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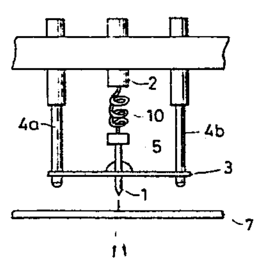
(54) Liquid metal ion source.

(57) A liquid metal ion source has a carrier strip 3 which melts and holds a substance 5 being ionized, a needle anode 1 located so that its pointed tip projects the ions of the molten substance supplied by the carrier strip, and a draw-out electrode 7 to apply a strong electric field between itself and the anode, thereby drawing out the ions from the pointed tip of the anode. The ion source has a thermal stress-absorbing element 10 installed between the needle anode and its support 2, or a plurality of such members between the carrier strip and its supports, to take up the thermal stresses that would result from the difference in thermal expansion coefficients between the needle anode and the carrier strip when both are secured to their supports, and which would damage the connected components.

FIG. 3



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LIQUID METAL ION SOURCE

This invention relates to a liquid metal ion source which melts a substance being ionized by the application of heat and provides a focused ion beam from the substance.

Such a source can provide an ion beam of a high brilliance with use of a strong electric field. In particular, the invention is intended to make it possible to extend the life and increase the reliability of an ion source of this type, so that the device may be employed, for example, as an ion source for ion microbeam equipment.

The prior-art techniques and its problems will now be described with reference to Figs. 1 and 2 of the accompanying drawings.

Fig. 1 shows the basic construction of a conventional liquid metal ion source using a needle anode. The anode 1 is connected to, and held by, a support 2. A carrier strip 3, which also acts as an electric heater for melting an ionizable substance 5, is secured at points near each end by a pair of support electrodes 4a, 4b. The needle anode 1 extends downward through a hole 6 formed in the centre of the strip 3. While the ionizable substance 5 is molten, the needle anode 1 and the carrier strip 3 are not in contact and are free to move relative to each other. As the temperature drops below the melting point, the ionizable substance 5 solidifies to connect the anode 1 and the strip 3 securely together. In operation, the heater 3 is switched on to melt the ionizable substance 5, and an electric field of a dozen or so kilovolts is applied between the needle anode 1 and a draw-out electrode 7. Ionization then takes place and the resultant ions 8 can be drawn from the pointed tip of the needle anode 1 downward through a corresponding aperture 9 formed in the draw-out electrode 7.

The prior art construction has the following problems. When an ionizable substance 5 of a high melting point is used, there is inevitably a wide difference between its melting temperature and the ambient temperature. Accordingly, when the ion source is switched on and off alternately to melt and solidify the substance 5, the difference in linear expansion coefficients between the needle anode 1 and the support electrodes 4a, 4b will produce thermal strains in the electrode 1 and the carrier strip 3. For example, when the device is switched on so that electricity is supplied, the needle anode 1, which has a greater coefficient of linear thermal expansion, begins to expand more than the support members 4a, 4b. However, the ionizable substance 5, which remains solid for some time, continues to join the anode 1 and the strip 3 together. This creates tensile stresses acting on the anode 1 and compressive stresses acting on the supports 4a, 4b, while the carrier strip 3 is subjected to bending, shearing, and other stresses. The thermal stresses tend to break the needle 1 and the strip 3, especially the latter which is often made of carbon and is more susceptible to stress. The result is an ion source with low reliability.

The present invention has for its object the provision of a liquid metal ion source which ameliorates or removes this problem of the prior art, and which can have high reliability and a long life in spite of temperature changes.

The invention proposes improvement of the connective structure between the needle shaped anode and its support. The invention provides a liquid metal ion source having a carrier which holds, and preferably melts, the substance being ionized, a needle anode located so that the pointed tip thereof projects the ions of the molten substance supplied by the carrier, and a draw-out electrode for applying an electric field between itself and the anode to draw out the ions from the pointed tip of the anode, characterized in that at least one element or member is provided to absorb the thermal stresses produced in the anode and the carrier by the temperature changes of the needle anode.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:-

Fig. 1 is a schematic view of the conventional liquid metal ion source already described, illustrating its general construction;

Fig. 2 is an enlarged perspective view of the conventional source of Fig. 1, particularly of the needle anode and the carrier strip;

Fig. 3 shows an embodiment of the invention in schematic side view; and

Fig. 4 shows another embodiment thereof also in schematic side view.

