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(54) **LITHIUM ROLLING APPARATUS AND LITHIUM ROLLING METHOD USING SAME**

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(57) **ABSTRACT**

The present disclosure relates to a lithium rolling apparatus for forming a lithium foil by rolling a lithium sheet and includes a first roll which contacts a first surface of the lithium sheet; a second roll which contacts a second surface of the lithium sheet; and a first conveyor device disposed at a rear side of the first roll and the second roll, including a belt which transports the lithium foil while controlling tension applied to the lithium foil by surface-contacting at least a part of the second surface of the lithium foil.

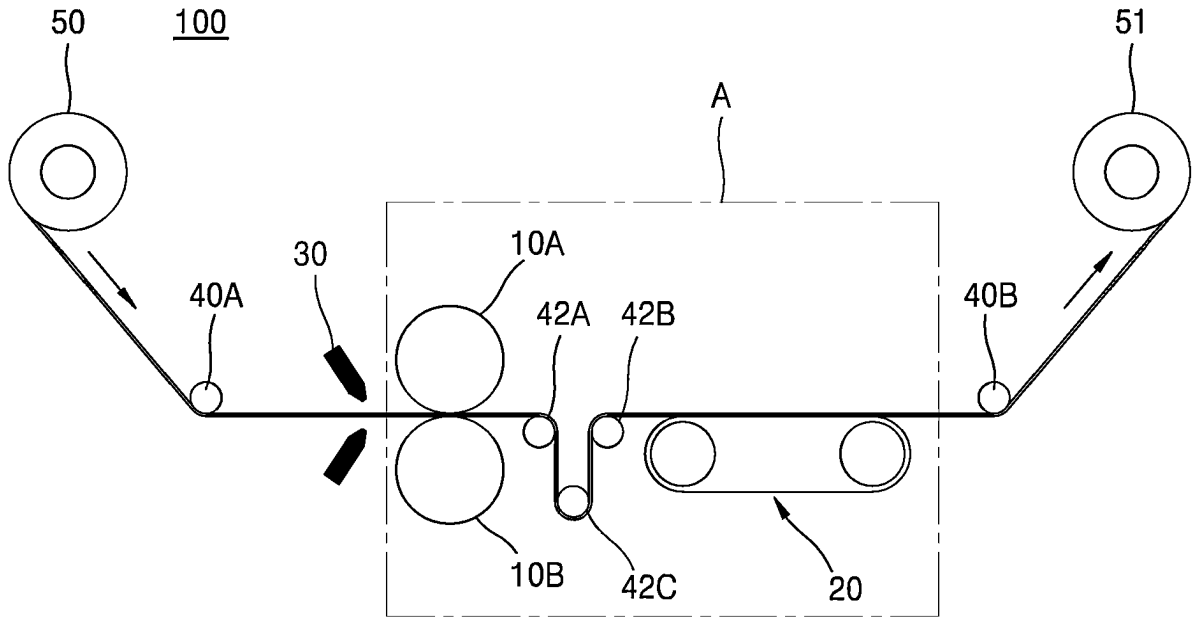


FIG. 1

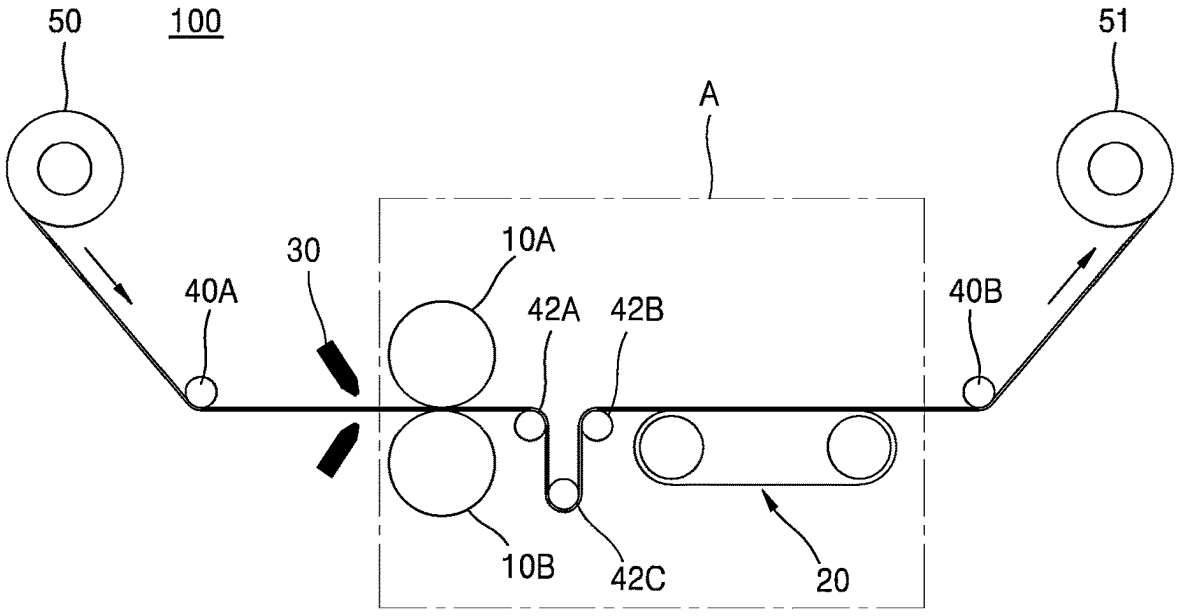


FIG. 2

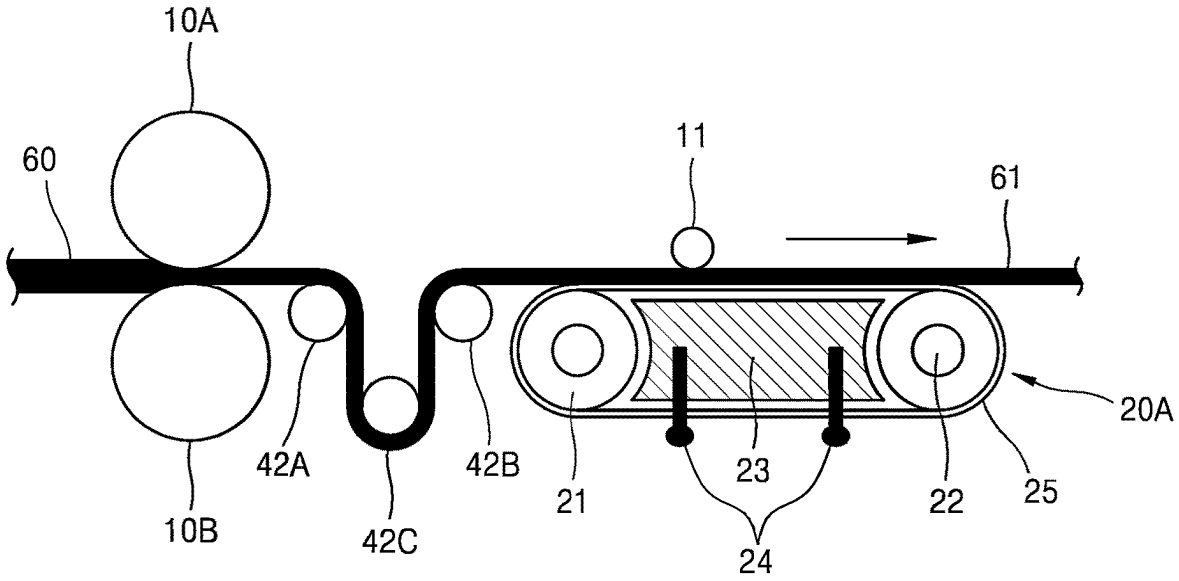


FIG. 3

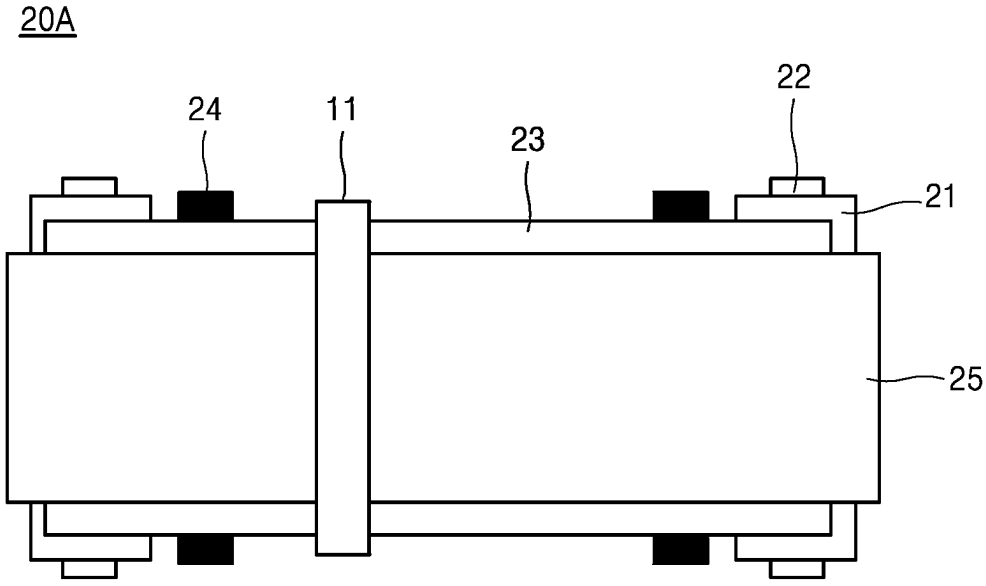


FIG. 4

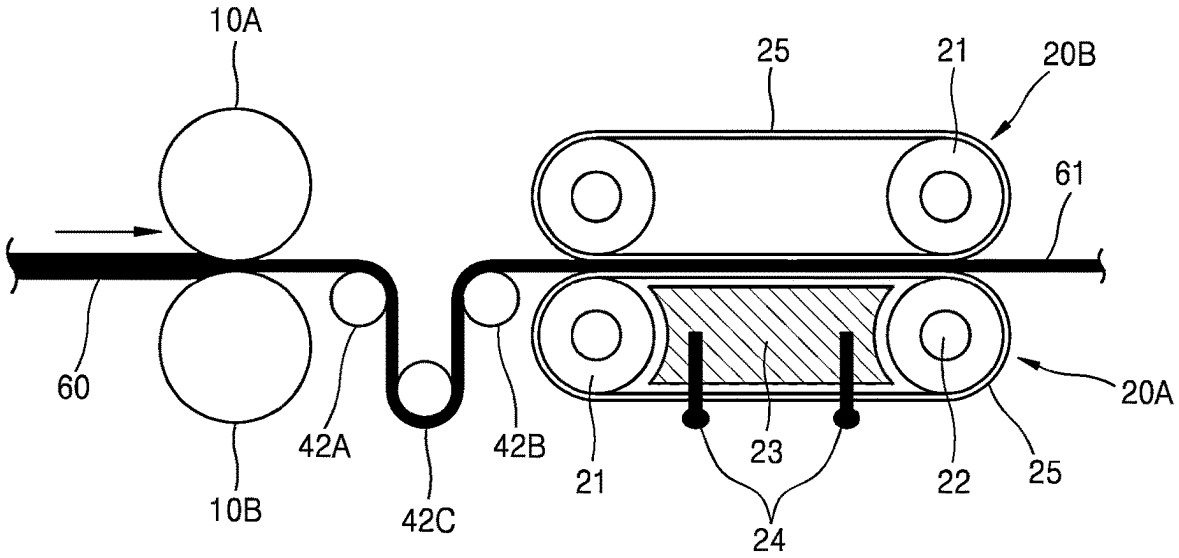


FIG. 5

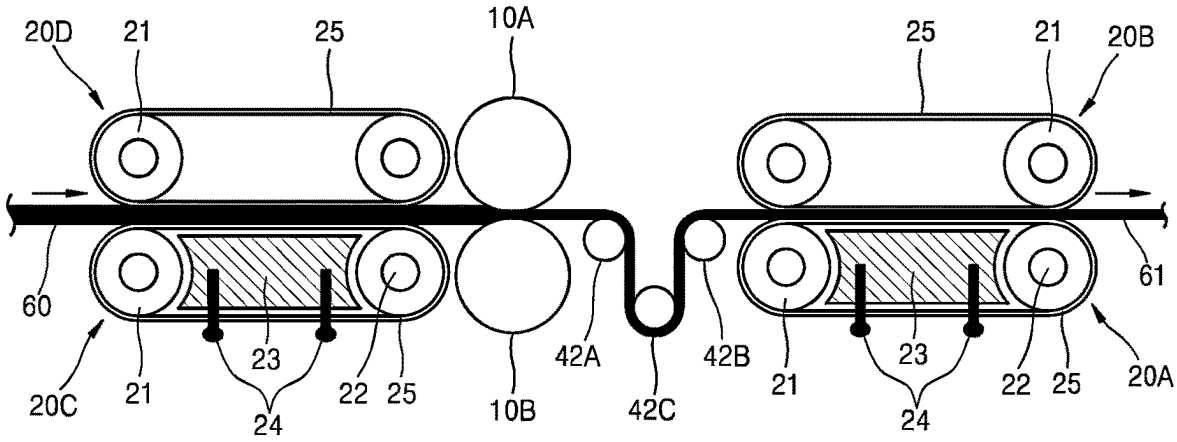

20D
21
25
10A
25
21
20B
60
61
20C
21
23
24
22
25
10B
42A
42C
42B
21
23
24
22
25
20A

FIG. 6

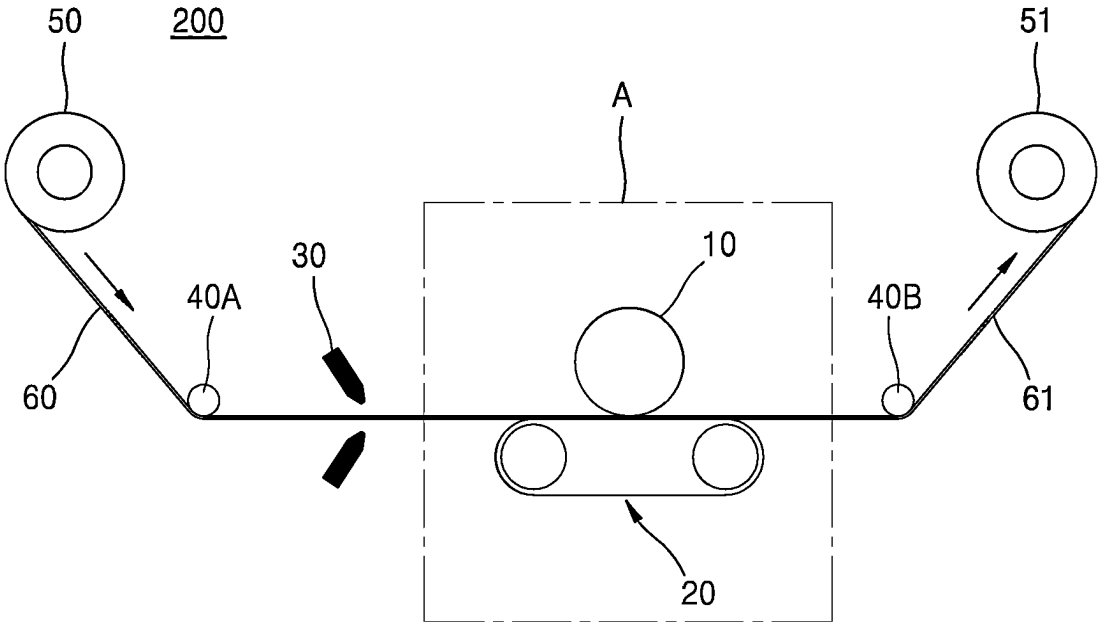


FIG. 7

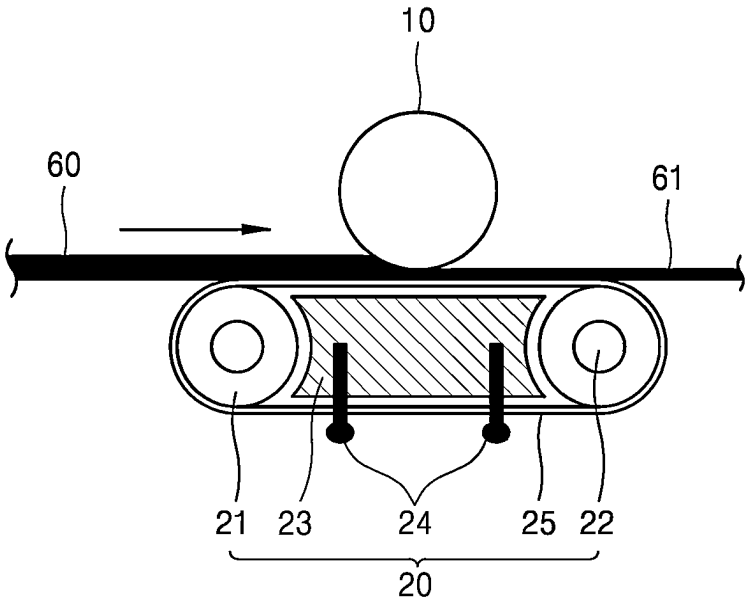


FIG. 8

