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(54) **HIGH THROUGHPUT ION BEAM ASSISTED DEPOSITION (IBAD)**

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H01L 39/24 (2006.01)

(52) **U.S. Cl.** **427/62**; 427/523; 427/533; 427/562; 505/325; 505/434; 505/470; 505/480; 29/599

(58) **Field of Classification Search** 427/62, 427/523, 533, 562; 505/325, 434, 470, 480; 29/599; 204/192.24
See application file for complete search history.

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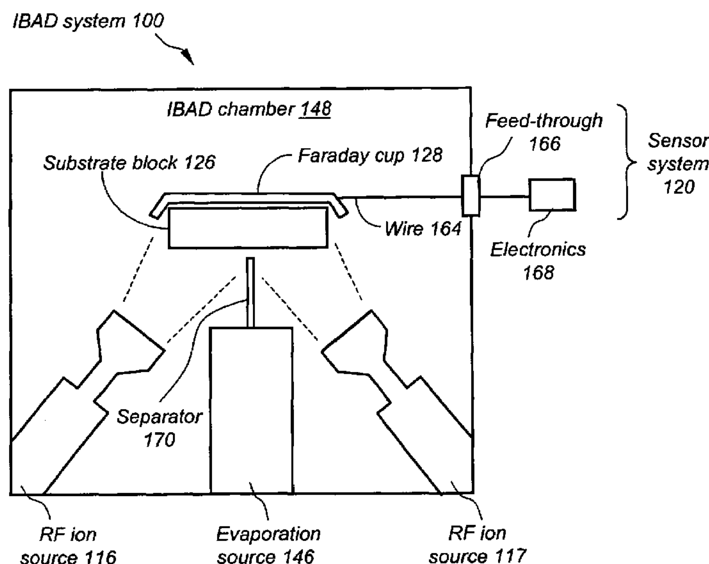
(57) **ABSTRACT**

A method of continuously coating at least one substrate with a buffer layer as a support for a ceramic superconducting material is disclosed. The method includes loading the at least one substrate onto a respective feed spool and feeding the at least one substrate through a vacuum deposition chamber. The method further includes coating the at least one substrate while the at least one substrate is bombarded by ion beams from dual RF-ion sources forming at least one coated substrate, and reloading the at least one coated substrate onto a respective take up spool.

14 Claims, 5 Drawing Sheets



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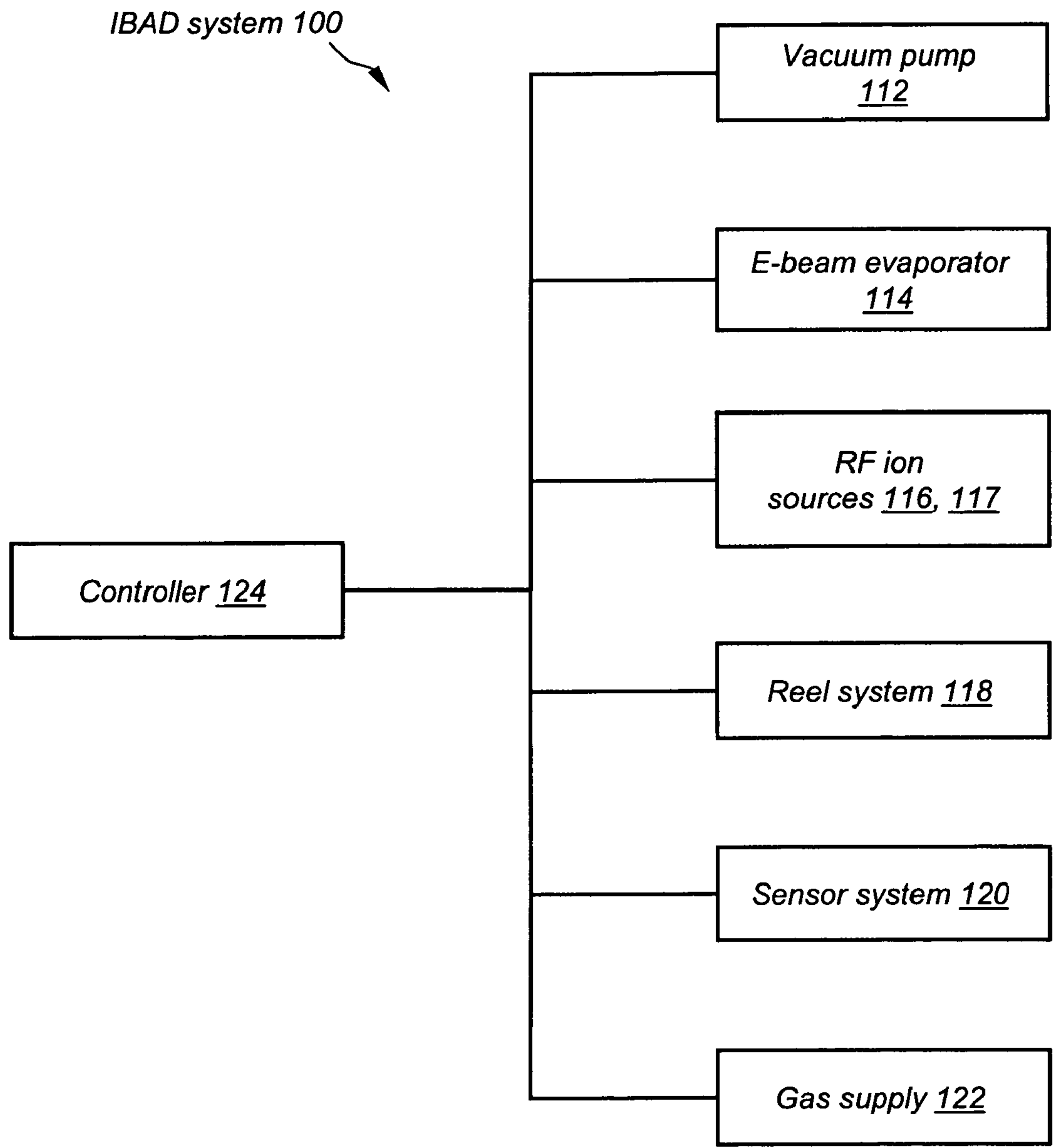


