device using a roll-to-roll method, operating by scrolling a flexible substrate in a bath containing an anode.

The techniques proposed in these documents however use tanks whose geometry does not optimize the homogenization of the solution present in the electrolytic bath. Additionally, these tanks could benefit from an optimization aiming to reduce the quantity of solution necessary for electroplating.

More advantageous geometries are known in the batch methods. In particular, with a cylindrical geometry, like the one described in document US 5,628,884, hydrodynamic control can be used to advantage by rotating a rigid cylindrical substrate around its axis in an electrochemical bath contained in a tank which itself is cylindrical.

There is therefore a need to optimize the electroplating technologies used for handling the flexible substrates, so as to be able to benefit from both some advantages provided by known technologies and used in the batch methods while also benefiting from production cost savings and speed of roll-to-roll technologies.

Summary ~~of the invention~~

In one aspect, there is provided a method for plating a thin layer on a flexible substrate, by electrochemistry, comprising:

- providing, in an electrolytic bath, a first closed cylinder inside a second hollow cylinder,

- applying the flexible substrate on one surface among an outer surface of the first cylinder and an

inner surface of the second cylinder, said flexible substrate forming a first electrode,

- providing, in said electrolytic bath, at least one second electrode, and

- applying a potential difference between the first electrode and the second electrode to electroplate the thin layer on the flexible substrate.

In another aspect, there is provided a device for electrochemically plating at least one thin layer on a flexible substrate, comprising:

- a first closed cylinder arranged inside of a second, hollow cylinder,

- a flexible substrate forming a first electrode on one surface among an outer surface of the first cylinder and an inner surface of the second cylinder,

- a second electrode.

In a further aspect, there is provided a facility for electroplating a stack of thin layers on a flexible substrate comprising a device for electrochemically plating at least one thin layer on a flexible substrate, comprising:

- a first closed cylinder arranged inside of a second, hollow cylinder,

- a flexible substrate forming a first electrode on one surface among an outer surface of the first cylinder and an inner surface of the second cylinder,

- a second electrode.

~~To get there, t~~The present ~~invention~~ disclosure proposes a method for plating a thin layer on a flexible substrate, by electrochemistry, comprising the following steps:

- providing, in an electrolytic bath, a first closed cylinder inside a second hollow cylinder,
- applying the flexible substrate to one of the surfaces among the outer surface of the first cylinder and the inner surface of the second cylinder where the flexible substrate forms a first electrode,

distinct successive plating steps, which is particularly suited to industrial methods.

Because of the movement of the carrier arm from one tank to the other, the method can be enriched with steps other than electroplating steps. In particular, the method can comprise the movement of the first cylinder towards an annealing enclosure. Annealing steps are particularly useful for producing photosensitive devices such as photovoltaic cells.

In parallel to the electroplating method described above, the ~~invention~~ disclosure also relates to the cylindrical reactor geometry used during the method.

Thus, the ~~invention~~ disclosure also relates to a device for electrochemically plating at least one thin layer on a substrate, comprising:

- a first closed cylinder arranged inside a second, hollow cylinder,
- a flexible substrate forming a first electrode on one of the surfaces among the outer surface of the first cylinder and the inner surface of the second cylinder,
- a second electrode.

This device proposes using a cylindrical geometry reactor in combination with a flexible substrate. With this combination it is possible to benefit from a smaller volume of electrolytic solution than in a parallelepiped geometry to do the plating, and also to do the plating in a more homogeneous solution because of the more attractive possibilities for mixing a solution contained between a closed cylinder and a hollow cylinder.

~~invention~~ disclosure also relates to a facility comprising a device such as described above.

According to an embodiment, such an installation furthermore includes:

- a mobile carrier arm, connected to the closed first cylinder, and
- at least one annealing enclosure.

These items are specifically suited for electroplating for implementing photosensitive cells. Indeed, by using the carrier arm, the substrate advantageously mounted on a closed cylinder can be moved from one tank to another. Furthermore, it is advantageous to provide a collar forming a cover rigidly connected to the carrier arm in order to seal the successive tanks of the facility.

Reducing annealing and high temperature, for example over 400°C, vapor phase deposition steps can be done using the annealing enclosure.

Advantageously, the carrier arm can comprise a collar intended to close the second cylinder. This collar can form an upper cover closing the various tanks in the facility, such as, for example, the electrolysis tanks and the annealing enclosure. In this way, it is possible to:

- inject a neutral gas in the tanks, to avoid any oxidation phenomena,
- avoid splashes of electrolytic solution out of the tanks or
- isolate the annealing enclosure from the remainder of the facility in order to avoid exposing the tanks to the high temperatures to which the substrate is exposed in the enclosure.

Brief summary of the drawings

CLAIMS

1. Method for plating a thin layer on a flexible (3) substrate, by electrochemistry, comprising the following steps:
   - providing, in an electrolytic bath, a first closed cylinder (1) inside a second hollow cylinder (2),
   - applying the flexible substrate (3) on one of the surfaces among the outer surface of the first cylinder (1) and the inner surface of the second cylinder (2), said flexible substrate (3) forming a first electrode (8),
   - providing, in said electrolytic bath, at least one second electrode (7, 4), and
   - applying a potential difference between the first electrode (8) and the second electrode to electroplate the thin layer on the flexible substrate (3).