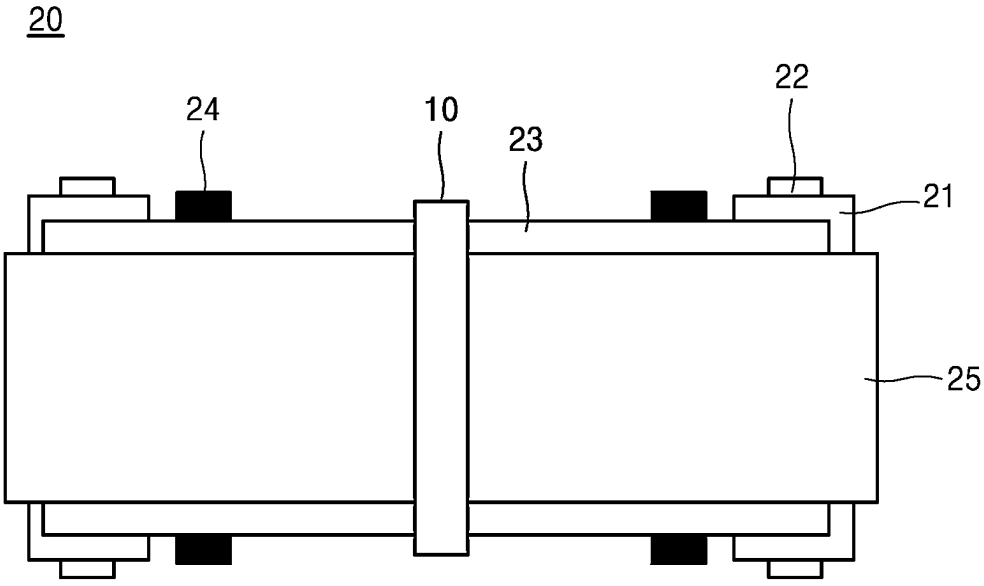


FIG. 9

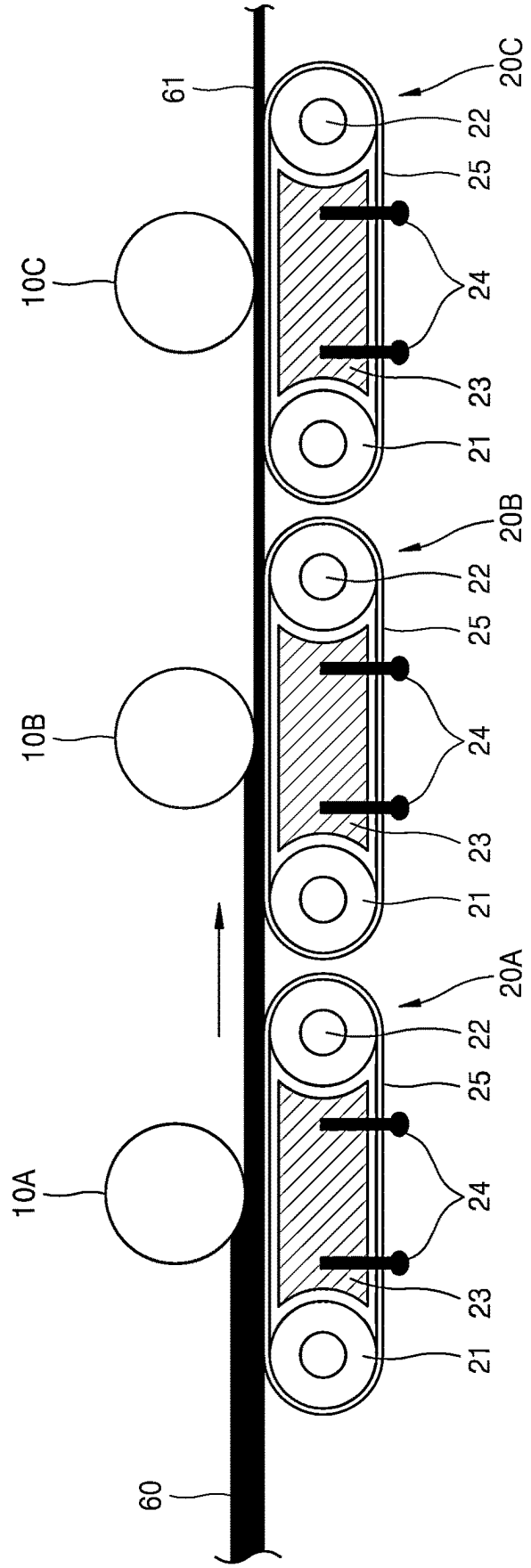
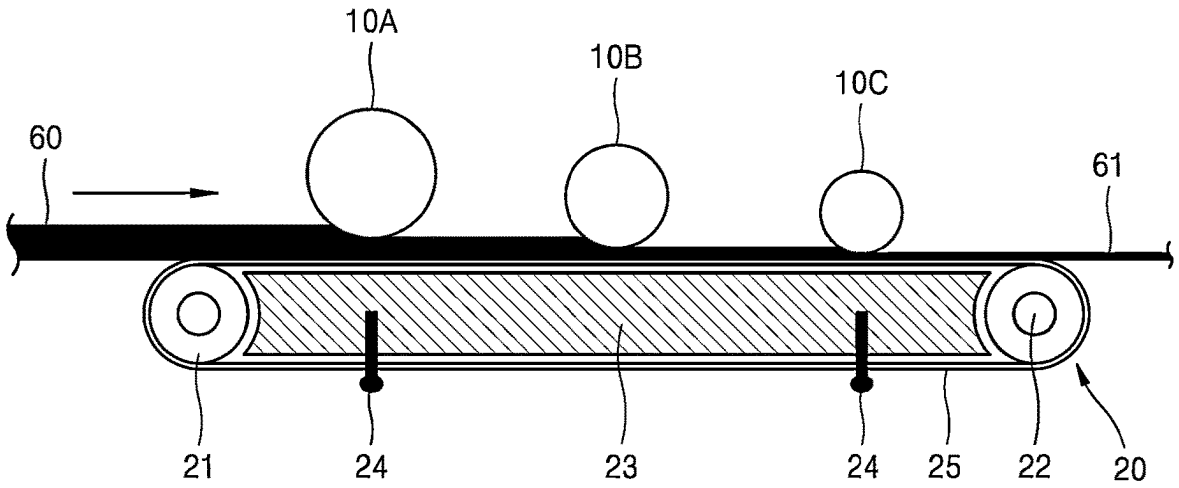

61
20C
22
25
10C
24
23
21
20B
22
25
10B
24
23
21
20A
22
25
10A
24
23
21
60

FIG. 10



LITHIUM ROLLING APPARATUS AND LITHIUM ROLLING METHOD USING SAME

TECHNICAL FIELD

[0001] The present disclosure relates to a lithium rolling apparatus and a lithium rolling method using the same, and more specifically to the lithium rolling apparatus for forming a lithium foil utilized as a negative electrode material of a lithium secondary battery and the lithium rolling method using the same.

