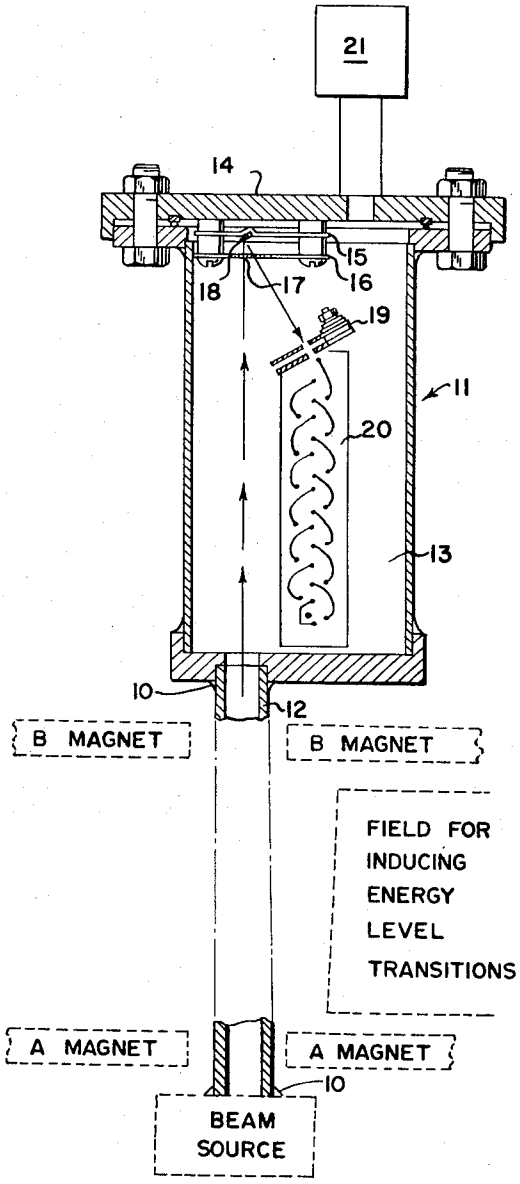
March 18, 1969 J. GEORGE 3,433,944

DETECTOR FOR MOLECULAR OR ATOMIC BEAM APPARATUS

Filed Oct. 11, 1966



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United States Patent Office 3,433,944
Patented Mar. 18, 1969

3,433,944

DETECTOR FOR MOLECULAR OR ATOMIC BEAM APPARATUS

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Filed Oct. 11, 1966, Ser. No. 585,815
U.S. Cl. 250—41.3 3 Claims
Int. Cl. G01n 27/78

ABSTRACT OF THE DISCLOSURE

A particle ionizer includes a heated element of titanium or zirconium in the path of the particles to be ionized.

This invention relates to improved hot wire ionizers. More specifically, the invention concerns the use of new materials in particle ionizers to improve the signal-to-noise ratio of detectors which utilize such ionizers.

One useful application of the present invention is in the detector of cesium beam tubes. Cesium beam tubes are used in frequency standards of the type described in U.S. Patent No. 2,972,115 to J. R. Zacharias et al., issued on Feb. 4, 1961. In this prior art device an ionizer detector is employed to convert the neutral cesium atomic beam into cesium ions. These ions are then readily detected and converted into an electrical signal. Ionization of the beam of cesium atoms is there accomplished by a ribbon of heated tungsten in the beam path. This is typical of the so called ionizer-detectors or hot-wire detectors in which heated platinum, tungsten or tantalum wires have been used. Although effective, these materials have also required the use of mass spectrometers to remove metallic impurities, especially alkali metal and carbide impurities which are converted into ions along with the cesium. For example, a heated tungsten wire generates as an impurity, potassium ions which degrade the signal-to-noise ratio of the detector unless removed by mass spectrometer means. Additionally, variations in the heater energy to the electrically heated tungsten ribbon, or thermal or mechanical shocks would tend to produce bursts of potassium ion emissions. Furthermore, out gassing of the detector was often required during manufacture of the beam tubes to reduce the production of residual ion impurities by the detector.

My U.S. Patent No. 3,258,713 teaches the use of niobium as an ionizer to overcome the deficiencies of tungsten and other prior art ionizer materials. While niobium does indeed provide a significant measure of improvement, it has subsequently been learned that some potassium ionization continues to occur despite the use of niobium. Then too, even with the use of niobium signal-to-noise ratios as high as 20:1 cannot be obtained.

