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2,394,984

STRUCTURE AND METHOD OF MAKING

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Fig. 1,

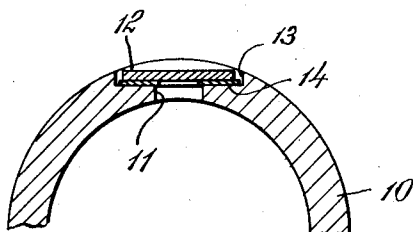


Fig. 2

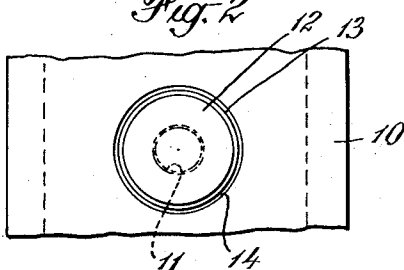


Fig. 3,

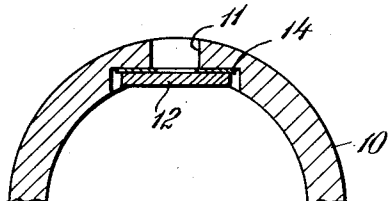


Fig. 4,

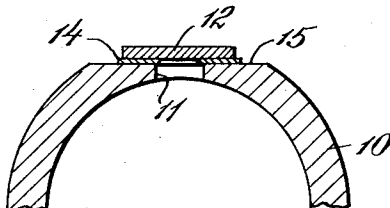


Fig. 5,

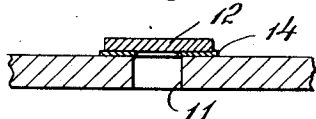


Fig. 6

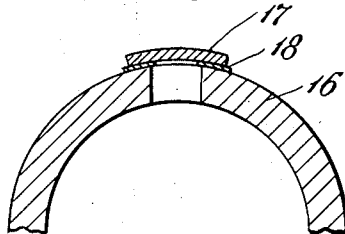
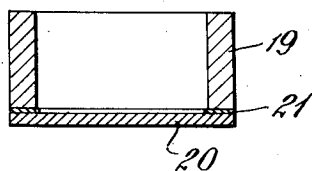


Fig. 7,



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STRUCTURE AND METHOD OF MAKING

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This invention relates to structures which comprise a member made of beryllium or beryllium-like material and a base of a suitable metallic substance to which the member is rigidly secured. More particularly, the invention is concerned with novel structures of the type referred to in which the beryllium member takes the form, for example, of a thin disc or plate and is attached to the base by a vacuum-tight joint, which is capable of withstanding subsequent reheating to relatively high temperatures without being injured. The invention further comprehends a new method by which structures, as described, can be readily made.

Structures comprising a beryllium member and a base serving as a support or mounting for the member find application for various purposes and, in particular, have been employed heretofore to some extent in the manufacture of X-ray tubes. In that use, the structure has ordinarily been disposed within an evacuated envelope with the base supported in any suitable way, as, for example, on a part of the cathode assembly. The structure is formed to serve as a screen to protect the walls of the envelope against electron bombardment and the beryllium member is aligned with the usual glass window so that the beam of useful rays may pass through the beryllium member and then through the window. Since, in this construction, the beryllium member lies within the evacuated space, it is unimportant whether or not the member and its joint to the remainder of the structure are vacuum-tight.

It has also been proposed and some attempts have been made to employ such a structure as a part of the envelope of an X-ray tube, with the beryllium member forming the window through which the X-rays pass. Such a beryllium window is highly desirable for use in tubes to be employed for spectrographic work and crystal analysis because of the low mass absorption coefficient of beryllium, but, up to the present, the use of beryllium X-ray windows has been very limited because no entirely satisfactory methods have been available for producing a structure comprising a vacuum-tight beryllium window secured to a base suitable for use as part of the vacuum-tight envelope of an X-ray tube.

One of the principal difficulties involved in the production of a beryllium window structure has been the formation of the window itself, and that difficulty arises from the physical characteristics of beryllium. The metal is of high melting point and considerable hardness, and, even in a state of extremely high purity, is very brittle, so that

it is not feasible, at least in commercial operations, to form it, as by rolling, into thin plates or discs without cracks. I have found, however, that an alloy comprising a great preponderance of beryllium and a minor amount of titanium or zirconium has all the desirable properties of pure beryllium for X-ray work and, in addition, has such malleability, when hot, as to permit it to be rolled into thin vacuum-tight sheets which, under proper conditions, can be bent, drawn into cups, etc., without cracking. Such an alloy is disclosed and claimed in my Patent No. 2,306,592, issued December 29, 1942, and windows of that alloy which are suitable for X-ray tube use can be readily made on a commercial basis by taking proper precautions.