BACKGROUND ART

[0002] A lithium ion secondary battery is a secondary battery that has high charge and discharge capacities and is capable of high output. The lithium ion secondary battery is mainly used as a power supply for a mobile electronic device and has recently been expected to be used as a power supply for an electric vehicle. The lithium ion secondary battery has active materials capable of adsorbing and releasing lithium at the positive and negative electrodes, respectively. In addition, the lithium ion secondary battery operates by movement of charge carriers, lithium ions, through the electrolyte liquid between the electrodes.

[0003] According to necessity, lithium ions are introduced into an object such as the active material, an electrode, the lithium ion secondary battery, etc., and the introduction of the lithium ions into the object is hereinafter referred to as lithium doping. Such lithium doping method includes an electrical doping method, direct target doping method, etc.

[0004] On the other hand, lithium is a relatively soft metal compared to other metals, and excessive deformation occurs in a lithium sheet during rolling. Therefore, shape collapse or damage is likely to occur in the lithium sheet after rolling. This is called a sticking phenomenon, and in fact, for this reason, it is not easy to manufacture the lithium sheet which is thin and has a good shape at the same time, by rolling.

[0005] The cause of deformation of the lithium sheet is that during rolling, a large force is applied to a lithium raw foil from a rolling roll, and when a shear plastic deformation by a frictional force with the material exceeds a yield strength of the material, the lithium raw foil is press-bonded onto the roll. If the lithium raw foil is press-bonded onto the roll, it is difficult to remove the lithium foil from the roll after rolling without deformation or damage. Therefore, a product lithium foil is prone to shape collapse or damage.

[0006] In order to solve the above-mentioned problems, a rolling method has been proposed in some documents for manufacturing the product lithium sheet for a cathode active material of lithium batteries by applying an organic solvent for an electrolytic liquid to the surface of the roll to reduce frictional force and prevent press-bonding. Here, the organic solvent can function as a lubricant, thereby suppressing the damage to the lithium foil. Also, a method of rolling by stacking a resin film on the lithium sheet is being suggested.

[0007] However, there was a problem in that it was difficult to control the sticking phenomenon of the material sticking to the rolling roll when manufacturing the lithium foil just by using the lubricant and the resin film. Further, when transporting a very thin lithium foil, a tension control applied to the lithium foil is sensitive. Therefore, the lithium foil may be torn even if a slightly strong tension is applied, making it difficult to manufacture the thin lithium foil with a thickness of 100 μm or less through a rolling process.

DISCLOSURE

Technical Problem

[0008] The present disclosure was designed to address the above requirements, and aims to provide a lithium rolling device configured to produce a very thin and wide lithium foil which is used as a negative electrode material for lithium secondary batteries, without deformation or damage to the lithium foil, and a lithium rolling method using the same. However, these problems are exemplary and do not limit the scope of the present disclosure.

Technical Solution

[0009] According to an embodiment of the present disclosure, a lithium rolling apparatus for forming a lithium foil by rolling a lithium sheet is provided. The lithium rolling apparatus may include a first roll which contacts a first surface of the lithium sheet; a second roll which contacts a second surface of the lithium sheet; and a first conveyor device disposed at a rear side of the first roll and the second roll, including a belt which transports the lithium foil while controlling tension applied to the lithium foil by surface-contacting at least a part of the second surface of the lithium foil.

[0010] The lithium rolling apparatus may include a guide roll formed at a position contacting the first surface of the lithium foil on the first conveyor device so that the lithium foil can be transported in a flat manner when the lithium foil is transported by the first conveyor device.

[0011] The lithium rolling apparatus may include a second conveyor device disposed at an upper part of the first conveyor device, which contacts the first surface of the lithium foil and transports the lithium foil, wherein the first conveyor device and the second conveyor device may be driven at a same speed.

[0012] The lithium rolling apparatus may include a third conveyor device disposed at a front side of the first roll and the second roll for transporting the lithium sheet while contacting at least any part of the second surface of the lithium sheet, wherein driving speed of the third conveyor device may be controlled to be equal to or slower than driving speed of the first conveyor device.

[0013] The lithium rolling apparatus may further include a fourth conveyor device disposed at an upper part of the third conveyor device, which contacts the first surface of the lithium sheet and transports the lithium sheet,

[0014] wherein the third conveyor device and the fourth conveyor device may be driven at a same speed.

[0015] The lithium rolling apparatus may include a lubricant supply part which sprays lubricant on at least any one surface of the lithium sheet before being rolled by the first roll and the second roll to suppress a sticking phenomenon.

[0016] The lithium rolling apparatus is characterized in that the first roll, the second roll and the belt may include a polymer material, and the polymer material may include any one of polyethylene, polypropylene, vinylidene, polyolefin, and polyester.

[0017] The lithium rolling apparatus is characterized in that a resin film may be further interposed on at least any one surface of the lithium sheet contacting any one of the first roll and the second roll to prevent a sticking phenomenon.

[0018] The lithium rolling apparatus is characterized in that a width of the belt of the first conveyor device may be

greater than a width of the lithium foil, and the lithium foil may be transported at a same speed as the belt by a driving force of the belt in a surface-contact state.

[0019] According to an embodiment of the present disclosure, a lithium rolling method for forming a lithium foil by rolling a lithium sheet may be provided. The lithium rolling method may include a step of forming a lithium foil by rolling using a first roll contacting a first surface of a lithium sheet and a second roll contacting a second surface of the lithium sheet; and a step of transporting the lithium foil with a first conveyor device disposed at a rear side of the first roll and the second roll while controlling tension applied to the lithium foil by surface-contacting at least any part of a second surface thereof with a belt provided on the first conveyor device.

[0020] The lithium rolling method is characterized in that when the lithium foil is transported by the first conveyor device by a guide roll formed at a position contacting the first surface of the lithium foil on the first conveyor device or by a second conveyor device, tension applied on the lithium foil may be controlled, and the lithium foil may be transported in a flat manner.

[0021] According to an embodiment of the present disclosure, a lithium rolling apparatus for forming a lithium foil by rolling a lithium sheet is provided. The lithium rolling apparatus may include a conveyor device for transporting and rolling the lithium sheet; and a roll disposed at an upper part of the conveyor device for rolling the lithium sheet; wherein the conveyor device may include a belt surface-contacting at least a part of a lower surface of the lithium sheet for rolling and transporting the lithium sheet while controlling tension applied on the lithium sheet, and a support part for supporting the lithium sheet.

[0022] The lithium rolling apparatus is characterized in that at least two or more rolling mills each comprising a unit of the conveyor device and the roll may be disposed continuously, and among at least two or more of the rolling mills, a driving speed of the rolling mill disposed at a rear side may be controlled to be equal to or faster than a driving speed of the rolling mill disposed at a front side.

[0023] The lithium rolling apparatus is characterized in that among at least two or more of the rolling mills, a diameter of the rolling mill disposed at the rear side may be equal to or smaller than a diameter of the rolling mill disposed at the front side.

[0024] The lithium rolling apparatus is characterized in that a plurality of the rolls may be provided on the conveyor device, and a diameter of the roll disposed at a rear side of the conveyor device may be equal to or smaller than a diameter of the roll disposed at the front side of the conveyor device.