It is, therefore, an object of my invention to provide an improved selective particle ionizer.

Another object of my invention is to provide an improved ionizer detector for use in a cesium beam tube apparatus which will significantly reduce potassium ionization and thereby provide a very high signal-to-noise ratio.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises an article of manufacture possessing the features, properties, and the relation of elements which will be exemplified in the article hereinafter described, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawing which illustrates a cesium beam tube detector including the ionizer of the present invention.

Briefly, in accordance with my invention, I provide an

improved selective particle ionized which includes a heated element in the path of particles to be ionized. The heated element is made of a material having a work function greater than the ionization potential of the atoms to be ionized but sufficiently less than the ionization potential of the principal impurities present in the material to provide a ratio of wanted ions to unwanted ions which is in excess of 20:1.

When the particle ionizer of my invention is used as part of a detector, it therefore enables the detector to operate with a signal-to-noise ratio greater than 20:1. If, for example, my invention is to be used in the detector of a cesium beam apparatus then the material used in the heated element of the ionizer would be, for example, zirconium or titanium. In this case the selection of zirconium or titanium is based upon the fact that the ionization potential of cesium is 3.89 electron volts, the work function of titanium is 3.95 electron volts, zirconium 3.90 electron volts and a principal impurity in titanium and zirconium is potassium which has an ionization potential of 4.3 electron volts.

The closer the work function of the ionizer material comes to the ionization potential of the principal impurity, in this case potassium, the more the impurity is apt to be ionized. On the other hand, the closer the work function of the ionizer material is to the material to be ionized, the less the ionization efficiency of the ionizer is. It is to be noted, though, that some decrease in ionization efficiency can certainly be tolerated as long as this is accompanied by an increase in the signal-to-noise ratio.

While it would appear that the selection of the ionizer material may be accomplished by consulting an appropriate handbook, this is clearly not the case. If, for example, the Handbook of Chemistry and Physics, published by the Chemical Rubber Publishing Company, is consulted it will be noted that innumerable values are listed as the work function for each element. Then too, the work function will vary depending on whether or not it is the thermionic work function, the photoelectric work function or work function by the contact potential method. To determine which of the values apply to the material used in the ionizer of the present invention is made even more difficult because metals with adsorbed monolayers may have different work functions than the base metals alone.

It is believed that when a free atom is brought into the neighborhood of a metal surface, an interaction takes place and the discrete energy occupied by the outermost electron in the free atom becomes broadened into a band of states of considerable width. In general, the broadening is greater the less the ionization potential. If none of the broadened states lies below the top of the Fermi level in the metal when the atom is on the surface, the atomic electron will leave the atom entirely and reside in the base metal, leaving the atom ionized and thereby establishing a strong double layer and producing an appreciable decrease of the work function. If, however, part of the band state lies below the Fermi level these states can be occupied by an electron part of the time by tunneling. Under these circumstances the adsorbed atom will not be completely ionized. The resulting charge double layer will not be as strong and the work function of the monolayer will not be so much smaller than the work function of the base metal. This mechanism by which the work function of a base metal is raised or lowered by the adsorption of monolayers of various atoms seems to account for the changes in work function found experimentally. Although this explanation is not universally accepted, it serves to point up some of the factors which must be considered and the complexity of the problems of selection of materials.

While a principal factor in the selection of a material for use as an ionizer is its work function with respect to

the atoms to be ionized, other characteristics of the material are likewise important. For example, the resistivity of the ionizing materials should be high because a higher voltage and lower current for the ionizer affords more efficient utilization of the power consumed. Then too, the thermal conductivity should be lower since this also contributes to minimizing power consumption by the ionizer.

Referring now to the drawing, which illustrates a typical embodiment of my invention, there is shown an ionizer detector **11** at one end of a conventional cesium beam tube **12**. The tube **12** is attached at one end to a cesium beam source by a seal **10**. At the other end, the tube **12** communicates with and is sealed by another seal **10** to the evacuated detector chamber **13**. The system, therefore, has a completely sealed construction. A cesium beam indicated by the arrows enters the detector **11** after it emerges from the B magnet field.