Another major problem in the production of a beryllium window structure to be used as part of the enclosure or envelope of an X-ray tube is presented by the necessity of securing the beryllium member to the base with a joint that is vacuum-tight and will withstand the prolonged heating at high temperatures to which the tube is subjected in the final processing and also the cycles of heating and cooling through which the tube passes in use.

The present invention is, accordingly, directed to the provision of a novel structure including a member of beryllium or beryllium-like material joined to a suitable metallic base by a joint which is vacuum-tight and is capable of withstanding reheating to substantial temperatures without suffering injury. The invention also comprehends the method by which such a structure can be made. The new structure is particularly adapted for use as part of an X-ray tube and examples of the structure for that purpose will, accordingly, be illustrated and described for purposes of explanation, although it will be readily apparent that the utility of the invention is not limited to that particular field.

In my experimental work leading to the development of the new structure, I have found that a joint between beryllium and a base metal, which is vacuum-tight and capable of withstanding prolonged reheating to elevated temperatures of the order of about 600° C. can be produced by a brazing operation, provided certain requirements are fulfilled. Thus, the temperature at which the brazing operation is carried on is very important, since I have found it impossible to secure adherence of another metal to beryllium without the intervention of a liquid phase. Moreover, beryllium has a superficial oxide film, which is tenacious and has pronounced resistance

to abrasion and high temperature. Unless the brazing operation is carried on at a temperature of at least about 700° C., liquid metals do not wet beryllium, that is, break through its stout superficial layer of oxide. Accordingly, the customary technique of welding and soldering other similarly reactive metals, such as magnesium, with the aid of flux or abrasion, has not been found applicable, in my experience, to beryllium.

Another important factor in the production of a structure having the characteristics described is the concurrent use of a suitable base and a suitable brazing material. The usual soldering materials, such as tin, lead, cadmium, zinc, and lead-tin and silver solders employed with appropriate fluxes do not wet beryllium. In vacuum, tin and aluminum do not wet beryllium, although the parts are very hot, and iron and nickel in vacuum produce porous joints resembling an ash. Gold employed in a vacuum is satisfactory in some respects, but the gold-beryllium eutectic formed in the joint has a melting point which is too low to enable the joint to withstand prolonged reheating at the temperatures ordinarily required in the final processing of vacuum equipment.

There are various brazing materials which are effective to secure beryllium to selected bases but which produce joints incapable of withstanding prolonged reheating. Thus, copper may be used to secure beryllium both to the alloy known commercially as "Kovar" and to steel, but the joints so made are incapable of withstanding prolonged reheating at temperatures of about 600° C. and are, therefore, unsatisfactory for vacuum tube use.

I have found that in the brazing of beryllium to a base metal, the brazing material may react with the beryllium and with the base metal to form the liquid brazing alloy and when this reaction occurs, it gives rise to the formation of extraordinarily brittle and weak compounds. These compounds may appear as continuous layers on the base or on the beryllium and if there is a continuous layer of such a compound on the base after the braze has solidified, the joint is likely to be sensitive to subsequent reheating and may crack during such heating. The weakness of such a joint arises not only from the brittleness of the compound ascribable to its inherent lack of ductility but also from the tendency of the layer of compound to split from the base because of the different crystal structures and dilatation characteristics of the layer and base. I have discovered, however, that by proper selection of the base and brazing material, it is possible to produce a joint in which there is no brittle compound or no continuous layer of such compound on the base. Joints characterized by entire absence of a brittle compound or of a continuous layer of such a compound on the base can be made vacuum-tight and are capable of withstanding subsequent reheating, so that such joints are satisfactory for use in vacuum equipment.

I have found that joints between beryllium and a base that are suitable for use as part of the envelope of a vacuum tube may be made by employing nickel or nickel-copper alloys as the base and copper as the brazing metal. The nickel-copper alloys to which I refer are those containing about 66% nickel and referred to generally as Monel metal. The cupro-nickels containing 20% or 30% nickel may also be used but are less desirable because their coefficient of expansion is not as favorable as that of Monel metal.

Another important factor having an influence on the success of the brazing operation is the atmosphere in which the operation is carried out. I have found that the presence of oxygen in that atmosphere is highly detrimental and I, therefore, prefer to do the brazing in a good vacuum or in an inert atmosphere, such as hydrogen of extreme purity.

For a better understanding of the invention, reference may be had to the accompanying drawing in which:

Fig. 1 is a fragmentary sectional view through a structure made in accordance with the invention;

Fig. 2 is a plan view of the structure shown in Fig. 1; and

Figs. 3 to 7, inclusive, are sectional views through modified forms of the new structure.

