US007869574B2

(12) **United States Patent**
Steinlage et al.

(10) **Patent No.: US 7,869,574 B2**
(45) **Date of Patent: Jan. 11, 2011**

(54) **BRAZE ASSEMBLY WITH BERYLLIUM DIFFUSION BARRIER AND METHOD OF MAKING SAME**

(75) Inventors: **Gregory Alan Steinlage**, Hartland, WI (US); **Thomas C. Tiearney**, Waukesha, WI (US); **Donald Robert Allen**, Waukesha, WI (US)

(73) Assignee: **General Electric Company**, Schenectady, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 112 days.

(21) Appl. No.: **12/327,255**

(22) Filed: **Dec. 3, 2008**

(65) **Prior Publication Data**

US 2010/0135466 A1 Jun. 3, 2010

(51) **Int. Cl.**
G21K 1/00 (2006.01)
B23K 1/19 (2006.01)

(52) **U.S. Cl.** **378/161**; 228/262.31

(58) **Field of Classification Search** 378/161; 228/262.31, 262.42–262.45, 262.51, 262.72, 228/262.8, 262.9; 427/250; 205/263, 264, 205/261, 283, 266, 271; 438/118; 428/649
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,871,108	A *	10/1989	Boecker et al.	228/122.1
5,226,067	A *	7/1993	Allred et al.	378/161
5,664,723	A	9/1997	Sastri	
6,164,524	A	12/2000	Iwadachi	
6,528,123	B1 *	3/2003	Cadden et al.	427/404
6,824,888	B2	11/2004	Hatano et al.	
7,016,472	B2	3/2006	Subraya et al.	

OTHER PUBLICATIONS

Araki et al., "Manufacturing and testing of a Be / OFHC—Cu divertor module," Journal of Nuclear Materials, 1996, pp. 632-637.

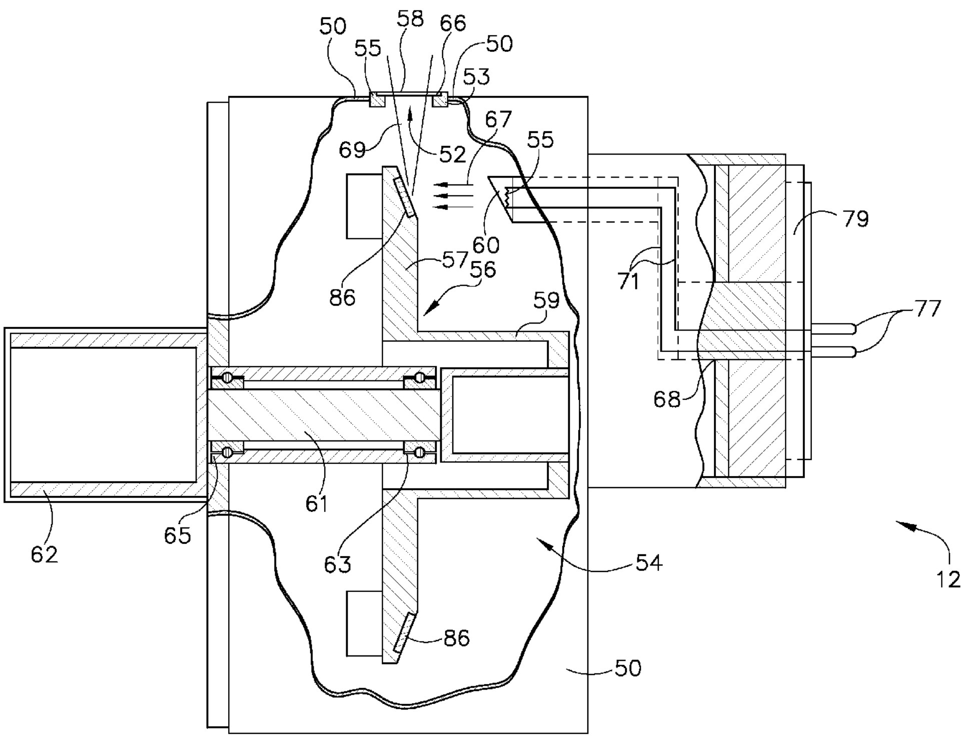
* cited by examiner

Primary Examiner—Hoon Song
(74) *Attorney, Agent, or Firm*—Ziolkowski Patent Solutions Group, SC

(57) **ABSTRACT**

A bonded assembly includes a member, and a substrate comprising beryllium, the substrate configured to be bonded to the member. The bonded assembly includes a first barrier applied to a surface of the substrate, a second barrier applied to a surface of the first barrier, a bonding material disposed between the second barrier and the member, and wherein the second barrier is configured to prevent dissolution of the first barrier into the bonding material.