Attached to the wall **14** are electrostatic plates **15** and **16**. A narrow slit **17** in the plates **15** and **16** permits the cesium atoms entering the detector chamber **13** to strike the ionizing ribbon **18**. The ionizing ribbon **18** of this exemplary embodiment is a heated zirconium or titanium ribbon filament which has its major axis aligned with the major axis of the cross-section of the beam of cesium atoms. The width of the ionizing ribbon is such that it will not be struck except by those atoms in that portion of the beam in which the atoms of the (4,0) energy level are located. Other energy levels, however, may be utilized with equal success. This hot ribbon is a "surface ionizer," that is, neutral cesium 133 particles strike the surface, are adsorbed, and quickly reevaporate as singly charged positive ions. As illustrated, the ribbon **18** is mounted at approximately a 30° angle from the normal of the cesium atoms striking the surface.

After ionization, the particles are accelerated to an energy of about 2000 ev. through the parallel plate system **15**, **16**. The particles are deflected through a 30° angle and subsequently accelerated by a parallel plate lens **19** from which they enter a **14** stage electron multiplier **20**. The multiplier **20** develops an electrical output signal. An ion pump **21** communicates with the detector chamber **13** to remove cesium atoms and gaseous impurities and to maintain the vacuum desired.

When used in a cesium beam tube the zirconium or titanium ionizer described herein will have approximately the same dimensions and mode of operation as the niobium ionizer-detector illustrated in my U.S. Patent No. 3,258,713 referenced above.

While zirconium, titanium and niobium appear to have only slight differences in work function—3.99 ev. for niobium, 3.95 ev. for titanium and 3.90 ev. for zirconium—this belies the true difference in performance. Actually, a hundredth of an electron volt in the work function value may make a significant difference in the amount of potassium ionization that occurs. The advantages of zirconium and titanium over niobium as an ionizer material in a cesium beam tube detector are dramatically pointed up by experimental data. For example, I have been able to demonstrate that, while niobium as an ionizer material reduces potassium ion formation in comparison with tungsten, zirconium and titanium may be used to provide for the first time, signal-to-noise ratios in excess of 20:1. The ratios of cesium to potassium ion formation for the various ionizer materials are as follows:

(1) $Zr—Cs^+/K^+=35/1.3=27.0:1$

(2) $Ti—Cs^+/K^+=45.2/2.0=22.6:1$

(3) $Nb—Cs^+/K^+=53/2.8=18.9:1$

As pointed out above, when certain base metals, such as zirconium or titanium, have monolayers, such as cesium, adsorbed thereon, synergistic effects may exist which vary the work function of the base metal. The efficiency with which the adsorbed monolayer ionizes depends on the difference in work function. This is, however, a matter of probability. The probability that an impinging particle will ionize is also temperature dependent; that is to say there is a certain probability that the adsorbed monolayer will ionize at the work function difference between the adsorbed monolayer and the base metal at a given temperature. With this in mind I employ the principles of my invention to select materials and conditions which enable me to maximize the ratio of wanted to unwanted ions. For example, in a cesium ionizer, as the work function of the ionizer material is reduced, the potassium ionization drops off much faster than the cesium ionization. The use of zirconium or titanium, therefore, enables me to operate in this particular region which maximizes the signal-to-noise ratio of the detector. The application of this principle is new to the field of particle ionizers.

It will thus be seen that the objects set forth above among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In a cesium beam apparatus having a source of cesium particles, a detector, an enclosure for the beam between the source and the detector, magnets external to and spaced along the enclosure to create an intense inhomogenous magnetic field through which the beam passes, means for inducing energy level transitions in the beam in the portion of the enclosure between the magnets, means for sealing the source, detector and enclosure from the atmosphere, and an ionizer filament in the detector to ionize the cesium atoms impinging thereon; the improvement comprising said ionizer filament formed of a metal selected from the group consisting of titanium and zirconium to reduce significantly potassium ionization on said filament and thereby increase the signal-to-noise ratio of said detector.

2. A selective particle ionizer which includes a heated element in the path of particles to be ionized wherein said element comprises a metal selected from the group consisting of zirconium and titanium and said particles to be ionized are cesium.

3. A detector, comprising:

(A) an evacuated detector chamber (**13**) adapted to receive a cesium beam;

(B) means (**21**) for maintaining the vacuum in said chambers;

(C) a heated ionizing surface (**18**) in the path of the beam of atoms, said surface comprising a metal selected from the group consisting of zirconium and titanium; and

(D) means (**20**) to convert the ionized atoms into an electrical signal.

References Cited

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U.S. Cl. X.R.

250—41.9; 313—103, 311; 331—3