[0025] The lithium rolling apparatus may include a lubricant supply part which sprays lubricant on at least any one surface of the lithium sheet before being rolled by the roll and the conveyor device to suppress a sticking phenomenon.

[0026] The lithium rolling apparatus is characterized in that a resin film may be further interposed on at least any one surface of the lithium sheet contacting any one of the roll and the conveyor device to prevent a sticking phenomenon.

[0027] The lithium rolling apparatus is characterized in that a width of the belt of the conveyor device may be greater than a width of the lithium foil, and the lithium foil may be transported at a same speed as the belt by a driving force of the belt in a surface-contact state.

[0028] The lithium rolling apparatus is characterized in that the roll and the belt may include a polymer material, and the polymer material may include any one of polyethylene, polypropylene, vinylidene, polyolefin, and polyester.

Effect of the Invention

[0029] According to an embodiment of the present disclosure as described above, a lithium foil with a thickness of 100 μm or less can be implemented using the lithium rolling apparatus configured to form the lithium foil used as a negative electrode material of the lithium secondary battery. However, the scope of the present disclosure is not limited by these effects.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] FIG. **1** is a schematic diagram illustrating a structure of a lithium rolling apparatus according to an embodiment of the present disclosure.

[0031] FIGS. **2** and **3** are a cross-sectional view and a top view schematically illustrating a structure of a conveyor device provided in the lithium rolling apparatus shown in FIG. **1**.

[0032] FIGS. **4** and **5** are cross-sectional views schematically illustrating a structure of a lithium rolling apparatus according to another embodiment of the present disclosure.

[0033] FIG. **6** is a schematic diagram illustrating a structure of a lithium rolling apparatus according to another embodiment of the present disclosure.

[0034] FIGS. **7** and **8** are a cross-sectional view and a top view schematically illustrating a structure of a conveyor device provided in the lithium rolling apparatus shown in FIG. **6**.

[0035] FIGS. **9** and **10** are cross-sectional views schematically illustrating a structure of a conveyor device of a lithium rolling apparatus according to another embodiment of the present disclosure.

MODE FOR INVENTION

[0036] Hereinafter, the present disclosure will be described in detail by explaining embodiments of the present disclosure with reference to the attached drawings.

[0037] Various embodiments of the present disclosure may be embodied in many different forms and should not be construed as being limited to the example embodiments set forth herein. Rather, these example embodiments of the disclosure are provided so that this disclosure will be thorough and complete and will convey inventive concepts of the disclosure to those skilled in the art. Embodiments of the disclosure are described herein with reference to schematic illustrations of idealized embodiments (and intermediate structures) of the disclosure.

[0038] FIG. **1** is a schematic diagram illustrating a structure of a lithium rolling apparatus according to an embodiment of the present disclosure.

[0039] Referring to FIG. **1**, the lithium rolling apparatus **100** according to an embodiment of the present disclosure has a rolling part which forms a lithium foil by rolling a lithium sheet between a first roll **10**A and a second roll **10**B. With respect to the rolling part, a lubricant supply part **30** configured to spray lubricant on the surface of the lithium sheet is placed at a front side where the lithium sheet is inserted.

[0040] While the first roll **10**A and the second roll **10**B are illustrated to be in a same size, the first roll **10**A and the second roll **10**B may be disposed having different diameters according to necessity. In this case, by controlling power supplied to each of the first roll **10**A and the second roll **10**B to control rotation linear velocity of the first roll **10**A and the second roll **10**B to be the same, a shear stress applied to a lithium sheet **60** can be controlled to roll the lithium sheet **60**. Here, a specific power control of the rolling rolls is already known in the art and will not be described in detail.

[0041] The form of lubricant supply part **30** may be in a form of applying droplets, spraying the lubricant in a form of a spray, or in a form of applying the lubricant directly to a surface of the lithium sheet **60** using a brush, etc. The lubricant may be any of the following organic solvents, for example, pentane, hexane, heptane, octane, nonane, decane, ethyl methyl carbonate, propylene carbonate, dimethyl carbonate, diethyl carbonate, fluoromethyl methyl carbonate, difluoromethyl methyl carbonate, 2, 2, 2-trifluoroethyl methyl carbonate, bis(2,2,2-trifluoroethyl) carbonate, acetonitrile, propionitrile, butyronitrile, acrylonitrile, dimethoxymethane, 1, 2-dimethoxyethane, tetrahydrofuran, 2-methyl tetrahydrofuran, 1, 2-dioxane, 1,3-dioxane, 1,4-dioxane, 2, 2-dimethyl-1,3-dioxolane, 2-methyl tetrahydropyran, 1, 3-dioxolane, N, N-dimethyl acetamide, isopropyl isocyanate, N-propyl isocyanate, chloromethyl isocyanate, dimethyl acetal, diethyl ether, methyl isobutyl ketone, 1, 2-dimethoxyethane, 1,2-diethoxyethane, methyl formate, ethyl formate, propyl formate, methyl acetate, ethyl acetate, butyl acetate, propyl acetate, isopropyl acetate, isobutyl acetate, methyl propionate, vinyl acetate, methyl acrylate, methyl methacrylate, glycidyl methyl ether, epoxy butane, 2-ethyl oxirane, oxazole, 2-ethyloxazole, oxazoline, 2-methyl-2-oxazoline, acetone, methyl ethyl ketone, acetic anhydride, 1-nitropropane, 2-nitropropane, furan, γ-butyrolactone, thiophene, pyridine, 1-methylpylorizine, N-methylmorpholine, etc.

[0042] The lithium sheet refers to a pre-extruded lithium raw foil, for example, from about 150 to 1000 μm thick. Further, the lithium sheet also refers to a pure lithium plate or an alloy plate containing lithium. Using the lithium rolling apparatus according to an embodiment of the present disclosure, the lithium sheet can be rolled to form a lithium foil having a thickness of 100 μm or less.

[0043] The lithium sheet is wound around a reel **50**, then unwound and supplied to the rolling part. After rolling, the lithium sheet is wound around a reel **51** disposed at a position opposite to the reel **50**. A plurality of tension rolls **40**A, **40**B are formed on a part of the lithium rolling apparatus **100** to adjust the speed of the lithium sheet, appropriately control the tension, and to ensure that the lithium sheet is would onto the reel **51** in a flat manner. The plurality of tension rolls **40**A, **40**B can be simply positioned in one direction to control the tension of the lithium sheet, or they can be arranged in a zigzag shape on both sides of the lithium sheet to control the tension of the lithium sheet more efficiently.

[0044] However, since lithium is a relatively soft metal compared to other metals, if the tension is controlled using only the tension rolls **40**A, **40**B, there is a high possibility that the lithium sheet may be torn or deformed.

[0045] In order to solve this problem, the present disclosure controlled the tension applied to the lithium foil using a conveyor device **20** in order to prevent a deformation or damage of the lithium foil rolled by the rolling part. Hereinafter, configuration of a conveyor belt **20** and a lithium rolling method will be described in detail with reference to the drawings.

[0046] Further, when controlling the tension using the conveyor device **20**, if the tension is applied between the rolling roll and a belt provided on the conveyor device **20**, the lithium foil receives the tension directly and there is a high possibility of a plate fracture or abnormality in surface quality. In order to solve this problem, it is important to configure a device (hereinafter referred to as a dancer roll) which adjusts the tension between the rolling roll and the belt so that the lithium foil does not receive direct tension between the rolling roll and the conveyor device **20**.

[0047] As shown in FIG. **1**, by additionally configuring dancer rolls **42**A, **42**B, **42**C between rolling rolls **10**A, **10**B and the conveyor device **20**, it is possible to control so that no direct tension is applied to the lithium foil. Hereinafter, the dancer rolls **42**A, **42**B, **42**C are already known in the art and will not be described in detail.

[0048] FIGS. **2** and **3** are a cross-sectional view and a top view schematically illustrating a structure of a conveyor device provided in the lithium rolling apparatus shown in FIG. **1**. Here, FIG. **2** is an enlarged view of a portion A of FIG. **1**, and FIG. **3** is a top view of the conveyor device in FIG. **2**.