2. Method according to claim 1, comprising the rotation of the first cylinder (1) around the axis thereof during electroplating.

3. Method according to anyone of the preceding claims, providing for the rotation of the second electrode (7,4).

4. Method according to one of the preceding claims providing a first, closed cylinder (1) coaxial with the second, hollow cylinder (2).

5. Method according to one of the preceding claims in which the other surface among the outer surface of the first cylinder (1) and the inner surface of the second cylinder (2) is the second electrode (7).

6. Method according to one of claims 1 to 4, providing a second soluble electrode (7).

7. Method according to one of the preceding claims in which the flexible substrate (3) is applied on the outer surface of the first cylinder (1), and a mobile carrier arm (6, 60) connected to the first cylinder is provided.

8. Method according to claim 7, comprising the displacement of the first cylinder (1) from the electrolytic bath in the second cylinder (2) to at least one tank (210, 220, 230) in a third cylinder.

9. Method according to one of claims 7 or 8, comprising the movement of the first cylinder (1) towards an annealing enclosure (201).

10. Device for electrochemically plating at least one thin layer on a flexible substrate (3), comprising:
- a first closed cylinder (1) arranged inside of a second, hollow cylinder (2),
- a flexible substrate (3) forming a first electrode (8) on one of the surfaces among the outer surface of the first cylinder (1) and the inner surface of the second cylinder (2),
- a second electrode (7,4).

11. Device according to claim 10, in which the other surface among the outer surface of the first cylinder (1) and the inner surface of the second cylinder (2) is the second electrode (7).

12. Device according to claim 10, in which the second electrode (7) is soluble.

13. Device according to one of claims 10 to 12, in which the first cylinder (1) comprises means for connection to a carrier arm (6, 60).

14. Facility for electroplating a stack of thin layers on a flexible substrate (3) comprising a device according to one of claims 10 to 13.

15. Facility according to claim 14 further comprising:
- a mobile carrier arm (60), connected to the closed first cylinder (1), and
- at least one annealing enclosure (201).

16. Facility according to one of claims 14 and 15, in which the carrier arm (60) comprises a collar (11) intended to close the second cylinder (2).

CLAIMS

1. A method for plating a thin layer on a flexible (3) substrate, by electrochemistry, comprising:
   - providing, in an electrolytic bath, a first closed cylinder (1) inside a second hollow cylinder (2),
   - applying the flexible substrate (3) on one surface among an outer surface of the first cylinder (1) and an inner surface of the second cylinder (2), said flexible substrate (3) forming a first electrode (8),
   - providing, in said electrolytic bath, at least one second electrode (7, 4), and
   - applying a potential difference between the first electrode (8) and the second electrode to electroplate the thin layer on the flexible substrate (3).

2. The method of claim 1, further comprising:
   - rotating the first cylinder around an axis thereof during electroplating.

3. Method according to anyone of the preceding claims, further comprising:
   - rotating the second electrode (7,4).

4. Method according to one of the preceding claims further comprising:
   - providing a first, closed cylinder (1) coaxial with the second, hollow cylinder (2).

5. Method according to one of the preceding claims in which the other surface among the outer surface of the first cylinder (1) and the inner surface of the second cylinder (2) is the second electrode (7).

6. Method according to one of claims 1 to 4, further comprising:
- providing a second soluble electrode (7).

7. Method according to one of the preceding claimsfurther comprising:
- applying the flexible substrate (3) on the outer surface of the first cylinder (1), and
- providing a mobile carrier arm (6, 60) connected to the first cylinder.

8. The method of claim 7, further comprising:
- displacing the first cylinder (1) from the electrolytic bath in the second cylinder (2) to at least one tank (210, 220, 230) in a third cylinder.

9. Method according to one of claims 7 or 8, further comprising:
- moving the first cylinder (1) towards an annealing enclosure (201).

10. Device for electrochemically plating at least one thin layer on a flexible substrate (3), comprising:
- a first closed cylinder (1) arranged inside of a second, hollow cylinder (2),
- a flexible substrate (3) forming a first electrode (8) on one surface among an outer surface of the

first cylinder (1) and an inner surface of the second cylinder (2),

- a second electrode (7,4).

11. Device according to claim 10, in which another surface among the outer surface of the first cylinder (1) and the inner surface of the second cylinder (2) is the second electrode (7).

12. Device according to claim 10, in which the second electrode (7) is soluble.

13. Device according to one of claims 10 to 12, in which the first cylinder (1) comprises means for connection to a carrier arm (6, 60).

14. Facility for electroplating a stack of thin layers on a flexible substrate (3) comprising a device for electrochemically plating at least one thin layer on a flexible substrate, comprising:

- a first closed cylinder arranged inside of a second, hollow cylinder,
- a flexible substrate forming a first electrode on one surface among an outer surface of the first cylinder and an inner surface of the second cylinder,
- a second electrode.

15. Facility according to claim 14 further comprising:

- a mobile carrier arm (60), connected to the closed first cylinder (1), and
- at least one annealing enclosure (201).

16. Facility according to one of claims 14 and 15, in which the carrier arm (60) comprises a collar (11) intended to close the second cylinder (2).