24 Claims, 6 Drawing Sheets



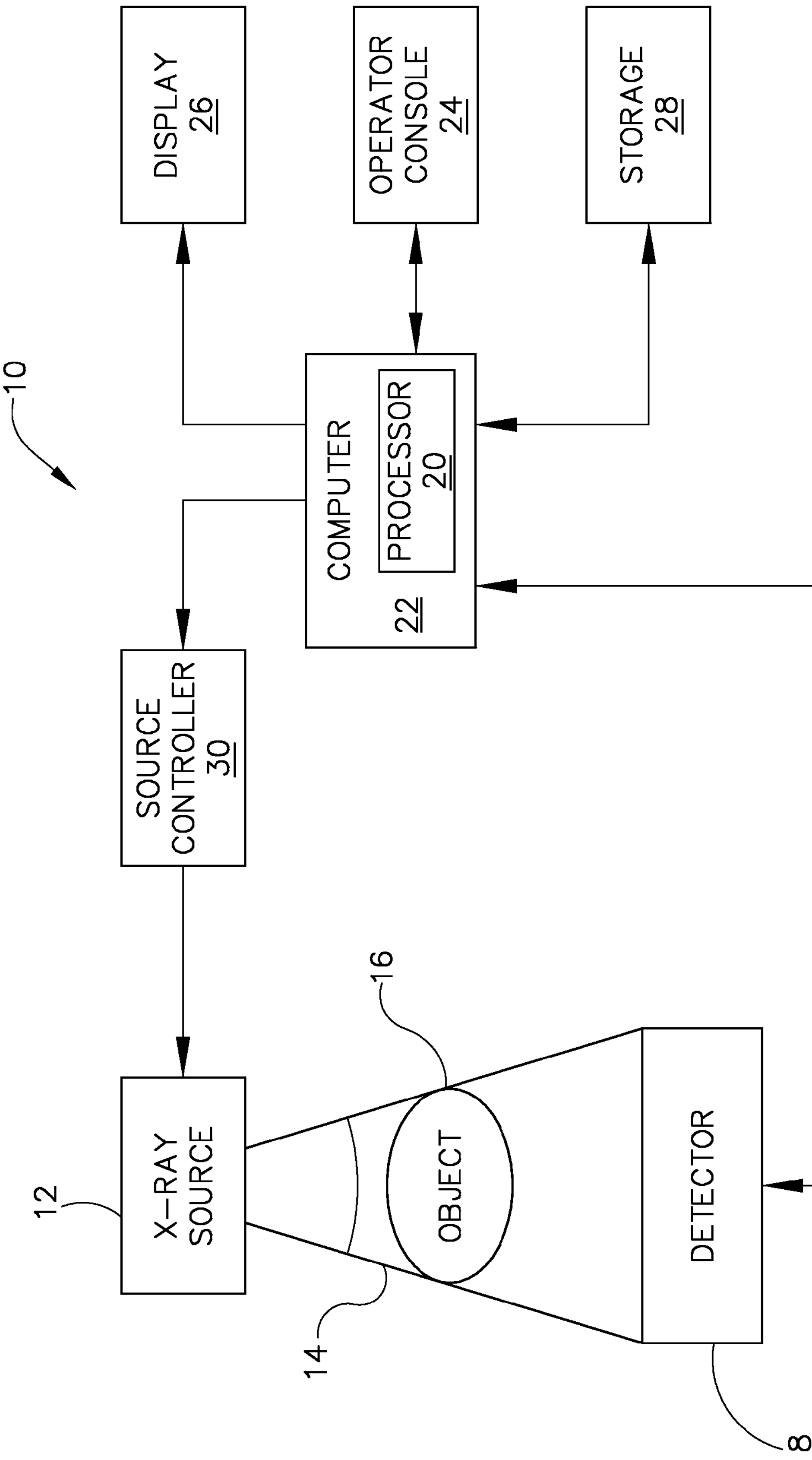

10
DISPLAY 26
OPERATOR CONSOLE 24
STORAGE 28
COMPUTER
PROCESSOR 20
22
SOURCE CONTROLLER 30
X-RAY SOURCE
12
OBJECT
16
14
DETECTOR
18