FIG. 1

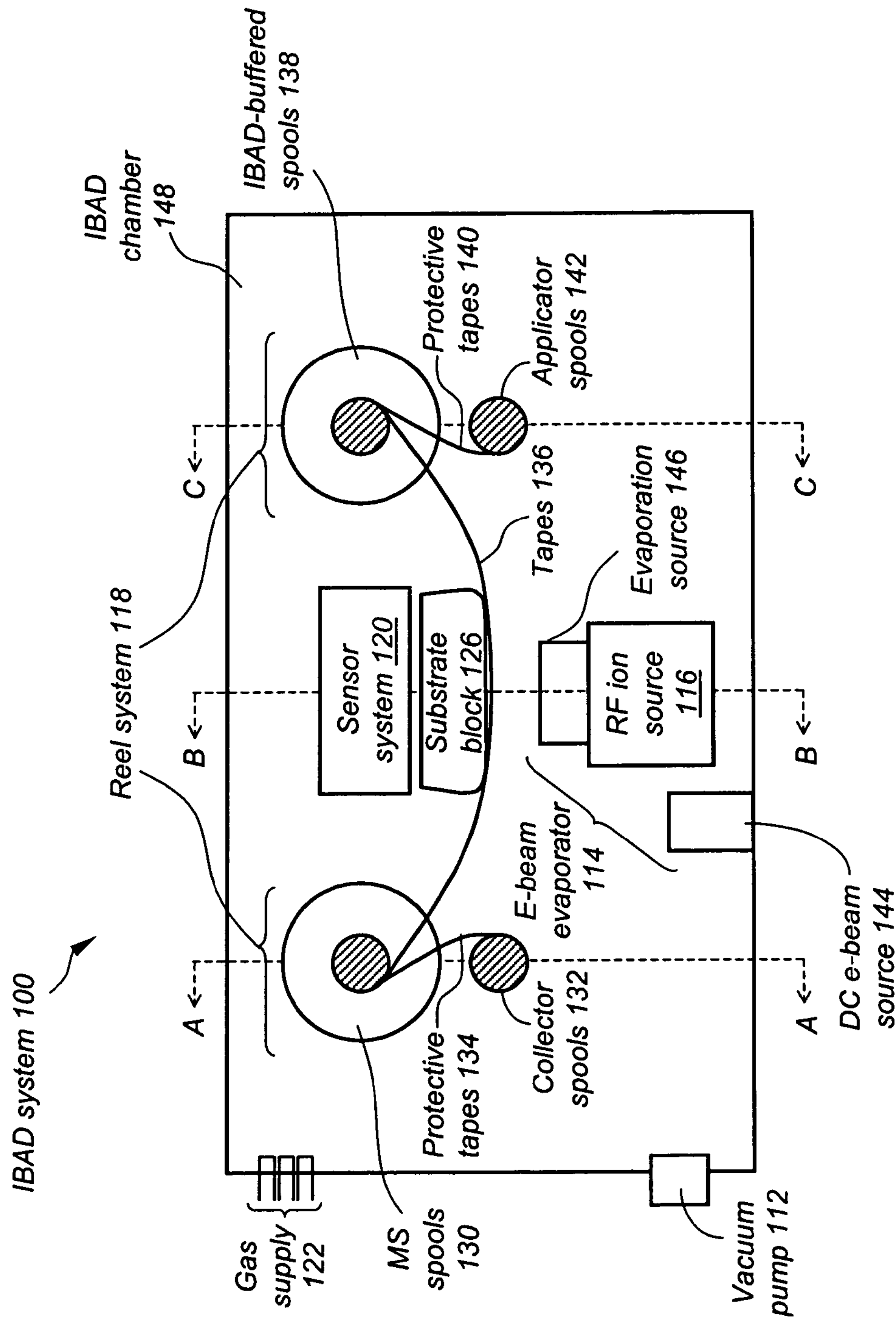


FIG. 2

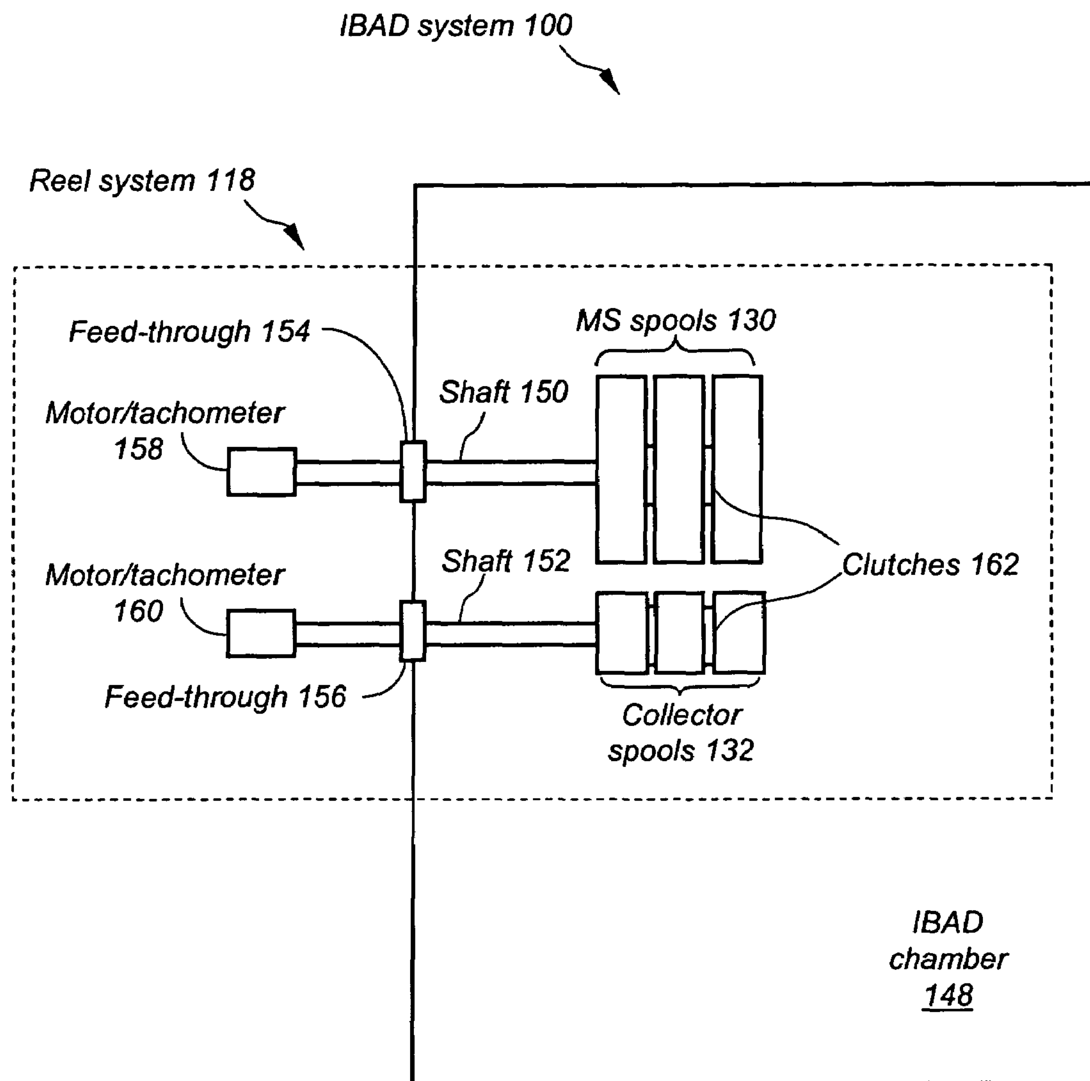


FIG. 3

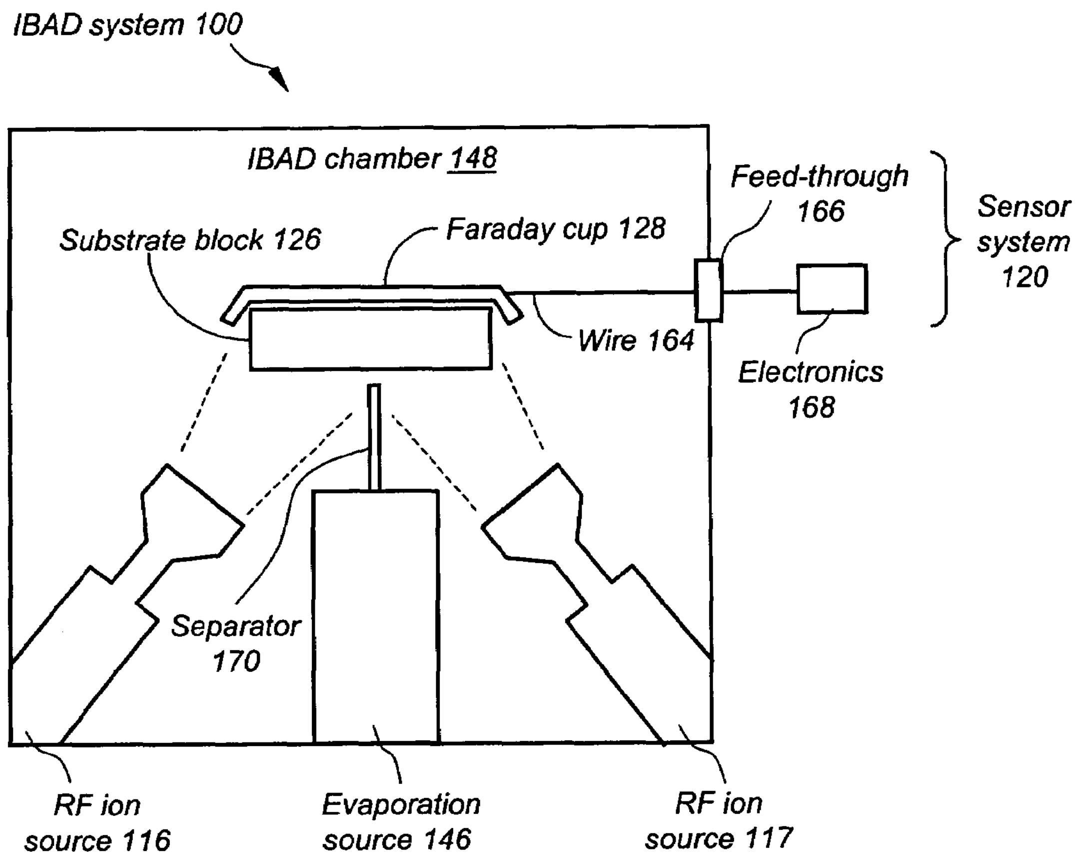