In the embodiment of the invention of Fig.3, a stress-absorbing element 10, such as a spring, is installed between a needle anode 1 and its support 2. Other parts are identical to those shown in Fig. 1 and are similarly numbered. The spring member 10 used here is a coil spring. The needle anode 1 is made of glassy carbon and measures about 0.5 mm in diameter and about 8 mm in length, with its tip pointed like that of a needle with a radius of curvature not exceeding about 10 microns. The spring member 10 consists of 0.8 mm diameter copper wire wound helically into a coil. A carrier strip 3 is formed of a 0.2 mm thick sheet of carbon. The ionizable substance 5 used in this embodiment is NiB, the melting point of which is about 1000°C. When a draw-out voltage of 13 kV was applied to such an ion source, a total ion current of about 200 μA, the sum of Ni and B ion currents, was stably obtained. During this time the power input to the carrier strip for heating was about 80 W. The ion source withstood more than 40 repetitions of the cycle of switching it on and off, demonstrating its high reliability as an ion source.

Another embodiment will now be described with reference to Fig. 4. In this embodiment a pair of stress-absorbing members 11a, 11b are interposed between each end of the carrier strip 3 and the support members 4a, 4b.

The needle anode 1 is made of glassy carbon, has a diameter of about 0.5 mm and a length of about 8 mm, and its tip is pointed like a needle with a radius of curvature of about 10 μm or less. The stress-absorbing members 11a, 11b are leaf springs formed of tantalum sheets, each measuring 0.3 mm thick and 5 mm wide, folded into a zigzag. The carrier strip 3 is a 0.2 mm-thick sheet of carbon. The ionizable substance 5 in this embodiment is NiB whose melting point is about 1000°C. When a draw-out voltage of 13 kV was applied, an ion current of about 200 μA, the sum of the Ni and B ion currents, was stably obtained. The power input to the carrier strip for heating was about 80 W. This ion source also proved highly reliable, by withstanding more than 40 repetitions of the cycle of switching it on and off.

According to the present invention, thermal stresses which will otherwise act upon the needle anode and the carrier strip are taken up by stress-absorbing member or members. This construction precludes damage orginating from thermal stress, and extends the life and increases the reliability of the ion source.

CLAIMS:

1. A liquid metal ion source having a carrier (3) which holds a substance (5) being ionized which substance is, in operation of the source, rendered molten, a needle anode (1) located so that the pointed tip thereof projects the ions of the molten substance supplied by said carrier, and a draw-out electrode (7) for applying an electric field between itself and said anode to draw out the ions from said pointed tip of said anode,

characterised in that

at least one element (10; 11a,b) is provided to absorb the thermal stresses produced in said needle anode (1) and said carrier (3) by the temperature changes of said needle anode.

2. An ion source according to claim 1 provided with at least one said thermal stress-absorbing element (10; 11a,b) in the form of a length-variable element mounted between said needle anode or said carrier and a support (2; 4a,b) therefor.

3. An ion source according to claim 1 or claim 2, wherein said thermal stress-absorbing element (10) is installed between said needle anode and a support (2) therefor.

4. An ion source according to claim 3 wherein said thermal stress-absorbing element (10) is a spring.

5. An ion source according to claim 1 or claim 2, wherein said thermal stress-absorbing element (11a,b) is installed between said carrier and a support (4a,b) therefor.

6. An ion source according to claim 5, wherein said thermal stress-absorbing element is a spring (11a,b).

7. An ion source according to claim 5 or claim 6, wherein a plurality of said thermal stress-absorbing elements (11a,b) are installed at a plurality of spaced points on said carrier.