FIG. 1

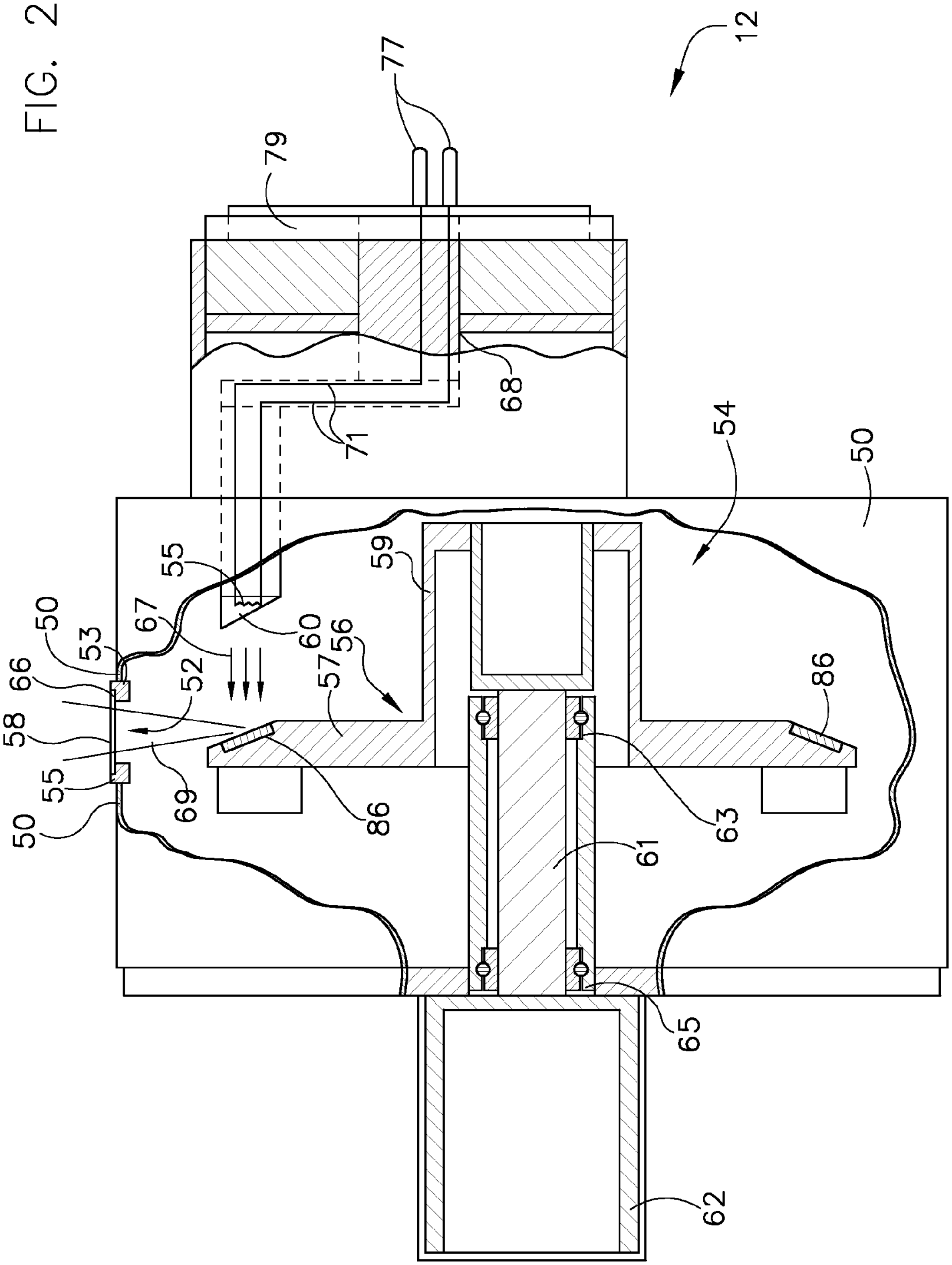


FIG. 2

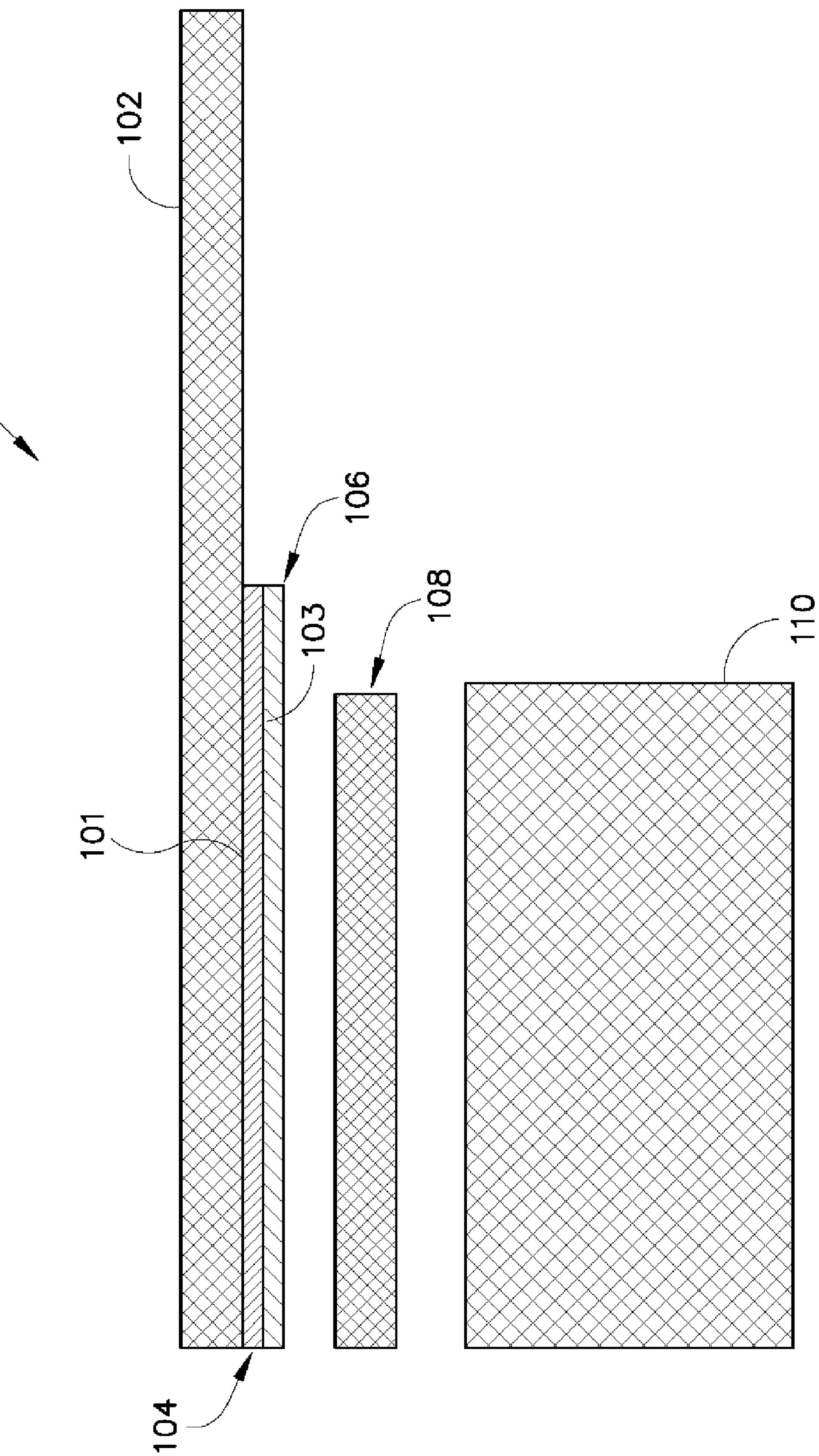