FIG. 4

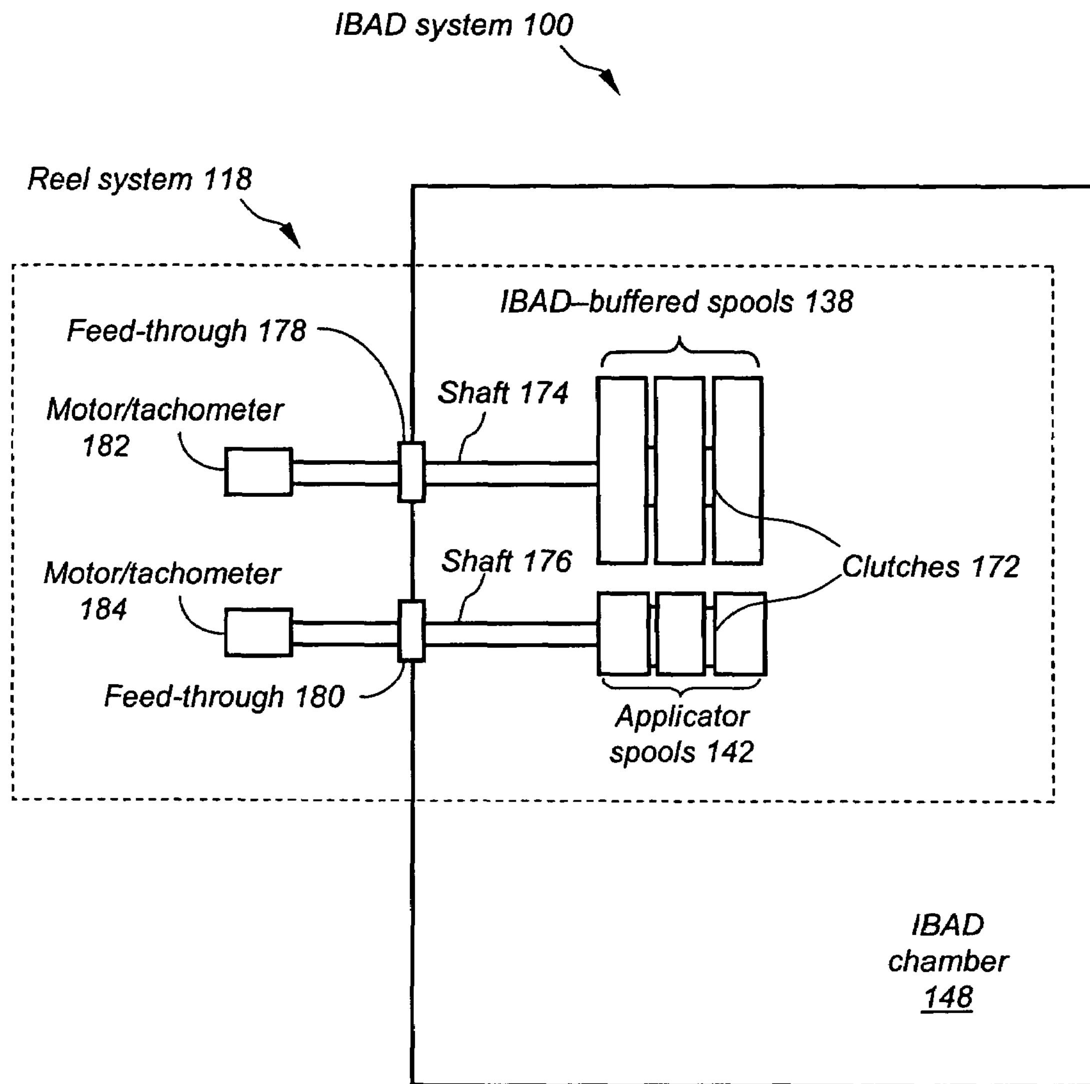


FIG. 5

HIGH THROUGHPUT ION BEAM ASSISTED DEPOSITION (IBAD)