[0049] Referring to FIGS. **2** and **3**, the lithium sheet **60** is rolled into a lithium foil **61** by the first roll **10**A contacting a first surface of the lithium sheet **60** and the second roll **10**B contacting a second surface of the lithium sheet **60**. Here, a first conveyor device **20**A disposed at a rear side of the first roll **10**A and the second roll **10**B may be included to transport the lithium sheet **60** contacting at least any part of the second surface of the lithium sheet **60** while controlling the applied tension.

[0050] In an example, the lithium rolling apparatus **100** according to an embodiment of the present disclosure can control the tension applied on the lithium foil **61** with a single first conveyor device **20**A. In this case, when one end of the lithium foil **61** is rolled by the first roll **10**A and the second roll **10**B, it may be curled up to either side. In order to solve this problem, the present disclosure further includes a guide roll **11** which contacts a first surface of the lithium foil **61** opposite to the first conveyor device **20**A, that is, the guide roll **11** that contacts any part of the upper surface of the lithium foil **61**. The guide roll **11** is only involved in transporting the lithium foil **61**, and it is in close contact with the first conveyor device **20**A while maintaining a constant gap so as not to affect the shape of the lithium foil **61**.

[0051] The first conveyor device **20**A may include a support part **23** for supporting the lithium foil **61**, a belt **25** surrounding the support part **23** and contacting the lithium foil **61**, and a driving part for driving the belt **25**. Here, the driving part may include a drive roll **21** and a power unit **22** configured to rotate the drive roll **21**.

[0052] Further, the first conveyor device **20**A may include the belt **25**, wherein at least a part of the belt **25** surface-contacts the second surface of the lithium foil **61**, which transports the lithium foil **61** while controlling the tension applied on the lithium foil **61**.

[0053] The belt **25** may be disposed to drive along an outer circumferential surface of the driving part, and the support part **23** is formed on the interior of the belt **25** to support the lithium foil **61**. Here, on both sides of the support part **23**,

anchor parts **24** are formed to support to prevent interference with driving of the first conveyor device **20**A. The support part **23** is formed to be approximately the same size as the diameter of the drive roll **21** of the first conveyor device **20**A and closely contacts the belt **25** to prevent the lithium foil **61** from sagging.

[0054] A width of the belt **25** is greater than a width of the lithium foil **61**, and the lithium foil **61** can be transported at the same speed as the belt **25** in a surface-contact state with the belt **25** by the driving force of the belt **25**. If the width of the belt **25** is equal to or smaller than the width of the lithium foil **61**, the tension applied on the lithium foil **61** is not adequately controlled, and a lithium sticking phenomenon may not be suppressed. Therefore, the width of belt **25** should always be formed to be greater than the width of the lithium foil **61**.

[0055] A material of the belt **25** may include, for example, a polymer material. In addition, the same material can be used for the first roll **10**A and the second roll **10**B as the belt **25**. Types of the polymer material may include any of polyethylene, polypropylene, vinylidene, polyolefin, and polyester, and any other material that has low adhesion to lithium and does not cause the lithium sticking phenomenon can be used.

[0056] The lithium foil **61** is transported along the belt **25** by resistance generated from a part of the belt **25** surface-contacting a lower surface of the lithium foil **61**, and is finally wound on the reel **51**. The reel **51** can be automatically rotated by a transporting force of the conveyor device **25** without a separate driving part.

[0057] Alternatively, the reel **51** be driven by a driving part provided on one side for winding the lithium foil **61**.

[0058] Furthermore, as described above with reference to FIG. **1**, if the lithium foil **61** is transported directly using the conveyor device **20**, the tension may be applied to the lithium foil **61** directly, which may cause an abnormality in quality. Therefore, the dancer rolls **42**A, **42**B, **42**C are provided after the first roll **10**A and the second roll **10**B to smoothly perform the transportation of the lithium foil **61** by the conveyor device **20**.

[0059] Although not shown in the drawings, if the material of the first roll **10**A and the second roll **10**B is not made of a polymer, for example, in case of using a metallic material, the rolling may be performed without the sticking phenomenon of the lithium sheet **60** by further interposing a resin film on at least one side of the lithium sheet **60** that contacts either of the first roll **10**A and the second roll **10**B. The resin film may include, for example, any one of polyethylene, polypropylene, vinylidene, polyolefin, and polyester.

[0060] On the other hand, the lithium rolling apparatus **100** according to an embodiment of the present disclosure may be further applied with a conveyor device instead of the guide roll **11**. This will be described later with reference to the drawings.

[0061] FIGS. **4** and **5** are cross-sectional views schematically illustrating a structure of a lithium rolling apparatus according to another embodiment of the present disclosure.

[0062] Referring to FIG. **4**, the lithium rolling apparatus **100** may have a second conveyor device **20**B formed on the first conveyor device **20**A instead of the guide roll **11** in order to control the tension of the lithium foil **61** more effectively.

[0063] The structure of the second conveyor device **20**B may be configured identically to the structure of the first conveyor device **20**A. However, the support part **23** provided on the first conveyor device **20**A may be omitted because the belt **25** of the second conveyor device **20**B can apply a load uniformly over the entire upper surface of the lithium foil **61** with gravity.

[0064] Driving speed of the first conveyor device **20**A and driving speed of the second conveyor device **20**B should be equal, and should be controlled to be equal to or faster than the driving speed of the first roll **10**A and the second roll **10**B. Here, if size of any one of the first roll **10**A and the second roll **10**B is different, the driving speed of the first conveyor device **20**A and the second conveyor device **20**B may be controlled appropriately.

[0065] Referring to FIG. **5**, the lithium rolling apparatus **100** includes a third conveyor device **20**C having the same structure as the first conveyor device **20**A at a front side of the rolling part for controlling the tension of the lithium sheet **60** as well as controlling the tension of the lithium foil **61**. Here, the tension of the lithium sheet **60** can be controlled only with the third conveyor device **20**C, but in order to control the tension of the lithium sheet more efficiently, a fourth conveyor device **20**D which has a same structure as the second conveyor device **20**B may be disposed on the third conveyor device **20**C. The structures of the third conveyor device **20**C and the fourth conveyor device **20**D are the same as the structures of the first conveyor device **20**A and the second conveyor device **20**B, respectively, so detailed descriptions thereof will be omitted.

[0066] Driving speed of the third conveyor device **20**C and driving speed of the fourth conveyor device **20**D should be equal. Here, the driving speed of the third conveyor device **20**C should be controlled to be equal to or slower than the driving speed of the first conveyor device **20**A provided at the rear side of the first roll **10**A and the second roll **10**B. That is, the driving speed of the third conveyor device **20**C, the rolling part (first roll **10**A and second roll **10**B), and the first conveyor device **20**A should all be controlled equally. Alternatively, the driving speed of the third conveyor device **20**C should be controlled to be slower than the driving speed of the first conveyor device **20**A. In addition, the driving speed of the third conveyor device **20**C should be controlled to be relatively slower than the driving speed of the rolling part (first roll **10**A and second roll **10**B).

[0067] FIG. **6** is a schematic diagram illustrating a structure of a lithium rolling apparatus according to another embodiment of the present disclosure.

[0068] Referring to FIG. **6**, a lithium rolling apparatus **200** according to an embodiment of the present disclosure includes a conveyor device **20** which transports and rolls a lithium sheet **60**, and a roll **10** disposed on top of the conveyor device **20** which rolls the lithium sheet **60**. The conveyor device **20** includes a belt (not shown), which is at least a part surface-contacted on a lower surface of the lithium sheet **60** and rolls and transports the lithium sheet **60** while controlling the tension applied on the lithium sheet **60**. In addition, a lubricant supply part **30** is included, which sprays lubricant on at least one surface of the lithium sheet **60** before being rolled by the roll **10** and the conveyor device **20** to suppress a sticking phenomenon.