The structure shown in Fig. 1 comprises a base 10 which is preferably of Monel metal but may also be made of nickel, or nickel-copper alloys other than Monel. The particular base shown is of generally tubular form and may be employed as a section of the envelope of an X-ray tube. The base has a window opening 11 closed by a disc 12 of beryllium or beryllium-like material, the alloy disclosed in my Patent No. 2,306,592, above mentioned, being preferred for the purpose. The disc serves as the window or port through which the useful beam of X-rays passes and the disc is held in place on the base by brazing.

In the formation of the structure shown in Fig. 1, the base is provided with a countersunk depression 13 and the window opening 11 is drilled into the bottom of the depression through the wall of the base. An open center disc or washer 14 of the brazing metal is then seated in the depression and the disc 12 placed thereon. The relative dimensions of the washer of brazing material and the disc and window opening are important and the washer should have a greater outside diameter than the disc and a smaller inside diameter than the opening. Thus, with a window opening $\frac{1}{8}$ " in diameter, the beryllium disc should be at least $\frac{1}{8}$ " in diameter and the countersunk depression correspondingly larger, for example, at least $\frac{1}{2}$ " in diameter. The washer is preferably 0.003" thick and should be of such size that the window opening is surrounded by a band of brazing metal $\frac{1}{8}$ " wide, since this is adequate to compensate for inaccuracies in locating and for minor defects in the joint. With a $\frac{1}{8}$ " window opening, the washer should have a $\frac{1}{4}$ " outer diameter and an inner diameter one drill size smaller than the opening.

When the parts have been assembled as described, they should be held tightly in position during the brazing operation. For this purpose, a slotted aluminum cylinder $\frac{1}{8}$ " in diameter and $\frac{1}{4}$ " high is placed upon the disc and two molybdenum wires are wound around the assembly and twisted tight to hold the parts in position. The assembly is then hung within a chamber with the beryllium disc on horizontal position and the chamber is evacuated. When a vacuum of about 10 microns has been obtained, a high frequency coil is placed about the chamber and the assembly is heated by induced currents until a temperature of at least 700° C. and preferably higher has been reached and the brazing metal has melted.

The duration of the heating should be as short as possible consistent with complete melting of the brazing metal since prolonging the operation may result in porous joints. The duration of the heating may be determined visually and it is to be

discontinued as soon as a fillet of liquid metal appears on all sides of the beryllium disc. Heating for a less time may result in incomplete melting and an imperfect joint. Excessive heating may not only result in porous joints but may cause the beryllium to be dissolved. Also, an excessive amount of molten brazing metal may be formed and squeezed out of the joint, with the result that the window opening may be closed.

After the heating operation is completed, the assembly is allowed to cool and although the tension in the wires probably decreases during the heating and cooling, the disc appears to be held against the base by surface tension of the brazing metal once the latter has melted. Instead of the wires, spring-actuated tongs may be employed to provide positive pressure during brazing.

In the completed joint, the base and beryllium disc are secured together by a metallic product which results from the melting of the brazing metal between them and is of a nature dependent on the kinds of metal used for the base and brazing material. When copper is used as the brazing metal and Monel metal as the base, a small amount of beryllium, such as 2%, is dissolved in the copper and two or more compounds are formed. The alloy in the joint thus consists of some copper-rich solid solution containing particles of a compound composed of beryllium and copper, and there is no continuous layer of the brittle compound on the base. Under these conditions, the presence of the brittle compound in the joint does not impair the capability of the joint to withstand subsequent reheating since the solid solution and base have about the same crystal structure and dilatation characteristics that are not very different. Also, the individual brittle particles of the compound do not seriously impair the toughness of the brazing alloy as a whole, since each particle is surrounded by tough solid solution. Accordingly, the thermal stresses that are applied in subsequent reheating are not destructive of a joint in which there is no continuous layer of brittle compound on the base. The joint is, accordingly, relatively insensitive to reheating to 800° C. The results above described are also obtained when nickel or nickel-copper alloys other than Monel are used for the base and copper for the brazing metal.

Structures made in the manner described, with the combinations of bases and brazing material above set forth, are suitable for use as the vacuum-tight part of an X-ray tube in the manufacture of which the structure is exposed to heating for short periods up to 800° C. during the soldering of other parts of the tube and for long periods at temperatures of about 600° C. during final processing.

The structure shown in Fig. 3 is similar to that shown in Fig. 1, except that the disc 12 is mounted in a depression in the inner wall of the base to close the opening 11, the disc being held in position by a washer 14 of brazing material. The disc may serve as an X-ray window and it is protected against injury by reason of being mounted within the base.