FIELD OF THE INVENTION

The present invention relates to an ion beam-assisted deposition (IBAD) system and method of utilizing such a system. More specifically, the present invention relates to large-scale ion beam-assisted deposition of thin films, such as the buffer layers of high-temperature superconducting (HTS) tapes.

BACKGROUND OF THE INVENTION

Wire forms the basic building block of the world's electric power system, including transformers, transmission and distribution systems, and motors. The discovery of revolutionary HTS compounds in 1986 led to the development of a radically new type of wire for the power industry; this discovery is the most fundamental advance in wire technology in more than a century. However, to date only short samples of the HTS tape used in the manufacture of next-generation HTS wires have been fabricated at high performance levels. In order for HTS technology to become commercially viable for use in the power generation and distribution industry, it will be necessary to develop techniques for continuous, high-throughput production of HTS tape.

Ion beam-assisted deposition processes, such as is described in Iijima, et al., U.S. Pat. No. 6,214,772, dated Apr. 10, 2001 and entitled "Process for Preparing Polycrystalline Thin Film, Process for Preparing Oxide Superconductor, and Apparatus Therefore," has shown great promise in creating desirable buffer layer characteristics as a support for a functional layer of a ceramic superconducting material, such as yttrium-barium-copper-oxide (YBCO) atop the buffering layers of yttrium-stabilized zirconia (YSZ) and cerium oxide (CeO_2).

During IBAD, a vacuum-deposition process that combines physical vapor deposition (PVD) with ion beam bombardment occurs: a vapor of coating atoms is generated with an electron beam evaporator or ion beam sputter source or magnetron sputter source and is deposited on a substrate. Ions are simultaneously extracted from a plasma from an ion source and accelerated into the growing PVD film at energies of a few hundred electron-volts (eV). The ions impart substantial energy to the coating and coating/substrate interface.

This achieves the benefits of substrate heating (which generally provides a denser, more uniform film) without significantly heating the substrate material and degrading bulk properties. The ions also interact with the coating atoms, driving them into the substrate and producing a graded material interface, which enhances adhesion. These factors combine to allow the deposition of uniform, adherent, low-stress films of virtually any coating material on most substrates. In addition, concurrent ion beam bombardment of a growing film has been shown to impart biaxial texture. IBAD has been specifically used for this purpose to achieve a high-degree of biaxial texture in materials used as buffer layers for HTS tapes.

Prior art IBAD processes, especially those used to achieve biaxial texture in buffer layers for HTS tapes are well known for their slow deposition rates. The deposition rates are excruciating slow, around 1 Angstrom/second. The low deposition rate severely restricts the throughput of the process. One possibility to increase the throughput is to increase the area of the deposition zone. The high-throughput continuous deposition of buffer layers necessary to enable cost-effective and, consequently, widespread adaptation of HTS materials in the electricity transmission/distribution industry necessitates an increase in the deposition zone that is achievable through the prior art.

It is thus an object of this invention to provide a high-throughput IBAD system that achieves a deposition zone of sufficient width to achieve optimum thin film characteristics atop multiple translating substrate tapes.

BRIEF SUMMARY OF THE PRESENT INVENTION

The present invention is an IBAD system characterized by increased throughput compared to prior art IBAD systems, while still achieving optimum thin film quality. The IBAD system of the present invention includes a bi-lateral arrangement of radio frequency (RF) ion sources that create a deposition zone of sufficient width to enable simultaneous deposition onto a plurality of translating metal substrate tapes arranged parallel to one another. The bilateral RF ion sources are arranged on opposite sides of an source of coating material in such a manner that a pair of ion beams is directed toward the substrate tapes at incident angles of, for example, 55 degrees normal to the tape surface.

A novel multiple spool feed system that serves to translate the plurality of substrate tapes through the system at optimum tension and speed is further disclosed. The system can accommodate form 2 to 16 tapes, desirably 6 to 12 and most preferably 8 to 10 simultaneously translating tapes.

The present invention is particularly well suited to the high-throughput, cost-effective deposition of the buffer layers of HTS tapes.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a block diagram of the IBAD system of the present invention depicting the functional relationships between the subsystems of the IBAD system.

FIG. **2** illustrates a front view of the IBAD system of the present invention.

FIG. **3** illustrates a cross-sectional view of the IBAD system of the present invention taken along line A-A of FIG. **2**.

FIG. **4** illustrates a cross-sectional view of the IBAD system of the present invention taken along line B-B of FIG. **2**.

FIG. **5** illustrates a cross-sectional view of the IBAD system of the present invention taken along line C-C of FIG. **2**.

DETAILED DESCRIPTION OF THIS INVENTION

FIG. **1** illustrates a high-level block diagram of an IBAD system **100** in accordance with the invention, depicting the functional relationships between each subsystem. The IBAD system **100** includes a plurality of subsystems as follows:

- a commercially available vacuum pump **112** that is capable of maintaining a vacuum of pressure in the order of magnitude of 10^{-5} Torr. One example of such a pump is an APD Cryogenics, Marathon 16 cryopump.
- an energy source **114** such as an electron beam (e-beam) evaporator or ion beam or magnetron sputtering source, that produces a vapor of depositing material via the erosion of the surface of a solid source. The e-beam evaporator **114** assembly includes elements that are described in reference to FIG. **2**.
- a first RF ion source **116** and a second RF ion source **117** that are commercially available ion sources such as a pair of Veeco-Ion Tech, RF 6*22 linear sources using a voltage of 1500 volts and having a power rating of 500 W;

a reel system **118** that is a reel-to-reel tape transport system serving to translate multiple strands of substrate tape through the IBAD system **100**. The reel system **118** includes a series of spools, motors, tachometers, shafts, and feed-throughs, as are described in reference to subsequent figures. Further details of the reel system **118** are described in reference to FIGS. **2**, **3**, and **5**;

a sensor system **120** that is a series of sensors that monitor process conditions and parameters of the IBAD system **100**. The sensor system **120** may include pressure gauges, film thickness sensors, a Faraday cup, and a temperature-sensing unit, as are described below. Further details of the sensor system **120** are described in reference to FIGS. **2** and **4**;

a gas supply **122** that is a gas injection system that provides gases, e.g. argon, nitrogen, helium and/or oxygen, at a flow rate to meet process specifications. The gas supply **122** may include a tank farm as well as a series of valves and flow meters and is described below in reference to FIG. **2**; and

a controller **124** with a plurality of inputs and outputs that meet the requirements of the peripherals described in reference to FIG. **2**. The controller **124** may be one or more micro-controllers or a PC with appropriate hardware & software. The controller **124** is electrically coupled to and provides control to the vacuum pump **112**, the e-beam evaporator **114**, the RF ion sources **116** and **117**, the reel system **118**, the sensor system **120**, and the gas supply **122**.