FIG. 3

FIG. 4

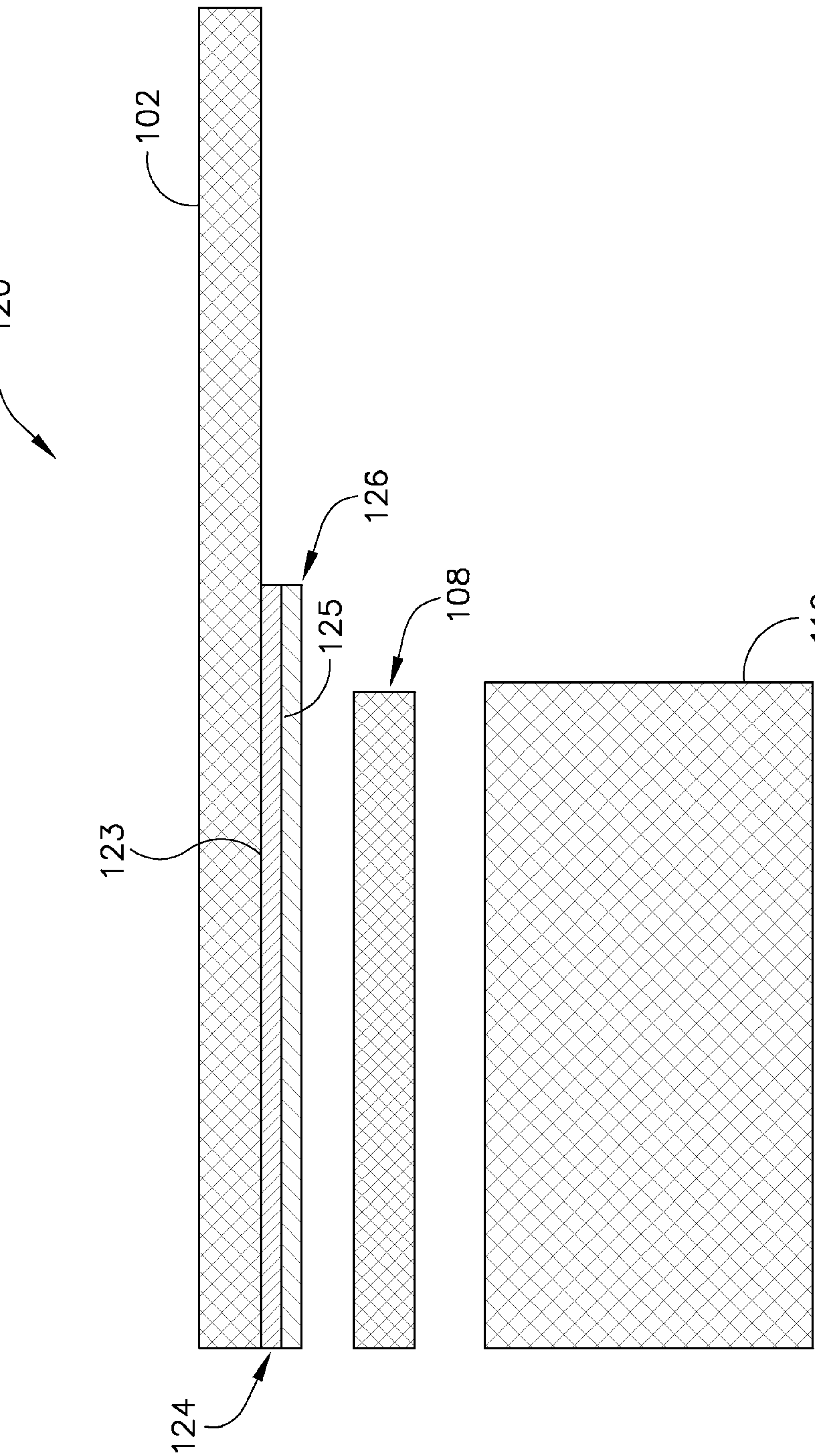
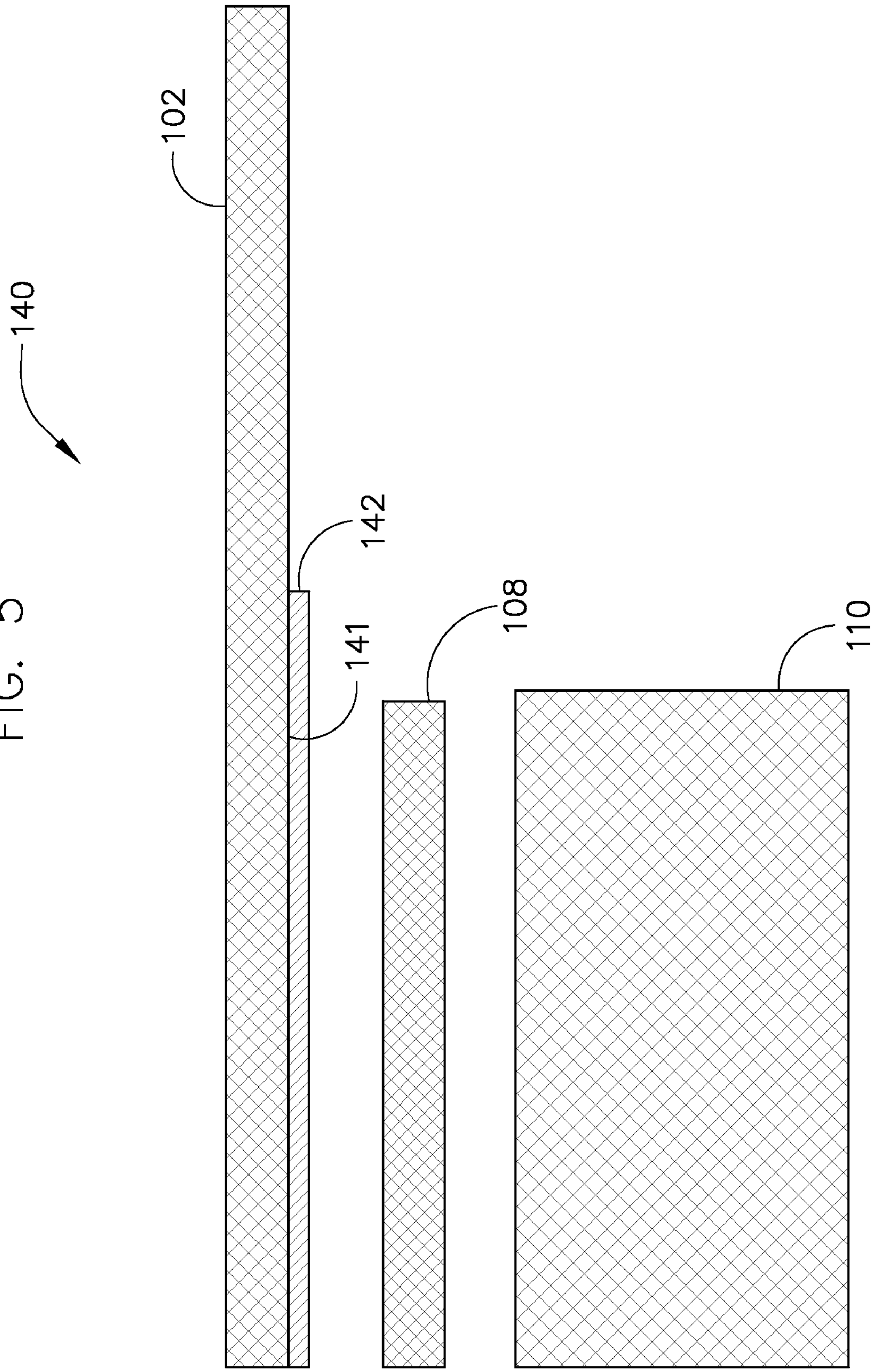


