a plurality of apertures located in the lower portion of the chamber.