However, increased rate and temperature may cause splashing of liquid material and spitting of solid material with splashes and spits reaching the substrate and causing coating inhomogeneities/defects.

An apparatus for evaporating material from a rotating crucible is disclosed in JP-A-62180068.

SUMMARY

According to the present invention there is provided a method of applying a coating to a substrate as set forth in claim 1.

~~[0005] One aspect of the disclosure involves an apparatus for applying a coating to a substrate. The apparatus comprises a deposition chamber and a crucible for holding a melt pool of coating material. The apparatus includes means for rotating the melt pool. Rotation creates a centrifugal effect.~~

~~[0006] The centrifugal effect may direct slag species, floating on the melt pool surface, toward the pool periphery and a solid boundary/edge/shore of the pool in order to minimize generating splashes and spits of the melted material and their hitting the substrate.~~

~~[0007] In various implementations, the coating material may consist essentially of one or more ceramics. The apparatus may further comprise an electron beam gun positioned to direct an electron beam to the melt pool. The apparatus may further comprise a plasmatron. An oxygen source may be coupled to the plasmatron. The apparatus may further comprise an RF antenna. The apparatus may further comprise an ingot of the coating material.~~

~~[0008] The apparatus may be operated by melting an ingot to form the melt pool. The means may be controlled to rotate the melt pool.~~

ejection from the pool. The denser the plasma, the higher the electron and ion currents to the spit and the stronger spit heating are. Also, the larger way or path length of spits through the plasma medium, the longer the time period of additional heating is, and the more mass of any spit is evaporated. Employing two plasmas (90 and 98) allows increasing the path length of the spits between the ingot and the substrate in the plasma medium (e.g., to be nearly equal to the full distance from the ingot to the substrate). Thus, the denser the plasma along the spit path and longer the path, the less probability of spits reaching the substrate.

[0035] The centrifugal action ~~may~~ is also ~~be~~ used to prevent such splatters and solid particles from reaching the substrate. This may involve rotating the melt pool and the ingot (FIG. 2). An exemplary rotation is driven by an actuator 100 (e.g., an electrical motor with gear mechanism (not shown)) which rotates the ingot carrier 101 (and may be assembled with the crucible) as a unit at an angular velocity ω. The imparting of angular velocity will cause any slag species/pieces floating on the pool surface to go off radially toward the pool periphery and a solid boundary/edge/shore of the pool.

[0036] FIG. 2 shows (as an example) a slag piece 97 floating near the middle of the pool and a slag piece 97' at the pool periphery. The arrow 102 depicts the action direction of the centrifugal force F. Due to this, the pool surface is cleaned of any solid species; therefore, one reduces instances of hitting slag pieces by electron beam 42 scanning over the pool surface. This avoids overheating the slag pieces and explosive boiling of

CLAIMS

What is claimed is:

1. An apparatus for applying a coating to a substrate, the apparatus comprising:

a deposition chamber;

a crucible for holding a melt pool of coating material; and

means for rotating the melt pool.

2. The apparatus of claim 1 wherein:

the coating material consists essentially of one or more ceramics.

3. The apparatus of claim 1 further comprising:

an electron beam gun positioned to direct an electron beam to the melt pool.

4. The apparatus of claim 1 further comprising:

a plasmatron.

5. The apparatus of claim 4 wherein:

the plasmatron comprises a pair of plasmatrons.

6. The apparatus of claim 5 further comprising:

a voltage source coupled across respective bodies of the pair of plasmatrons.

7. The apparatus of claim 6 further comprising:

an oxygen source coupled to the plasmatrons.

8. The apparatus of claim 1 further comprising:
an RF antenna.

9. The apparatus of claim 1 further comprising:
an ingot of the coating material.

10. The apparatus of claim 1 wherein:
the means comprises an electric motor; and
the electric motor is coupled to an ingot carrier to rotate the ingot and melt pool about a central longitudinal axis of the ingot.

11. A method for operating the apparatus of claim 1, the method comprising:
melting an ingot to form the melt pool; and
controlling the means to rotate the melt pool.

12. The method of claim 11 wherein:
the melting comprises heating the melt pool with an electron beam; and
the electron beam is scanned over a central portion of the pool and over a peripheral slag-covered portion.

Claims

1. A method of applying a coating to a substrate: the method comprising:

i) providing an apparatus having:

a deposition chamber (22);

a cooled crucible (34) for holding a melt pool (44) of coating material; and

means (100) for rotating the melt pool (44)

ii) melting an ingot (30) in the crucible to form the melt pool (44); and

iii) controlling the means (100) to rotate the melt pool (44) so as to move slag floating on the pool surface radially towards the pool periphery and freeze.

2. The method of claim 1 wherein:

the melting comprises heating the melt pool (44) with an electron beam (42); and

the electron beam (42) is scanned over a central portion of the pool (44) and over a peripheral slag-covered portion.

3. The method of claim 1 or 2 wherein the frozen slag comprises at least an outboard 2-10% of the ingot radius.

4. The method of claim 1 or 2 wherein the frozen slag comprises at least an outboard 3-7% of the ingot radius.

5. The method of claim 1 or 2 wherein the frozen slag comprises at least an outboard 5% of the ingot radius.

6. The method of any preceding claim further comprising: providing a plasmatron (80) for generating a plasma within the chamber (22), said plasmatron (80) being arranged within the chamber (22) or on a wall of the chamber (22).

7. The method of claim 6 wherein:
the plasmatron comprises a pair of plasmatrons (80A, 80B).

8. The method of claim 7 further comprising: coupling a voltage source (84) across respective bodies (82) of the pair of plasmatrons (80A, 80B).

9. The method of claim 7 or 8 further comprising: coupling an oxygen source (86) to the plasmatrons (80A, 80B).

10. The method of any preceding claim further comprising: providing an RF antenna (70) surrounding the space between the crucible (34) and the substrate.

11. The method of any preceding claim wherein the coating material consists essentially of one or more ceramics.