[0069] In the roll **10**, by controlling power to control rotation linear velocity of a belt provided on the roll **10** and the conveyor device **20** to be the same, a shear stress applied to the lithium sheet **60** can be controlled to roll the lithium

sheet **60**. Here, a specific power control of the rolling rolls is already known in the art and will not be described in detail.

[0070] The form of lubricant supply part **30** may be in a form of applying droplets, spraying the lubricant in a form of a spray, or in a form of applying the lubricant directly to a surface of the lithium sheet using a brush, etc. The lubricant may be any of the following organic solvents, for example, pentane, hexane, heptane, octane, nonane, decane, ethyl methyl carbonate, propylene carbonate, dimethyl carbonate, diethyl carbonate, fluoromethyl methyl carbonate, difluoromethyl methyl carbonate, 2, 2, 2-trifluoroethyl methyl carbonate, bis(2,2,2-trifluoroethyl) carbonate, acetonitrile, propionitrile, butyronitrile, acrylonitrile, dimethoxymethane, 1, 2-dimethoxyethane, tetrahydrofuran, 2-methyl tetrahydrofuran, 1, 2-dioxane, 1,3-dioxane, 1,4-dioxane, 2, 2-dimethyl-1,3-dioxolane, 2-methyl tetrahydropyran, 1, 3-dioxolane, N, N-dimethyl acetamide, isopropyl isocyanate, N-propyl isocyanate, chloromethyl isocyanate, dimethyl acetal, diethyl ether, methyl isobutyl ketone, 1, 2-dimethoxyethane, 1,2-diethoxyethane, methyl formate, ethyl formate, propyl formate, methyl acetate, ethyl acetate, butyl acetate, propyl acetate, isopropyl acetate, isobutyl acetate, methyl propionate, vinyl acetate, methyl acrylate, methyl methacrylate, glycidyl methyl ether, epoxy butane, 2-ethyl oxirane, oxazole, 2-ethyloxazole, oxazoline, 2-methyl-2-oxazoline, acetone, methyl ethyl ketone, acetic anhydride, 1-nitropropane, 2-nitropropane, furan, γ-butyrolactone, thiophene, pyridine, 1-methylpylorizine, N-methylmorpholine, etc.

[0071] The lithium sheet is wound around a reel **50**, then unwound and supplied to a rolling part. After rolling, the lithium sheet is wound around a reel **51** disposed at a position opposite to the reel **50**. A plurality of tension rolls **40**A, **40**B are formed on a part of the lithium rolling apparatus **200** to adjust the speed of the lithium sheet, appropriately control the tension, and to ensure that the lithium sheet is would onto the reel **51** in a flat manner. The plurality of tension rolls **40**A, **40**B can be simply positioned in one direction to control the tension of the lithium sheet, or they can be arranged in a zigzag shape on both sides of the lithium sheet to control the tension of the lithium sheet more efficiently.

[0072] FIGS. **7** and **8** are a cross-sectional view and a top view schematically illustrating a structure of a conveyor device provided in the lithium rolling apparatus shown in FIG. **6**. Here, FIG. **7** is an enlarged view of a portion A of FIG. **6**, and FIG. **8** is a top view of the conveyor device in FIG. **6**.

[0073] Referring to FIGS. **7** and **8**, the lithium sheet **60** is rolled into a lithium foil **61** by the roll **10** contacting an upper surface of the lithium sheet **60** and the conveyor device **20** contacting a lower surface of the lithium sheet **60**. Here, the conveyor device **20** may be in surface-contact with at least a part of the lower surface of the lithium sheet **60** or the lithium foil **61** to transport the lithium sheet **60** or the lithium foil **61** while controlling the tension applied thereon.

[0074] In an example, the lithium rolling apparatus **200** according to an embodiment of the present disclosure can control the tension applied on the lithium sheet **60** or the lithium foil **61** with the conveyor device **20**. The conveyor device **20** is in close contact with the roll **10** while maintaining a constant gap to roll the lithium sheet **60**. In order to perform a stable rolling, the conveyor device **20** may further include a support part **23** for supporting the lithium sheet **60** and a driving part for driving a belt **25**. Here, the driving part may include a drive roll **21** and a power unit **22** configured to rotate the drive roll **21**.

[0075] The belt **25** may be disposed to drive along an outer circumferential surface of the driving part, and the support part **23** is formed on the interior of the belt **25**. Here, on both sides of the support part **23**, anchor parts **24** are formed to support to prevent interference with driving the conveyor device **20**. The support part **23** is formed to be approximately the same size as the diameter of the drive roll **21** of the conveyor device **20** and closely contacts the belt **25** to roll the lithium sheet **60**. In addition, the support part **23** can prevent the lithium foil **61** from sagging downward while it is being transported.

[0076] A width of the belt **25** is greater than a width of the lithium sheet **60** or the lithium foil **61**, and the lithium sheet **60** or the lithium foil **61** can be transported at the same speed as the belt **25** in a surface-contact state with the belt **25** by the driving force of the belt **25**. The width of the lithium foil **61** may be equal to the width of the lithium sheet **60**, or the lithium sheet **60** may be rolled so that the width of the lithium foil **61** is relatively greater than the width of the lithium sheet **60**. Therefore, the width of belt **25** should be equal to or greater than the width of lithium foil **61**. If the width of the belt **25** is equal to or smaller than the width of the lithium foil **61**, the tension applied on the lithium foil **61** is not appropriately controlled, and a lithium sticking phenomenon may not be suppressed. Therefore, the width of belt **25** should always be formed to be greater than the width of the lithium foil **61**.

[0077] A material of the belt **25** may include, for example, a polymer material In addition, the same material can be used for the roll **10** as the belt **25**. Types of the polymer material may include any of polyethylene, polypropylene, vinylidene, polyolefin, and polyester, and any other material that has low adhesion to lithium and does not cause the lithium sticking phenomenon can be used.

[0078] The lithium foil **61** is transported along the belt **25** by resistance generated from a part of the belt **25** surface-contacting a lower surface of the lithium foil **61**, and is finally wound on the reel **51**. The reel **51** can be automatically rotated by a transporting force of the conveyor device **25** without a separate driving part.

[0079] Alternatively, the reel **51** may be driven with the driving part provided on one side for winding the lithium foil **61**.

[0080] Although not shown in the drawings, if the material of the roll **10** and the belt **25** is not made of a polymer, for example, in case of using a metallic material, the rolling may be performed without the sticking phenomenon of the lithium sheet **60** by further interposing a resin film on at least one side of the lithium sheet **60** that contacts the roll **10**. The resin film may include, for example, any one of polyethylene, polypropylene, vinylidene, polyolefin, and polyester.

[0081] On the other hand, the lithium rolling apparatus **200** according to an embodiment of the present disclosure may be further applied with a conveyor device or a rolling roll. This will be described later with reference to the drawings.

[0082] FIGS. **9** and **10** are cross-sectional views schematically illustrating a structure of a conveyor device of a lithium rolling apparatus according to another embodiment of the present disclosure.

[0083] Referring to FIG. **9**, a lithium rolling apparatus **200** may have at least two or more rolling mills each including a unit of a conveyor device **20** and a roll **10** disposed continuously. Hereinafter, the rolling mill may be referred to as a conveyor device for convenience.

[0084] For example, assuming that three unit rolling mills are disposed continuously, a first conveyor device **20**A, a second conveyor device **20**B, and a third conveyor device **20**C are disposed adjacent to each other. Here, a rolling roll configured to roll a lithium sheet **60** is provided in each of the conveyor device **20**A, **20**B, **20**C. That is, the first conveyor device **20**A in which a first roll **10**A is provided, the second conveyor device **20**B in which a second roll **10**B is provided, and the third conveyor device **20**C in which a third roll **10**C is provided are arranged continuously.