Functional connections exist among the vacuum pump **112**, the energy source **114**, such as an e-beam evaporator, the RF ion source **116**, the RF ion source **117**, the reel system **118**, the sensor system **120**, the gas supply **122**, and the IBAD chamber (described below).

FIG. **2** illustrates a front view of the IBAD system **100** apparatus. This view shows that the IBAD system **100** further includes an IBAD chamber **148** that is a pressurized vacuum chamber. The IBAD chamber **148** may be constructed of any non-corroding metal, such as 304 stainless steel. The IBAD chamber **148** includes all the necessary gaskets, seals, and seal plates to maintain a vacuum to the order of 10^{-7} Torr.

As shown in FIG. **2**, the vacuum pump **112** and the gas supply **122** are disposed in the outer wall of the IBAD chamber **148**. The vacuum pump **112** is functionally connected such that a vacuum seal is maintained.

A substrate block **126** is disposed within the IBAD chamber **148** in close proximity to the sensor system **120**. A plurality of tapes **136** come into contact with and translates underneath the substrate block **126** via the action of elements of the reel system **118**, which may or may not be disposed inside the IBAD chamber **148**. The reel system **118** includes a plurality of metal substrate (MS) spools **130**, a plurality of collector spools **132**, a plurality of protective tapes **134**, a plurality of IBAD-buffered spools **138**, a plurality of protective tapes **140**, and a plurality of applicator spools **142**.

Also disposed within the IBAD system **100** are the energy source to vaporize the coating material **114**, which may be e-beam evaporator, which includes a DC E-beam source **144**, or an ion beam or magnetron sputtering system [not shown], and a coating source **146**. The coating source **146** is oriented within the IBAD chamber **148** between the RF ion source **116** and the RF ion source **117** (not shown), and is horizontally aligned with the center of the substrate block **126**, as illustrated in FIG. **4**. Similarly, the DC e-beam source **144** or ion beam or magnetron sputtering system is aligned with the coating source **146** as per the specifications from the manufacturer of the DC e-beam source **144** or the ion beam or magnetron sputtering system.

Furthermore, the RF ion sources **116** and **117** are arranged on opposite sides of the coating source **146** in such a manner that a pair of ion beams (not shown) is directed toward the substrate tapes **136** at incident angles of, for example, 55 degrees normal to the tape surface, as illustrated in FIG. **4**.

The substrate block **126** is a metal block having an internal coolant passageway loop to increase the heat dissipation capacity. The substrate block **126** incorporates all necessary mounting holes and coolant connectors. The substrate block **126** is positioned within the IBAD chamber **148** such that a deposition zone for a plurality of tapes **136** is created at the surface of the substrate block **126**. In addition, the substrate block **126** may include a shutter (not shown) that can be opened or closed to expose the tapes **136** to the deposition zone.

The tapes **136** are lengths of material formed from a variety of metals capable of withstanding temperatures up to 900° C. and suitable for IBAD, such as stainless steel or a nickel alloy such as Inconel. The dimensions of the tapes **136** may vary to meet the desired finished product and system limitations. For example, the tapes **136** may have a thickness of 25 microns, a width of 1 cm and a length of 100 meters.

The DC e-beam source **144** is a commercially available electron source having the capability of dynamically controlling the trajectory of a beam of electrons. One example of a commercially available e-beam source is a Thermionics (Thermionics Vacuum Products, 231 Otto St., Port Townsend, Wash. 98368) source having a power rating of 10 kW. Other suitable e-beam sources are available in power ranges of from 1 to 20 kW.

The ion beam and magnetron sputtering systems are also commercially available units.

The coating source **146** is a commercially available deposition source composed of material such as yttria-stabilized zirconium (YSZ) or Magnesium Oxide (MgO) suitable for exposure to electron bombardment. Other evaporation sources suitable for use as a buffer with YBCO may also be used. The coating source **146** is a consumable and can be purchased from e.g. Transdec. The electrons delivered to the coating source **146** by the DC e-beam source **144** or ion beam or magnetron sputtering source, heat and evaporate the material of the coating source **146**, forming a gas which is subsequently deposited onto the tapes **136** with the assistance of embedding ions emitted from the RF ion sources **116** and **117**.

The MS spools **130** are spools on which the non-IBAD processed tapes **136** and the plurality of protective tapes **134** are wound in alternating layers. The diameter and width of the MS spools **130** may vary with the dimensions of the desired product. The MS spools **130** may be constructed from a variety of materials capable of withstanding vacuum chamber conditions. A typical material is anodized aluminum.

The IBAD-buffered spools **138** are constructed from similar material and dimensions to the MS spools **130**. The IBAD-buffered spools **138** are spools onto which the tapes **136** and the protective tapes **140** wind after the tapes **136** have undergone an IBAD process.

The protective tapes **134** and the protective tapes **140** are polymeric tapes having protective properties such as scratch-resistant surfaces, and serve to protect the layers of the tapes **136** wound about the MS spools **130** and the IBAD-buffered spools **138**. A useful protective tape is one composed of kapton. The dimensions of the protective tapes **134** and the protective tapes **140** correspond to the dimensions of the tapes **136**, as described below.

The collector spools **132** are spools similar to the MS spools **130**, onto which the protective tapes **134** wind as the tapes **136** and the protective tapes **134** unwind from the MS spools **130**. The collector spools **132** may be constructed from a variety of materials capable of withstanding IBAD vacuum chamber conditions.

The applicator spools **142** are of similar material and dimensions to the collector spools **132** and are the spools from which the protective tapes **140** unwind as the protective tapes **140** are interleaved with the tapes **136** onto the IBAD-buffered spools **138**.