FIG. 5



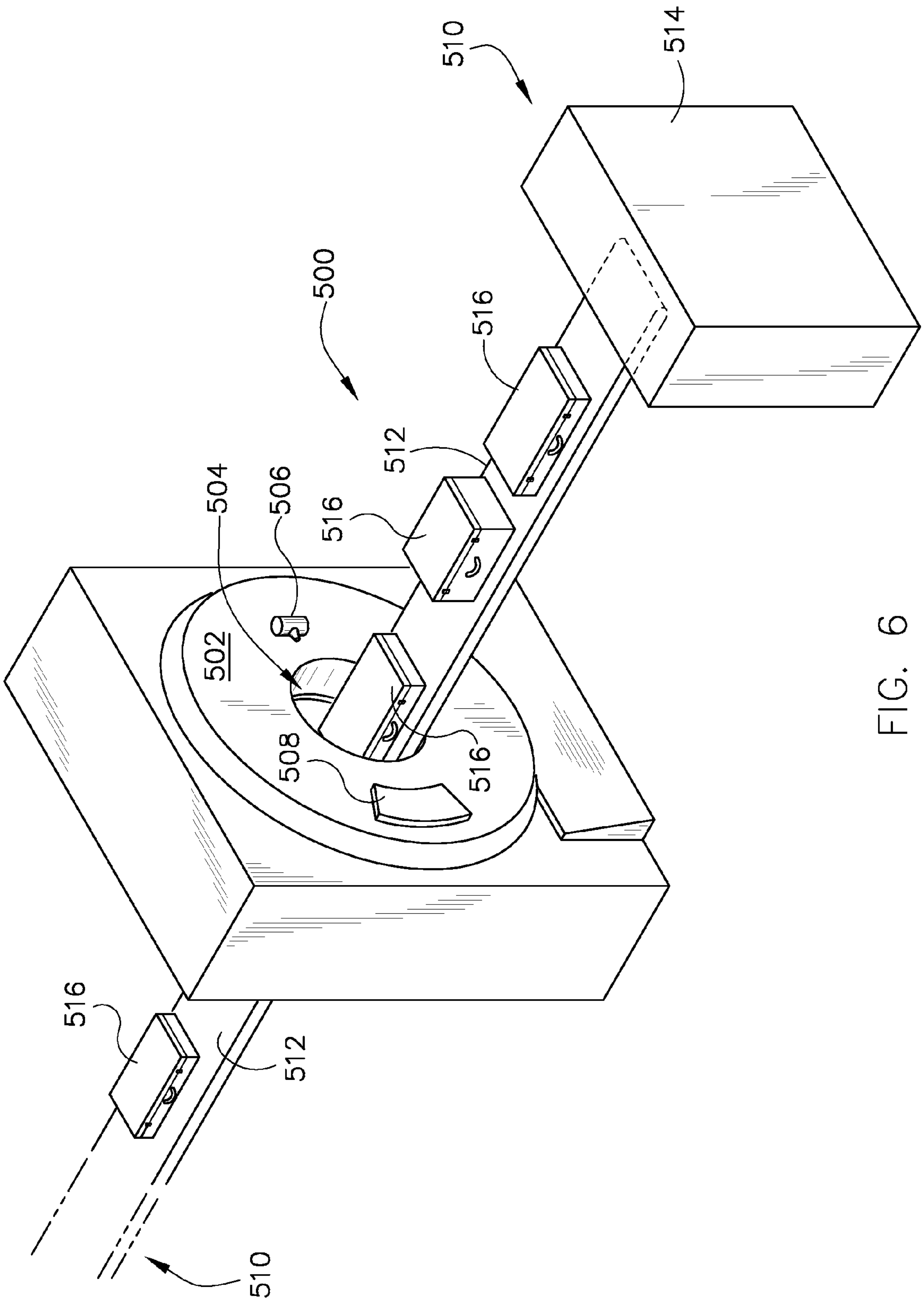


FIG. 6

BRAZE ASSEMBLY WITH BERYLLIUM DIFFUSION BARRIER AND METHOD OF MAKING SAME

BACKGROUND OF THE INVENTION

The invention relates generally to x-ray tubes and, more particularly, to a method and apparatus for creating an improved braze in x-ray tube components.

X-ray systems typically include an x-ray tube, a detector, and a gantry to support the x-ray tube and the detector. In operation, an imaging table, on which an object is positioned, is located between the x-ray tube and the detector. The x-ray tube typically emits radiation, such as x-rays, toward the object. The radiation typically passes through the object on the imaging table and impinges on the detector. As radiation passes through the object, internal structures of the object cause spatial variances in the radiation received at the detector. The detector then processes the received data, and the system translates the radiation variances into an image, which may be used to evaluate the internal structure of the object. One skilled in the art will recognize that the object may include, but is not limited to, a patient in a medical imaging procedure and an inanimate object as in, for instance, a package in a computed tomography (CT) package scanner.

X-ray tubes include a rotating anode structure for the purpose of distributing heat generated at a focal spot. The anode is typically rotated by an induction motor having a cylindrical rotor built into a cantilevered axle that supports a disc-shaped anode target and an iron stator structure with copper windings that surrounds an elongated neck of the x-ray tube. The rotor of the rotating anode assembly is driven by the stator. An x-ray tube cathode provides a focused electron beam that is accelerated across a cathode-to-anode vacuum gap and produces x-rays upon impact with the anode. Because of the high temperatures generated when the electron beam strikes the target, it is necessary to rotate the anode assembly at high rotational speed.