[0085] Diameters of the first roll **10**A, the second roll **10**B, and the third roll **10**C may all be in a same size. Alternatively, considering a linear velocity according to the transportation of the lithium foil **61**, the diameter of the third roll **10**C provided on the third conveyor device **20**C disposed at the rear side may be formed smaller than the diameter of the first roll **10**A provided on the first conveyor device **20**A disposed at the front side.

[0086] Further, depending on a reduction ratio of rolling the lithium sheet **60**, the driving speed of the third conveyor device **20**C disposed at the rear side of at least two or more of the rolling mills may be controlled to be the equal speed or faster than the driving speed of the first conveyor device **20**A disposed at the front side.

[0087] Although not shown in the drawings, when a plurality of rolling rolls are provided in a plurality of unit rolling mills, the plurality of rolls may have increasing diameters from the rolling rolls provided in the conveyor device disposed at the front side, to the rolling rolls provided in the conveyor device disposed at the rear side. In this case, considering the thickness of the lithium sheet **60** and a linear velocity of the lithium sheet **60** contacting the rolling rolls, each of the driving speed of the plurality of rolling rolls can be controlled differently.

[0088] Referring to FIG. **10**, the lithium rolling apparatus **200** may include a plurality of rolls on one conveyor device **20**.

[0089] For example, assuming that three rolls are disposed continuously on one conveyor device **20**, the second roll **10**B and the third roll **10**C may be disposed sequentially with respect to the first roll **10**A disposed at the front side where the lithium sheet **60** is inserted. Here, considering the thickness of the rolled lithium foil **61**, the diameter of the third roll **10**C provided at the rear side of the conveyor device **20** may be formed to be equal to or smaller than the diameter of the first roll **10**A provided at the front side.

[0090] In case a plurality of rolling rolls are provided in the single conveyor device **20**, the driving speed of the belt **25** that is surface-contacting the lower surface of the lithium sheet **60** is always equal. Therefore, by controlling the plurality of rolling rolls to be in different sizes, or by controlling the plurality of rolling rolls to have different driving speed, a shear stress applied to the lithium sheet **60** can be controlled to roll the lithium sheet **60**.

[0091] Although not shown in the drawing, when the plurality of rolling roll is provided inside a single conveyor device **20**, the plurality of rolls may have the same diameter. Alternatively, the diameter of rolling roll may become increasingly larger from the front side of the conveyor device **20** to the rear side. In this case, considering the thickness of the lithium sheet **60** and a linear velocity of the lithium sheet **60** contacting the rolling rolls, each of the driving speed of the plurality of rolling rolls can be controlled differently.

[0092] The present disclosure has been described with reference to the embodiments illustrated in the drawings, but these embodiments are merely illustrative and it should be understood by a person with ordinary skill in the art that various modifications and equivalent embodiments can be made without departing from the scope of the present disclosure. Therefore, the true technical protective scope of the present disclosure should be determined based on the technical concept of the appended claims.

1. A lithium rolling apparatus for forming a lithium foil by rolling a lithium sheet, comprising:

a first roll which contacts a first surface of the lithium sheet;

a second roll which contacts a second surface of the lithium sheet; and

a first conveyor device disposed at a rear side of the first roll and the second roll, comprising a belt which transports the lithium foil while controlling tension applied to the lithium foil by surface-contacting at least a part of the second surface of the lithium foil.

2. The lithium rolling apparatus of claim **1**, comprising

a guide roll formed at a position contacting the first surface of the lithium foil on the first conveyor device so that the lithium foil can be transported in a flat manner when the lithium foil is transported by the first conveyor device.

3. The lithium rolling apparatus of claim **1**, comprising

a second conveyor device disposed at an upper part of the first conveyor device, which contacts the first surface of the lithium foil and transports the lithium foil,

wherein the first conveyor device and the second conveyor device are driven at a same speed.

4. The lithium rolling apparatus of claim **1**, comprising

a third conveyor device disposed at a front side of the first roll and the second roll for transporting the lithium sheet while contacting at least any part of the second surface of the lithium sheet,

wherein driving speed of the third conveyor device is controlled to be equal to or slower than driving speed of the first conveyor device.

5. The lithium rolling apparatus of claim **4**, further comprising

a fourth conveyor device disposed at an upper part of the third conveyor device, which contacts the first surface of the lithium sheet and transports the lithium sheet,

wherein the third conveyor device and the fourth conveyor device are driven at a same speed.

6. The lithium rolling apparatus of claim **1**, comprising

a lubricant supply part which sprays lubricant on at least any one surface of the lithium sheet before being rolled by the first roll and the second roll to suppress a sticking phenomenon.

7. The lithium rolling apparatus of claim **1**,

wherein the first roll, the second roll and the belt comprises a polymer material, and the polymer material comprises any one of polyethylene, polypropylene, vinylidene, polyolefin, and polyester.

8. The lithium rolling apparatus of claim **1**,
wherein a resin film is further interposed on at least any one surface of the lithium sheet contacting any one of the first roll and the second roll to prevent a sticking phenomenon.

9. The lithium rolling apparatus of claim **1**,
wherein a width of the belt of the first conveyor device is greater than a width of the lithium foil, and the lithium foil is transported at a same speed as the belt by a driving force of the belt in a surface-contact state.

10. A lithium rolling method comprising:
a step of forming a lithium foil by rolling using a first roll contacting a first surface of a lithium sheet and a second roll contacting a second surface of the lithium sheet; and
a step of transporting the lithium foil with a first conveyor device disposed at a rear side of the first roll and the second roll while controlling tension applied to the lithium foil by surface-contacting at least any part of a second surface thereof with a belt provided on the first conveyor device.

11. The lithium rolling method of claim **10**,
wherein when the lithium foil is transported by the first conveyor device by a guide roll formed at a position contacting the first surface of the lithium foil on the first conveyor device or by a second conveyor device, tension applied on the lithium foil is controlled, and the lithium foil is transported in a flat manner.

12. A lithium rolling apparatus for forming a lithium foil by rolling a lithium sheet, comprising:
a conveyor device for transporting and rolling the lithium sheet, and
a roll disposed at an upper part of the conveyor device for rolling the lithium sheet;
wherein the conveyor device comprises
a belt surface-contacting at least a part of a lower surface of the lithium sheet for rolling and transporting the lithium sheet while controlling tension applied on the lithium sheet, and a support part for supporting the lithium sheet.

13. The lithium rolling apparatus of claim **12**,
wherein at least two or more rolling mills each comprising a unit of the conveyor device and the roll are disposed continuously, and among at least two or more of the rolling mills, a driving speed of the rolling mill disposed at a rear side is controlled to be equal to or faster than a driving speed of the rolling mill disposed at a front side.

14. The lithium rolling apparatus of claim **13**,
wherein among at least two or more of the rolling mills, a diameter of the rolling mill disposed at the rear side is equal to or smaller than a diameter of the rolling mill disposed at the front side.

15. The lithium rolling apparatus of claim **12**,
wherein a plurality of the rolls are provided on the conveyor device, and
a diameter of the roll disposed at a rear side of the conveyor device is equal to or smaller than a diameter of the roll disposed at the front side of the conveyor device.

16. The lithium rolling apparatus of claim **12**, comprising
a lubricant supply part which sprays lubricant on at least any one surface of the lithium sheet before being rolled by the roll and the conveyor device to suppress a sticking phenomenon.

17. The lithium rolling apparatus of claim **12**,
wherein a resin film is further interposed on at least any one surface of the lithium sheet contacting any one of the roll and the conveyor device to prevent a sticking phenomenon.

18. The lithium rolling apparatus of claim **12**,
wherein a width of the belt of the conveyor device is greater than a width of the lithium foil, and the lithium foil is transported at a same speed as the belt by a driving force of the belt in a surface-contact state.

19. The lithium rolling apparatus of claim **12**,
wherein the roll and the belt comprise a polymer material, and the polymer material comprises any one of polyethylene, polypropylene, vinylidene, polyolefin, and polyester.

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