The MS spools **130** and the collector spools **132** are further described in reference to FIG. **3**. The protective tapes **134** are wound simultaneously with the tapes **136** about the MS spools **130**, such that a winding of the protective tape **134** exists between each layer of wound tape **136**. The protective tapes **134** wind onto the collector spools **132** as the tapes **136** unwind from the MS spools **130**. The tapes **136** come into contact with the surface of the substrate block **126** as they span from the MS spools **130** to the IBAD-buffered spools **138**. The tapes **136** are wound simultaneously with the protective tapes **140** onto the IBAD-buffered spools **138**, such that a layer of the protective tapes **140** exist between each layer of the tapes **136** on the IBAD-buffered spools **138**. The protective tapes **140** unwind from the applicator spools **142** and wind onto the IBAD-buffered spools **138**.

FIG. **3** illustrates a cross-sectional view of the IBAD system **100** taken along line A-A of FIG. **2** such that further details of the reel system **118** are illustrated. The reel system **118** includes the MS spools **130**, the collector spools **132**, a shaft **150**, a shaft **152**, a feed-though **154**, a feed-through **156**, a motor/tachometer **158**, a motor/tachometer **160**, and a plurality of clutches **162**.

The shafts **150** and **152** are commercially available drive shafts capable of supporting the loads and stresses of the MS spools **130** and the collector spools **132**, respectively.

The clutches **162** are commercially available elements that connect multiple spools to a single shaft in such a manner that each spool experiences the same torque as transmitted by the shaft. The number of clutches **162** that exist on each of the shafts **150** and **152** corresponds to the number of the tapes **136** that translate through the IBAD chamber **148**.

The feed-throughs **154** and **156** are commercially available feed-throughs, such as those produced by Ferrofluidics, and allow the shafts **150** and **152**, respectively, to pass through the wall of the IBAD chamber **148** while still maintaining a vacuum seal.

The motors/tachometers **158** and **160** are commercially available motor and tachometer systems capable of translating the tapes **136** and protective tapes **134**, respectively, at speeds between 0.5 and 300 meters/hour, usefully with an accuracy of +/−1% of the linear speed. The translation speed varies widely since IBAD may be utilized with a material that textures slowly, such as YSZ, or one that textures quickly, such as MgO. For YSZ, a speed in the range of from about 0.5 to about 5.0 m/hr is useful; for MgO a speed in the range for from about 20 to about 300 m/hr is useful.

The MS spools **130** exist within the IBAD chamber **148** and are functionally connected to the shaft **150**, which passes through the feed-through **154** while still maintaining a vacuum seal. The shaft **150** is then functionally connected to the motor/tachometer **158**. The feed-through **154** is functionally integrated into the IBAD chamber **148**, such that a seal is maintained between the feed-through **154** and the IBAD chamber **148**.

Similarly, the collector spools **132** exist within the IBAD chamber **148**. The collector spools **132** are functionally connected to the shaft **152**, which passes through the feed-through **156** while still maintaining a vacuum seal. The shaft **152** is then functionally connected to the motor/tachometer **160**. The feed-through **156** is functionally integrated into the IBAD chamber **148**, such that a seal is maintained between the feed-through **156** and the IBAD chamber **148**.

Alternately, the feedthroughs **154** and **156** may serve to pass the shafts **150** and **152** through the wall of a chamber adjacent to and dynamically isolated from the IBAD chamber **148**, such that the MS spools **130** and the collector spools **132** are housed in the adjacent chamber and translate the tapes **136** and the protective tapes **134**, respectively, through a slit in the wall of the IBAD chamber **148** capable of maintaining the vacuum requirements of the IBAD chamber **148**.

FIG. **4** illustrates a cross-sectional view of the IBAD system **100** taken along line B-B of FIG. **2**, such that further details of the RF ion sources **116** and **117** and the sensor system **120** are shown disposed within the IBAD chamber **148**.

The RF ion sources **116** and **117** emit ion beams (not shown) that are focused on the substrate block **126** and separated by a separator **170** mounted on the evaporation source **146**. The sensor system **120** is shown to further include a Faraday cup **128**, a wire **164**, a feed-through **166**, and a system of electronics **168**.

The Faraday cup **128** is a device capable of collecting and detecting ions. It includes a coaxial cable (not shown) bent at an angle, for example 55 degrees, an ion collector plate (not shown), and a metallic shield/collector (not shown). The Faraday cup **128** is an element of the sensor system **120**. The Faraday cup **128** is mechanically fastened to a surface of the substrate block **126**, as described in further detail in reference to FIG. **4**.

The wire **164** is any commercially available shielded wire capable of transmitting an electrical signal. The wire **164** may include a high-temperature resistant sheath such as Teflon.

The feed-through **166** is a commercially available feed-through that is capable of allowing a signal wire to pass through the wall of the IBAD chamber **148** while still maintaining a vacuum seal.

The electronics **168** is a system of electronics that detects an ion charge sensed by the Faraday cup **128** and generates a corresponding electric signal.

The separator **170** is a barricade that is impervious to ions ejected from the RF ion sources **116** and **117**. The separator **170** is composed of a material characterized by a low sputtering yield and a chemical compatibility with the IBAD thin film. One example is a sheet of zirconium oxide or a stainless steel sheet coated with a layer of zirconium oxide. The separator may be coated with whatever oxide is being used for the buffer layer. The separator **170** is disposed upon a stationary fixture within the IBAD chamber **148** near the center of the translating tapes **136** in such an orientation as to be in closer proximity to the substrate block **126** than to the RF ion sources **116** and **117**.

The Faraday cup **128** is fixedly attached to a surface of the substrate block **126** such that the Faraday cup **128** is aligned with the direction of propagation of ions from the RF ion sources **116** and **117**. Alternately, a plurality of Faraday cups **128** with a variety of different orientations may exist to monitor ion emissions released from the RF ion sources **116** and **117**. The Faraday cup **128** is electrically coupled to the wire **164**, which in turn passes through the feed-through **166** and is electrically coupled to the electronics **168**. The feed-through **166** is functionally integrated into the IBAD chamber **148**

such that a seal is maintained between the feed-through **166** and the IBAD chamber **148**. The electronics **168** exist outside of the IBAD chamber **148**.

The coating source **146** is disposed within the IBAD chamber **148** such that the longitudinal axis of the coating source **146** is aligned with the longitudinal axis of the substrate block **126**. The RF ion sources **116** and **117** exist within the IBAD chamber **148** on opposite sides of the coating source **146** in such a manner that a pair of ion beams is directed toward the substrate tapes **136** at incident angles of, for example, 55 degrees.

FIG. **5** illustrates a cross-sectional view of the IBAD system **100** taken along line C-C of FIG. **2** such that further details of the reel system **118** are shown disposed within the IBAD chamber **148**. The reel system **118** includes the IBAD-buffered spools **138**, the applicator spools **142**, a plurality of clutches **172**, a shaft **174**, a shaft **176**, a feed-through **178**, a feed-through **180**, a motor/tachometer **182**, and a motor/tachometer **184**.

