This invention relates to ion sources comprising an extraction probe, that is to say a perforated electrode which has applied to it a high negative potential with respect to a discharge plasma which is preferably obtained by means of a high-frequency discharge. Such apparatus is described, for example, in Review of Scientific Instruments, 24, 635.

The probe in most cases is formed as a small tube which on the side adjacent the plasma is protected against bombardment by ions by the provision of a cylindrical shield of an insulator as a quartz. Due to the extraction of ions from the plasma, a boundary termed the "plasma boundary" is formed between the plasma and the space free from plasma at a small distance from the probe, which plasma boundary is projected by the probe by ion-optical means to the space on the other side of the probe.

Since, on the one hand, the plasma requires a certain gas pressure and, on the other hand, the beam of ions requires the presence of as high a vacuum as possible and undue loss of gas and/or large vacuum pumps are undesirable, the duct in the probe is required to be comparatively narrow.

Inside the duct of the probe the beam of ions exhibits a contraction from which the beam extends further with a large aperture up to half an apical angle of 20°. However, an apertures of 6° at the most is admissible for the majority of applications.

The large apical angle is not the result of ion-optical action, but the result of deconcentration of the ion beam due to action of the space charge. It is already known to avoid deconcentration of ion beams by introducing electrons into the beam, similarly as it is known to avoid deconcentration of electron beams by introducing ions into the beam.

The object of the invention is to avoid deconcentration of the beam in an ion probe by the use of electrons.

According to the invention, an ion source comprising an extraction probe is provided with means of preventing electrons produced in the probe from being extracted therefrom in such manner that deconcentration of the ion beam due to space charge is avoided. Electrons may be produced in the probe by means of thermal emission or photo-electric emission, but the electrons are preferably produced by secondary emission due to ions from the beam striking the walls of the duct of the probe.

The means may consist in a particular shape of the probe and/or in providing particular electrodes in the vicinity of the probe. In the latter case an electrode having a negative potential with respect to the probe is preferably arranged only on the side of the plasma. In the former case the probe comprises a long narrow duct which on the side of the plasma exhibits a widened part preventing penetration of the electric field from the side of the plasma into the narrow portion.

In order that the invention may be readily carried into effect, it will now be described with reference to the accompanying drawing, given by way of example, in which:

Fig. 1 shows an ion probe of known type.

Fig. 2 shows an ion probe in front of which an electrode having negative potential is provided.

Figs. 3 and 4 show graphs of the measuring results obtained with a probe as shown in Fig. 2.

Fig. 5 shows a probe with the shape of its duct matched to the beam of ions.

Fig. 6 shows a probe having a long narrow duct with a cylindrical widened part.

Fig. 7 is a cross-sectional view of an ion source containing the extraction probe illustrated in Fig. 2.

Referring now to Fig. 1, reference numeral 1 indicates the plasma from which ions are extracted from the plasma boundary 6, the ion beam 3 acquiring a contraction 5 inside the duct 4 of the known probe 2. 7 indicates a quartz cylinder having a conical flange for protection of the probe against bombardment by ions. If the lower end of the probe would be sufficiently wide, the ion beam would diverge into a cone of which half the apical angle is indicated by 8. The maximum angle that can be used is indicated by 9.

In Fig. 2, a narrow part 8 is provided in the duct 4 of the inventive probe 2 at the area of the contraction of the ion beam, thus avoiding unnecessary loss of gas from the plasma space without the yield of ions being reduced.

The narrow part 8 also avoids unnecessary loss of electrons to the side of the plasma. At this narrow part and also farther in the duct 4 of the probe there are always ions striking the wall with the result that electrons are released. In order to prevent the said electrons from being drawn to the plasma by the electric field between the plasma boundary 5 and the probe 2, provision is made of a conductor 10 which is at negative potential with respect to the probe.

Fig. 3 shows the variation of the current of the probe of Fig. 2 as a function of the potential difference between the probe and the electrode at the other end of the ion source.

Fig. 4 shows the same function for another embodiment on the principles of Fig. 2.

In Fig. 5 the probe, as before, has a narrow part 11 which widens only gradually to such an extent as corresponds to the serviceable aperture of ion beam.

In Fig. 6 the probe comprises a wide cylindrical part 12 which contains a small tube 13 having a narrow duct 14 in order to increase the resistance to flow for the gas.

In both the construction of Fig. 5 and Fig. 6 the amount of electrons released from the wall of the duct of the probe is sufficient to avoid deconcentration of the beam.

The electrode 10 and the wide part 15 prevent electrons from being extracted from the duct of the probe.

Fig. 7 is a cross-sectional view of the entire ion source containing the probe depicted in Fig. 2. The source comprises an envelope 20 having a gas inlet at its lower end through which the gas to be ionized may be supplied to the envelope. Surrounding the envelope 20 is a cell 21, which, when connected to a radio-frequency source of currents, will establish an R. F. field for exciting the gas. At the top end of the envelope is an electrode 22, to which a high positive potential relative to the probe 2 at the bottom end may be applied. The electrostatic field thus produced, together with the R. F. field, cooperate to produce a discharge in the gas and thus establish a discharge plasma in the envelope. The discharge, of course, ionizes the gas.

The ions, being positive, are attracted to the negative probe 2, which is mounted on and electrically connected to a support 24, which ions are then accelerated and thus projected vertically downward through the probe 2 along the vertical axis of the source.

As is also shown in this figure, the electrode 10 is mounted on a support insulated from the support 24, and has applied to it a negative potential relative to the probe 2 to repel electrons produced in the probe 2 and
thus prevent them from being attracted to the positive electrode 22. The ions extracted by the probe 2 are accelerated by a cylindrical electrode 23, at a negative potential, and can then be collected in the usual way, and the resultant ion current employed for the purpose desired.

What is claimed is:

1. An extraction probe for withdrawing ions from a discharge plasma, comprising a hollow tubular conductive member which upon bombardment by ions produces electrons, said electrons when within the probe tending to prevent deconcentration of a beam of ions withdrawn from the plasma, and means associated with said probe for preventing said electrons from being extracted from the probe.

2. An extraction probe as set forth in claim 1 wherein the tubular member has a long narrow duct and a widened part at one end thereof, said narrow duct and widened part tending to prevent the extraction of electrons from within the probe.

3. An extraction probe as set forth in claim 1 wherein said last-named means includes a perforated electrode disposed in front of said member, and means for applying to said electrode a potential negative with respect to the tubular member.

4. An extraction probe as set forth in claim 3 wherein the tubular member contains a duct having a narrowed part spaced from the front end thereof.

5. In combination, a vessel having a discharge plasma therein; and an extraction probe for withdrawing ions from said plasma, said probe comprising a hollow tubular conductive member disposed in said vessel in the vicinity of said plasma, an insulating shield surrounding the front end of said probe, said probe being at a negative potential relative to the plasma, and means associated with said probe for preventing electrons produced therein due to ion bombardment from being extracted therefrom.

No references cited.