8. An ion source according to any one of the preceding claims wherein the carrier (3) is arranged to pass current in use, thereby to be heated and thus to effect melting of the substance being ionized.

FIG. 1
PRIOR ART

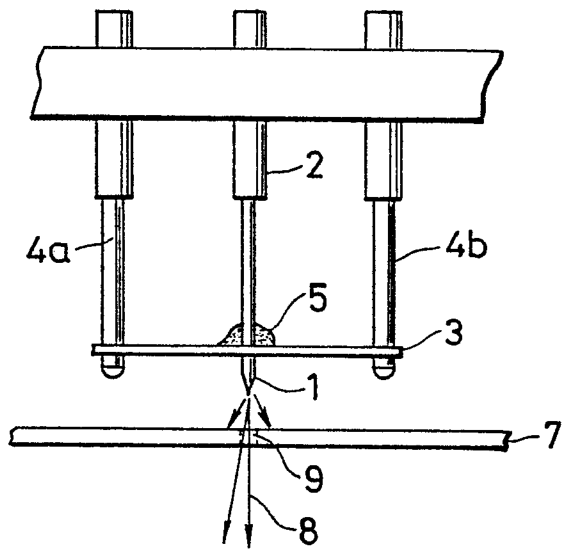

FIG. 2

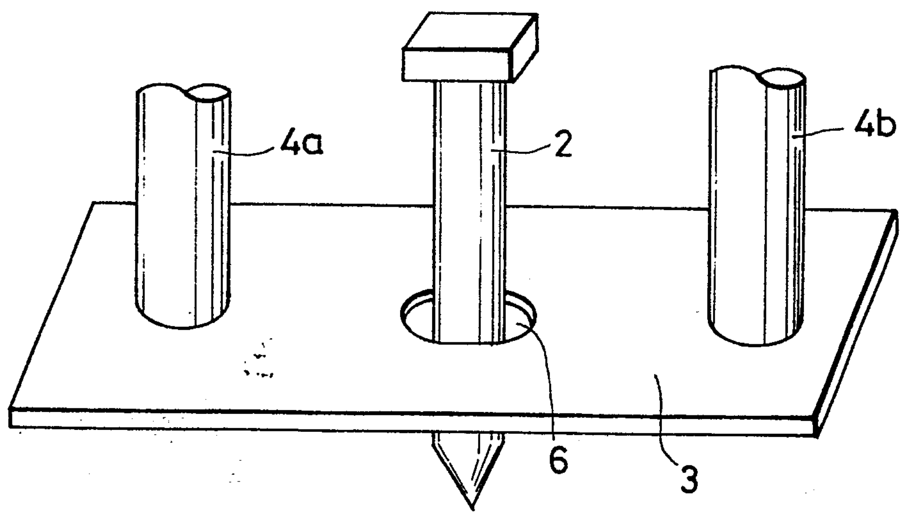

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FIG. 3

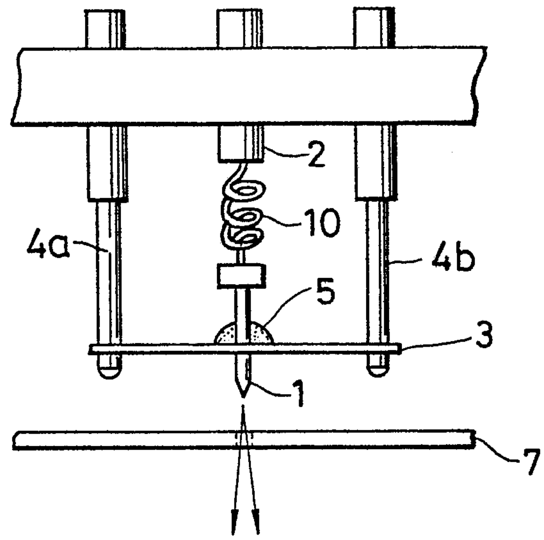

FIG. 4