X-rays may be produced when high-speed electrons are decelerated when directed from the cathode to the target substrate via an electrical potential difference therebetween. The electrons impact a target track material at a focal point and x-rays emit therefrom. The x-ray tube includes a frame, typically constructed from stainless steel, and has an x-ray window formed therein. The x-ray window is typically made from beryllium, or other low-atomic number material. X-rays are emitted through the beryllium window toward a detector array. The x-ray tube may also include a collector attached to a perimeter of the beryllium window at an interface, wherein the collector absorbs stray electrons from the cathode or the target and conducts heat away from the interface. The collector is typically attached to the beryllium window using a brazing process.

Brazing and soldering are commonly used methods for joining two parts involving heating a fusible material, causing it to melt and wet both parts, and allowing the material to cool and bond the parts. However, diffusion and alloying between the fusible material and the parts being joined may result in formation of brittle intermetallic compounds, sometimes referred to as Laves phase intermetallics, which can weaken the braze joint and cause early life failure of the x-ray tube.

Therefore, it would be desirable to have a method for joining two parts, such as a beryllium window and an electron collector, having improved integrity and hermeticity therebetween.

BRIEF DESCRIPTION OF THE INVENTION

The invention provides an apparatus and method of brazing a first material to a second material having improved integrity and hermeticity therebetween.

According to an aspect of the invention, a bonded assembly includes a member, and a substrate comprising beryllium, the substrate configured to be bonded to the member. The bonded assembly includes a first barrier applied to a surface of the substrate, a second barrier applied to a surface of the first barrier, a bonding material disposed between the second barrier and the member, and wherein the second barrier is configured to prevent dissolution of the first barrier into the bonding material.

In accordance with another aspect of the invention, a method of fusibly joining a substrate and an object includes providing a substrate comprising beryllium, providing an object configured to be fusibly joined to the substrate, depositing a first barrier layer onto a surface of the substrate, wherein the first barrier layer is configured to prevent formation of intermetallics at an interface between the object and the substrate, and depositing a second barrier layer onto a surface of the first barrier layer. The method further includes interposing a fusible material between the second barrier layer and the object, and heating the assembly to a temperature sufficient to create a fuse joint between the substrate and the object via the fusible material.

According to yet another aspect of the invention, an x-ray tube includes a window comprising beryllium, a collector configured to be braze joined to the window, a first diffusion barrier applied to a surface of the window, the first diffusion barrier configured to prevent formation of Laves phase intermetallics, a second diffusion barrier applied to a surface of the first diffusion barrier, and a braze material disposed between the second diffusion barrier and the collector.

Various other features and advantages will be made apparent from the following detailed description and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings illustrate one preferred embodiment presently contemplated for carrying out the invention.

In the drawings:

FIG. **1** is a block diagram of an imaging system that can benefit from incorporation of an embodiment of the invention.

FIG. **2** is a cross-sectional view of an x-ray tube that incorporates embodiments of the invention.

FIG. **3** is a schematic diagram of a braze assembly with two diffusion barriers according to an embodiment of the invention.

FIG. **4** is a schematic diagram of another braze assembly with two diffusion barriers according to an embodiment of the invention.

FIG. **5** is a schematic diagram of another braze assembly with a diffusion barrier according to an embodiment of the invention.

FIG. **6** is a pictorial view of a CT system for use with a non-invasive package inspection system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** is a block diagram of an embodiment of an imaging system **10** designed both to acquire original image data and to process the image data for display and/or analysis in accordance with the invention. It will be appreciated by those skilled in the art that the invention is applicable to numerous medical imaging systems implementing an x-ray tube, such as x-ray or mammography systems. Other imaging systems such as computed tomography (CT) systems and digital radiography (RAD) systems, which acquire image three dimensional data for a volume, also benefit from the invention. The following discussion of x-ray system **10** is merely an example of one such implementation and is not intended to be limiting in terms of modality.

As shown in FIG. **1**, x-ray system **10** includes an x-ray source **12** configured to project a beam of x-rays **14** through an object **16**. Object **16** may include a human subject, pieces of baggage, or other objects desired to be scanned. X-ray source **12** may be a conventional x-ray tube producing x-rays having a spectrum of energies that range, typically, from 30 keV to 200 keV. The x-rays **14** pass through object **16** and, after being attenuated by the object, impinge upon a detector **18**. Each detector in detector **18** produces an analog electrical signal that represents the intensity of an impinging x-ray beam, and hence the attenuated beam, as it passes through the object **16**. In one embodiment, detector **18** is a scintillation based detector, however, it is also envisioned that direct-conversion type detectors (e.g., CZT detectors, etc.) may also be implemented.

A processor **20** receives the signals from the detector **18** and generates an image corresponding to the object **16** being scanned. A computer **22** communicates with processor **20** to enable an operator, using operator console **24**, to control the scanning parameters and to view the generated image. That is, operator console **24** includes some form of operator interface, such as a keyboard, mouse, voice activated controller, or any other suitable input apparatus that allows an operator to control the x-ray system **10** and view the reconstructed image or other data from computer **22** on a display unit **26**. Additionally, console **24** allows an operator to store the generated image in a storage device **28** which may include hard drives, flash memory, compact discs, etc. The operator may also use console **24** to provide commands and instructions to computer **22** for controlling a source controller **30** that provides power and timing signals to x-ray source **12**.

FIG. **2** illustrates a cross-sectional view of an x-ray tube **12** incorporating embodiments of the invention. X-ray tube **12** includes a frame **50** that encloses vacuum region **54**, and an anode **56** and a cathode **60** are positioned therein. Anode **56** includes a target **57** having a target track **86**, and a target hub **59** attached thereto. Target **56** is attached to a shaft **61** supported by front bearing **63** and rear bearing **65**. Shaft **61** is attached to rotor **62**. Cathode **60** typically includes a filament **55** coupled to electrical leads **71** that pass through a center post **68**. Feedthrus **77** pass through an insulator **79** and are electrically connected to electrical leads **71**.