The clutches **172** are commercially available clutches that are capable of connecting multiple spools to a shaft, such that each spool experiences the same torque as transmitted by the clutches **172**. For simplicity, only three clutches **172** are shown in FIG. **5**; in practice, upwards of sixteen tapes **136** may translate through the IBAD chamber **148** simultaneously, requiring a corresponding number of the clutches **172**. We prefer to utilize 2 to 16, preferably 6 to 12, most preferably 8 to 10 simultaneously translating tapes.

The shafts **174** and **176** are commercially available drive shafts capable of supporting the loads and stresses of the IBAD-buffered spools **138** and the applicator spools **142**, respectively, and are elements of the reel system **118**.

The feed-throughs **178** and **180** are commercially available feed-throughs, such as those produced by Ferrofluidics, and allow the shafts **174** and **176**, respectively, to pass through the wall of the IBAD chamber **148** while still maintaining a vacuum seal.

The motors/tachometers **182** and **184** are commercially available motor and tachometer systems capable of translating the tapes **136** and protective tapes **140**, respectively, at speeds between 0.1 and 50 meters/hour with an accuracy of +/−1% of the linear speed.

The IBAD-buffered spools **138** exist within the IBAD chamber **148** and are functionally connected to the shaft **174**, which passes through the feed-through **178** while still maintaining a vacuum seal. The shaft **174** is then functionally connected to the motor/tachometer **182**. Similarly, the applicator spools **142** exist within the IBAD chamber **148**. The applicator spools **142** are functionally connected to the shaft **176**, which passes through the feed-through **180** while still maintaining a vacuum seal. The shaft **176** is then functionally connected to the motor/tachometer **184**. Alternately, the feedthroughs **178** and **180** may serve to pass the shafts **174** and **176**, respectively, through the wall of a chamber adjacent to and dynamically isolated from the IBAD chamber **148**, such that the IBAD-buffered spools **138** and the applicator spools **142** are housed in the adjacent chamber and translate the tapes **136** and the protective tapes **140**, respectively, through a slit in the wall of the IBAD chamber **148** capable of maintaining the vacuum requirements of the IBAD chamber **148**.

In operation and in reference to the IBAD system **100** described in FIG. **1**, FIG. **2**, FIG. **3**, FIG. **4**, and FIG. **5**, the sensor system **120** continuously monitors conditions and system parameters within the IBAD system **100**. The sensor system **120** transmits the observed data as electric signals to the controller **124**. The controller **124** then processes the electric signals received from the sensor system **120** using a set algorithm or program embedded in the memory of the controller **124** to optimize the IBAD system **100** performance. The controller **124** then sends a separate and appropriate electric signal to the vacuum pump **112**, the e-beam evaporator **114**, the RF ion source **116**, the RF ion source **117**, the reel system **118**, the sensor system **120**, and the gas supply **122**, thereby controlling the devices' performance appropriately.

The controller **124** commands the gas supply **122** to inject gases into the IBAD chamber **148**. Similarly, the controller **124** commands the vacuum pump **112** to exhaust chamber gases to create an appropriate vacuum. The motor/tachometer **158** rotates the shaft **150** that passes through the feed-through **154** and in turn rotates one of the clutches **162**. The clutches **162** then provide equal torque to each of the MS spools **130**. Similarly, the motor/tachometer **160** rotates the shaft **152** that passes through the feed-through **156** and in turn rotates one of the clutches **162**. The clutches **162** then provide equal torque to each of the collector spools **132**.

The shaft **152** and the collector spools **132** rotate in such a manner that as the plurality of tapes **136** unwind from the MS spools **130**, the protective tapes **134** simultaneously wind onto the collector spools **132** at an equal rate. Similarly, the tapes **136** unwind from the MS spools **130**. The controller **124** controls and monitors the motors/tachometers **158** and **160** to maintain a desired feed-rate and tension across all the tapes **136**. Additionally, tension can be monitored actively with the use of a load cell mechanism.

A load cell may come into contact with the tapes **136** and communicate actively with the controller **124** in a feedback loop. The controller **124** may compare the communicated tension with a preset tension value stored within its memory and subsequently adjust the tension of the tapes **136** via control of one of the motor/tachometers **158** and **160**.

The tapes **136** then contact the substrate block **126**, at which point the tapes **136** are in the deposition zone of the IBAD chamber **148**. The tapes **136** are exposed to vapor emitted from the coating source **146**. The coating source **146** emits a vapor upon bombardment by the DC e-beam source **144** or ion beam or magnetron source. Similarly, the tapes **136** are bombarded by ions emitted from the RF ion sources **116** and **117**. The Faraday cup **128** detects ions released from the RF ion sources **116** and **117** at the substrate block **126**, and forms an electric current in proportion to the amount of ions impinging upon the Faraday cup **128**. This electric signal is transmitted via the wire **164** through the feed-through **166** to the electronics **168**. The electronics **168** convert the electric current to a signal proportional to the amplitude of the electric current sensed by the Faraday cup **128** and transmit a new electric signal to the controller **124**.

The motor/tachometer **182** rotates the shaft **174** that passes through the feed-through **178** and in turn rotates one of the clutches **172**. The clutches **172** then provide equal torque to each of IBAD-buffered spools **138**. Similarly, the motor/tachometer **184** rotates the shaft **176** that passes through the feed-through **180** and in turn rotates one of the clutches **172**. The clutches **172** then provide equal torque to each of the applicator spools **142**. The motor/tachometer **184** and the applicator spools **142** rotate in such a manner that as the protective tapes **140** unwind from the applicator spools **142**, the protective tapes **140** simultaneously wind onto the IBAD-buffered spools **138** at an equal rate. Similarly, the tapes **136** wind onto the IBAD-buffered spools **138**, such that for every wind of the tapes **136** on the IBAD-buffered spools **138** there exists a wind of the protective tapes **140**. The controller **124** controls and monitors the motor/tachometer **182** and the

motor/tachometer **184** to maintain a desired feed-rate and tension across all the tapes **136**.

The inclusion of the RF ion sources **116** and **117** in conjunction with the e-beam evaporator **114** assembly enables a deposition zone to be created of sufficient width to enable the plurality of tapes **136** to translate through the IBAD chamber **148** and receive optimum thin film deposition. The translational velocity of the tapes **136** through the IBAD chamber **148**, and thus the deposition rate per tape, is similar to the IBAD systems of the prior art in which deposition occurs upon a single tape. Thus, the IBAD system **100** has increased throughput over the prior art a factor on the order of the number of the tapes **136** translating parallel to one another.