In the structure shown in Fig. 4, the curved surface of the base is milled flat as at 15 instead of being provided with a countersunk depression. In the structure shown in Fig. 5, the base is of flat rather than curved section and neither countersinking no milling is required.

In the construction shown in Fig. 6, the base is of curved section and the disc 17 and the washer 18 are shaped to conform to the curvature of the sur-

face of the base. A disc having such a curvature can be made without difficulty of the beryllium alloy of my patent above identified.

In the structure shown in Fig. 7, the base 19 is of tubular formation and the end of the tube is closed by a beryllium disc 20. The washer 21 of brazing material interposed between the end of the base and the face of the disc is of an inner diameter slightly less than the inner diameter of the base and its outer diameter is approximately the same as that of the disc.

The various forms of the new structure illustrated in the drawings are merely examples of typical constructions and the base and beryllium member will be given such forms and dimensions as may be necessary for the particular purpose for which the structure is to be employed. In all instances in the manufacture of such structures, the principles above set forth will be put into practice, that is, the brazing will be carried on at a temperature of about 700° C. and in an atmosphere from which oxygen has been excluded and the base and brazing material will be so selected that in the joint, no continuous layer of brittle compound is formed on the base.

I claim:

1. A joint which may be heated to a temperature of 800° C. for short periods without injury and which when part of a vacuum-tight enclosure can withstand prolonged reheating at temperatures of the order of about 600° C. without becoming leaky, which comprises a base of a member of the class consisting of nickel and nickel-copper alloys, an element formed predominantly of beryllium and a thin intervening layer of copper fused to and securing the base and element together.
2. A structure which may be heated to a temperature of 800° C. for short periods without injury and which when part of a vacuum-tight enclosure can withstand prolonged reheating at temperatures of the order of about 600° C. without becoming leaky, comprising a base of a member of the class consisting of nickel and nickel-copper alloys and having an opening, an element formed predominantly of beryllium mounted on the base to close the opening, and a thin intervening layer of copper fused to and securing the base and element together around the opening.
3. A structure capable of being heated to a temperature of 800° C. for short periods without injury and which when part of a vacuum-tight enclosure can withstand prolonged reheating at temperatures of the order of 600° C. without becoming leaky, which comprises a base of Monel metal, an element formed predominantly of beryllium, and a thin intervening layer of copper fused to and securing the base and element together.
4. A structure capable of being heated to a temperature of 800° C. for short periods without injury and which when part of a vacuum-tight enclosure can withstand prolonged reheating at temperatures of the order of 600° C. without becoming leaky, which comprises a base of nickel, an element formed predominantly of beryllium, and a thin intervening layer of copper fused to and securing the base and element together.
5. A structure capable of being heated to a temperature of 800° C. for short periods without injury and which when part of a vacuum-tight enclosure can withstand prolonged reheating at temperatures of the order of 600° C. without becoming leaky, which comprises a base of cupro-

nickel alloy containing from about 20% to about 30% nickel, an element formed predominantly of beryllium, and a thin intervening layer of copper fused to and securing the base and element together.

6. The method of making a joint which may be heated to a temperature of 800° C. for short periods without injury and which when part of a vacuum-tight enclosure can withstand prolonged reheating at temperatures of the order of about 600° C. without becoming leaky and comprising a base of a member of the class consisting of nickel and copper-nickel alloys and an element formed predominantly of beryllium secured to the base, which comprises placing the element and base in contact with opposite faces of a thin member of copper and heating the assembly to a temperature of at least 700° C.

7. The method of making a joint which may be heated to a temperature of 800° C. for short periods without injury and which when part of a vacuum-tight enclosure can withstand prolonged reheating at temperatures of the order of about 600° C. without becoming leaky and comprising a base of a member of the class consist-

ing of nickel and copper-nickel alloys and an element formed predominantly of beryllium secured to the base, which comprises placing the element and base in contact with opposite faces of a thin member of copper and heating the assembly to a temperature of at least 700° C. in a non-oxidizing atmosphere.

8. The method of making a structure which may be heated to a temperature of 800° C. for short periods without injury and which when part of a vacuum-tight enclosure can withstand prolonged heating at temperatures of the order of about 600° C. without becoming leaky and comprising a base of a member of the class consisting of nickel and copper-nickel alloys and having an opening and an element formed predominantly of beryllium secured to the base to close the opening, which comprises placing a thin copper washer on the base to encircle the opening, placing the element on the copper member, and heating the assembly to a temperature of at least 700° C. while the parts are maintained in close contact to effect brazing of the element to the base.

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