X-ray tube **12** includes an electron collector **53** attached to frame **50**. Electron collector **53** includes a window **58** proximate a passageway **52**. Collector **53** is typically made of copper and may be joined via a braze or solder joint **66** to window **58**. Window **58** is typically made of a low atomic number metal, such as beryllium, to allow passage of x-rays therethrough with minimum attenuation. Joint **66**, referred to above as a braze or solder joint, may be formed or fused via either a braze or solder process according to embodiments of the invention. Thus, although the embodiments described below may be referred to as using a braze process, one skilled in the art will recognize that the joints and assemblies described herein may be formed via soldering or brazing, and that such terms in no way imply or limit a temperature at which the joint or assembly is formed. Thus, the terms braze and solder may interchangeably and equally refer to joining or fusing two or more materials by heating an additional material therebetween.

In operation, target **56** is spun via a stator (not shown) external to rotor **62**. An electric current is applied to filament **55** via feedthrus **77** to heat filament **55** and emit electrons **67** therefrom. A high-voltage electric potential is applied between anode **56** and cathode **60**, and the difference therebetween accelerates the emitted electrons **67** from cathode **60** to anode **56**. The electrons **67** impinge the target **57** at the target track **86** and x-rays **69** emit therefrom and pass through passageway **52**. During operation, stray electrons from cathode **60** may strike collector **53**, thereby increasing the temperature in joint **66**.

A solder or braze assembly **100** is illustrated in FIG. **3** according to an embodiment of the invention. Assembly **100** includes a substrate **102** that includes beryllium or an alloy thereof, with a first diffusion barrier **104** of silver applied to a surface **101** of the substrate **102**. Assembly **100** also includes a second diffusion barrier **106** applied to the surface **103** of first diffusion barrier **104**. It is contemplated that second diffusion barrier **106** may include gold, nickel, platinum, palladium, chromium, or manganese. The assembly **100** includes an object or member **110** and a fusible material **108** having a liquidus temperature below 760° C. In one embodiment material **108** is Cusiltin-10. Cusil® is a registered trademark of Morgan Crucible Company of Berkshire, England. Material **108** is disposed between second diffusion barrier **106** and member **110**. Member **110** may include any metal for removing heat, and in embodiments of the invention, includes copper, stainless steel, Kovar, or a nickel-plated substrate as examples.

First diffusion barrier layer **104** may be applied to substrate **102** using chemical vapor deposition, physical vapor deposition, electroplating, and the like. Second diffusion barrier layer **106** may likewise be applied to first diffusion barrier layer **104** using chemical vapor deposition, physical vapor deposition, electroplating, and the like. In the illustrated embodiment, silver is selected as the first diffusion barrier **104** material because, at or below 760° C., silver and beryllium do not form brittle Laves phase intermetallics at an interface therebetween. However, copper-silver based alloys with liquidus temperatures below 760° C. such as Cusiltin-10 would tend to dissolve the silver within first diffusion barrier **104**, thus forming Laves phase intermetallics between the copper constituent of the material **108** and the substrate **102**. As such, the second diffusion barrier **106**, which may be gold or nickel, is included to prevent the silver from dissolving in the braze alloy. Thus, at or below 760° C., neither gold nor nickel will interact with the silver diffusion barrier or interact with the braze alloy to form Laves phase intermetallics at the interfaces therebetween.

An assembly **120** is illustrated in FIG. **4** according to another embodiment of the invention. Assembly **120** includes substrate **102** with a first diffusion barrier **124** of aluminum applied to a surface **125** of the substrate **102**. Assembly **120** also includes a second diffusion barrier **126** constructed of, for example, cobalt or nickel. Second diffusion barrier **126** is applied to a surface **125** of first diffusion barrier **124**. Fusible material **108** with melting point below that of the aluminum-beryllium eutectic (~644° C.), is disposed between second diffusion barrier **126** and member **110**.

First diffusion barrier **124** may be applied to the surface **123** of substrate **102** using chemical vapor deposition, physical vapor deposition, electroplating, and the like. Second diffusion barrier **126** may likewise be applied to the surface **125** of first diffusion barrier **124** using chemical vapor deposition, physical vapor deposition, electroplating, and the like. Aluminum is selected as a first diffusion barrier **124** material because, at or below 644° C., aluminum and beryllium do not form brittle Laves phase intermetallics at the interface between the two materials. Second diffusion barrier **126**, which may include a transition metal such as cobalt or nickel, will not form brittle Laves phase intermetallics at the aluminum interface nor at the material **108** interface.

Assembly **140** is illustrated in FIG. **5** according to another embodiment of the invention. Assembly **140** includes substrate **102** with a diffusion barrier **142** formed of titanium or chromium and applied to a surface **141** of the substrate **102**. Fusible material **108**, such as a Cusiltin-10 alloy or other copper-silver based alloys with liquidus temperatures below 760° C., is disposed between diffusion barrier **142** and member **110**. Diffusion barrier **142** may be applied to the surface **141** of substrate **102** using chemical vapor deposition, physical vapor deposition, electroplating, and the like. Diffusion barrier **142** prevents formation of Laves phase intermetallic compounds at the interface between diffusion barrier **142** and substrate **102** and also at the interface between diffusion barrier **142** and material **108**.

Referring now to FIG. **6**, package/baggage inspection system **500**, having an x-ray tube that incorporates an embodiment of the invention, includes a rotatable gantry **502** having an opening **504** therein through which packages or pieces of baggage may pass. The rotatable gantry **502** houses a high frequency electromagnetic energy source **506** as well as a detector assembly **508**. A conveyor system **510** is also provided and includes a conveyor belt **512** supported by structure **514** to automatically and continuously pass objects **516** such as packages or baggage pieces through opening **504** to be scanned. Objects **516** are fed through opening **504** by conveyor belt **512**, imaging data is then acquired, and the conveyor belt **512** removes the objects **516** from opening **504** in a controlled and continuous manner. As a result, postal inspectors, baggage handlers, and other security personnel may non-invasively inspect the contents of objects **516** for explosives, knives, guns, contraband, etc.