The invention claimed is:

1. A method of continuously coaling at least one substrate with a buffer layer as a support for a ceramic superconducting material comprising:

loading the at least one substrate having a width and opposite major surfaces onto a respective feed spool;

feeding the at least one substrate across a substrate block within a deposition zone in a vacuum deposition chamber wherein a coating generated from a single deposition source is applied to the at least one substrate white the at least one substrate is bombarded by ions from a dual RF-ion source along the deposition zone;

forming at least one coated substrate within the deposition zone; and

reloading the at least one coated substrate onto a respective take-up spool,

wherein the dual RF-ion source includes first and second RF-ion sources bi-laterally oriented with respect to the at least one substrate, on the same side of the substrate, and located such that a projection on a major surface of the at least one substrate of a line intersecting the first and second RF-ion sources is substantially perpendicular to the longitudinal axis of the at least one substrate so as to be aimed at respective first and second portions of the same major surface of the at least one substrate and bombard the respective first and second portions of the same major surface of the at least one substrate, wherein the first portion and the second portion each span one-half the width of the at least one substrate such that the first and second portions span an entirety of the width of the at least one substrate and

wherein a separator is disposed within the deposition chamber, between the bilaterally oriented dual RF-ion sources, and in closer proximity to the substrate block than to the dual RF-ion sources, the separator being oriented along a direction that longitudinally bisects the substrate block and functioning to barricade impingement of ions from the first RE-ion source on the second portion and barricade impingement of ions from the second RF-ion source on the first portion.

2. The method of claim **1** where the respective feed spool and take-up spools are located external to the deposition chamber.

3. The method of claim **1** where the at least one substrate is inter-spooled with kapton polymer protective tapes.

4. The method of claim **1** where the coating is generated from a deposition source, the deposition source is an electron beam evaporator.

5. The method of claim **1** where from about **2** to about **12** substrates are simultaneously being coated.

6. The method of claim **1** where at least two substrates are simultaneously being coated.

7. A method of continuously coating at least one substrate with a buffer layer as a support for a ceramic superconducting material comprising:

providing at least one substrate feed spool of substrate, the substrate having a width and opposite major surfaces,

unspooling and tbreading the at least one substrate through a vacuum deposition chamber,

loading coating material that is to be deposited onto a surface of the at least one substrate into the vacuum deposition chamber,

reducing the pressure in the deposition chamber to no greater than about 10^{-5} Torr,

injecting oxygen into the deposition chamber,

initializing dual RF-ion sources located in the deposition chamber to a pre-determined power level and trajectory where the resulting ion beams are directed toward the at least one substrate tape translating through a deposition zone in the deposition chamber, wherein the dual RF-ion source includes first and second RF-ion sources bi-laterally oriented with respect to the at least one substrate and on the same side of the substrate, the first and second RF-ion sources located such that a projection on a major surface of the at least one substrate of a line intersectin the first and second RF-ion sources is substantially perpendicular to the longitudinal axis of the at least one substrate so as to be aimed at respective first and see on portions of the same major surface of the at least one substrate and bombard the respective first and second portions of the same major surface of the at least one substrate, wherein the first portion and the second portion each span one-half the width of the at least one substrate such that the first and second portions span an entirety of the width of the at least one substrate and wherein a separator is disposed between the bilaterally oriented dual RF-ion sources and in closer proximity to the substrate block than to the dual RF-ion sources, the separator being oriented along a direction that longitudinally bisects a substrate block and functioning to barricade impingement of ions from the first RF-ion source on the second portion and barricade impingement of ions from the second RF-ion source on the first portion,

eroding the coating material by bombarding the coating material with electrons or ions produced by an energy source selected from the group consisting of DC electron beam, magnetron and ion beam energy sources,

feeding the at least one substrate across the substrate block through a deposition zone in the vacuum chamber,

allowing the coating material eroded from the coating source to impinge upon a sufface of the at least one substrate for a period of time sufficient to deposit a coating of evaporated coating material onto the tape forming at least one coated substrate, and

collecting the at least one coated substrate on a respective take-up spool.

8. The method of claim **7** wherein RF ion sources are arranged on opposite sides of the coating source in a manner such that the resulting ion beams are directed toward the at least one substrate at incident angles of approximately 55 degrees.

9. A method of continuously coating at least one substrate with a buffer layer as a support for a ceramic superconducting material, comprising:

translating at least one substrate from a respective feed spool, through a deposition chamber, and onto a respective take-up spool, the deposition chamber having an internal volume defined by a plurality of walls, located within the internal volume are a substrate block having a

width and a length, a single deposition source, a first and a second RF-ion sources, and a separator disposed between the first and the second RF-ion sources and in closer proximity to the substrate block than to the first and second RF-ion sources, the first and second RF-ion sources being bilaterally oriented with respect to the at least one substrate, the separator being oriented along a direction that bisects the substrate block along the length, wherein the at least one substrate provides multiple substrate portions translating across the substrate block;

depositing a coating generated from the single deposition source onto the multiple substrate portions while the multiple substrate portions are translating across the substrate block; and

bombarding a first portion of the multiple substrate portions within a first region of the substrate block with ions from the first RF-ion source and a second portion of the multiple substrate portions within a second region of the substrate block with ions from the second RF-ion source while depositing the coating on the multiple substrate portions translating across the substrate block, the ions from the first and second RF-ion sources, the separator functioning to barricade impingement of ions from the first RF-ion source on the second portion and barricade impingement of the second RF-ion source on the first portion, wherein the first region and the second region each span one-half the width of the substrate block such that the first and second regions span an entirety of the width of the substrate block.

10. The method of claim **9**, where the respective feed spool and the respective take-up spool are located external to the deposition chamber.

11. The method of claim **9**, where the at least one substrate is inter-spooled with kapton polymer protective tapes.

12. The method of claim **9**, where the deposition source is an electron beam evaporator.

13. The method of claim **9** where from about 2 to about 12 substrates are simultaneously being coated, each of the substrate portions provided by corresponding one of said about 2 to about 12 substrates.

14. The method of claim **9**, where at least two substrates are simultaneously being coated.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

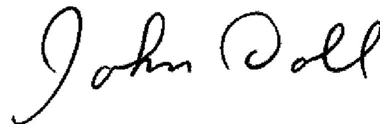
PATENT NO. : 7,531,205 B2
APPLICATION NO. : 10/602467
DATED : May 12, 2009
INVENTOR(S) : Venkat Selvamanickam et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 10, line 23, please delete “intersectin” and insert therefor --intersecting--;
line 26, please delete “see on” and insert therefor --second--; and
line 49, please delete “sufface” and insert therefor --surface--.

Signed and Sealed this

Twenty-eighth Day of July, 2009



JOHN DOLL
Acting Director of the United States Patent and Trademark Office