According to an embodiment of the invention, a bonded assembly includes a member, and a substrate comprising beryllium, the substrate configured to be bonded to the member. The bonded assembly includes a first barrier applied to a surface of the substrate, a second barrier applied to a surface of the first barrier, a bonding material disposed between the second barrier and the member, and wherein the second barrier is configured to prevent dissolution of the first barrier into the bonding material.

In accordance with another embodiment of the invention, a method of fusibly joining a substrate and an object includes providing a substrate comprising beryllium, providing an object configured to be fusibly joined to the substrate, depositing a first barrier layer onto a surface of the substrate, wherein the first barrier layer is configured to prevent formation of intermetallics at an interface between the object and the substrate, and depositing a second barrier layer onto a surface of the first barrier layer. The method further includes interposing a fusible material between the second barrier layer and the object, and heating the assembly to a temperature sufficient to create a fused joint between the substrate and the object via the fusible material.

According to yet another embodiment of the invention, an x-ray tube includes a window comprising beryllium, a collector configured to be braze joined to the window, a first diffusion barrier applied to a surface of the window, the first diffusion barrier configured to prevent formation of Laves phase intermetallics, a second diffusion barrier applied to a surface of the first diffusion barrier, and a braze material disposed between the second diffusion barrier and the collector.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A bonded assembly comprising:

a member;

a substrate comprising beryllium, the substrate configured to be fusibly bonded to the member;

a first barrier applied to a surface of the substrate;

a second barrier applied to a surface of the first barrier;

a bonding material disposed between the second barrier and the member; and

wherein the second barrier is configured to prevent dissolution of the first barrier into the bonding material.

2. The bonded assembly of claim **1** wherein the first barrier is configured to prevent formation of intermetallics at an interface between the substrate and the member.

3. The bonded assembly of claim **1** wherein the first and second barriers comprise first and second diffusion barriers.

4. The bonded assembly of claim **1** wherein the first barrier comprises silver.

5. The bonded assembly of claim **4** wherein the bonding material has a melting point below 760 degrees Celsius.

6. The bonded assembly of claim **4** wherein the second barrier comprises one of gold, palladium, platinum, nickel, chromium, and manganese.

7. The bonded assembly of claim **1** wherein the first barrier comprises aluminum.

8. The bonded assembly of claim **7** wherein the second barrier comprises one of nickel and cobalt.

9. The bonded assembly of claim **7** wherein the bonding material has a melting point at or below 644 degrees Celsius.

10. The bonded assembly of claim **1** wherein the member comprises one of copper, stainless steel, and Kovar.

11. A method of fusibly joining a substrate and an object comprising:

providing a substrate comprising beryllium;

providing an object configured to be fusibly joined to the substrate;

depositing a first barrier layer onto a surface of the substrate, wherein the first barrier layer is configured to prevent formation of intermetallics at an interface between the object and the substrate;

depositing a second barrier layer onto a surface of the first barrier layer;

interposing a fusible material between the second barrier layer and the object; and heating the assembly to a temperature sufficient to create a fused joint between the substrate and the object via the fusible material.

12. The method of claim **11** wherein depositing a first barrier layer onto a surface of the substrate comprises depositing one of an aluminum layer and a silver layer onto a surface of the substrate.

13. The method of claim **12** wherein, when depositing the first barrier layer comprises depositing an aluminum layer, depositing the second barrier layer comprises depositing one of a nickel layer and a cobalt layer onto the surface of the first barrier layer.

14. The method of claim **12** wherein, when depositing the first barrier layer comprises depositing a silver layer, depositing the second barrier layer comprises depositing one of a gold layer, a platinum layer, a nickel layer, a palladium layer, a manganese layer, and a chromium layer onto the surface of the first barrier layer.

15. The method of claim **12** wherein, when depositing the first barrier layer comprises depositing a silver layer, interposing a fusible material comprises interposing a Cusiltin-10 alloy between the second barrier layer and the object.

16. The method of claim **11** wherein depositing the first barrier layer comprises depositing the first barrier layer via one of a physical vapor deposition process, a chemical vapor deposition process, and an electroplating process; and

wherein depositing the second layer comprises depositing the second layer via one of a physical vapor deposition process, a chemical vapor deposition process, and an electroplating process.

17. An x-ray tube comprising:

a window comprising beryllium;

a collector braze joined to the window;

a first diffusion barrier applied to a surface of the window, the first diffusion barrier configured to prevent formation of Laves phase intermetallics;

a second diffusion barrier applied to a surface of the first diffusion barrier; and

a braze material disposed between the second diffusion barrier and the collector.

18. The x-ray tube of claim **17** wherein the second diffusion barrier is configured to prevent dissolution of the first diffusion barrier into the braze material.

19. The x-ray tube of claim **17** wherein the braze material comprises a copper-silver based braze alloy having a liquidus temperature below 760° C.

20. The x-ray tube of claim **17** wherein the first diffusion barrier comprises a silver diffusion barrier, and wherein the braze material has a melting point at or below 760 degrees Celsius.

21. The x-ray tube of claim **20** wherein the second diffusion barrier comprises one of gold, nickel, palladium, platinum, chromium, and manganese.

22. The x-ray tube of claim **17** wherein the first diffusion barrier comprises an aluminum diffusion barrier, and wherein the braze material has a melting point at or below 644 degrees Celsius.

23. The x-ray tube of claim **22** wherein the second diffusion barrier comprises a transition metal comprising one of nickel and cobalt.

24. The x-ray tube of claim **17** wherein the collector comprises one of copper, stainless steel, and Kovar.

* * * * *