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INFRARED RADIATION ENTRANCE WINDOW

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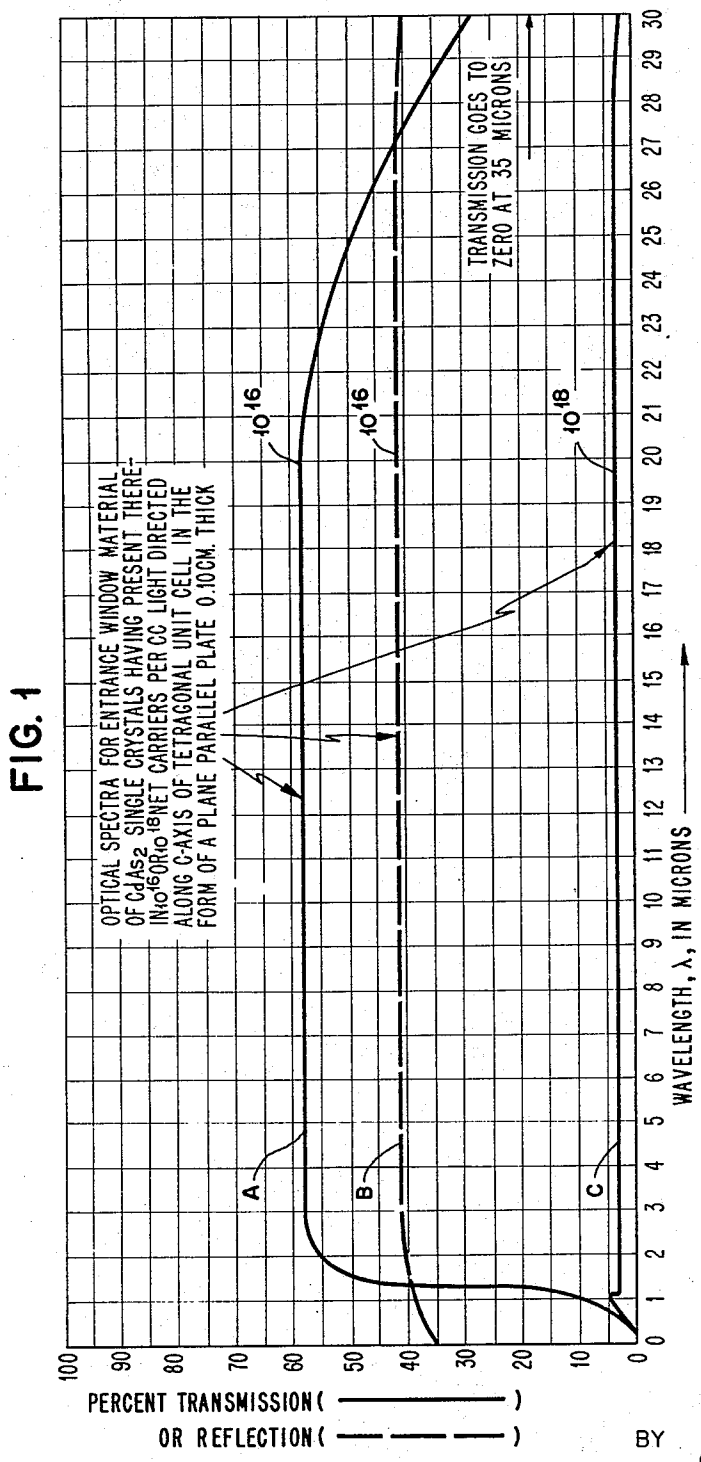


FIG. 1

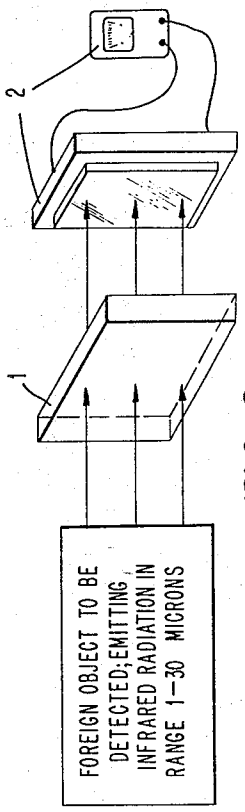


FIG. 2

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INFRARED RADIATION ENTRANCE WINDOW

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This invention relates to entrance windows for infrared energy and more particularly to an infrared filter element of semiconductor $CdAs_2$ capable of transmitting infrared energy over the range 1–25 microns.

A typical infrared detection system consists of an entrance window or filter followed by an optical detector. The entrance window material used in such a system must be able transmit adequately in the infrared region and at the same time possess the physical attributes which can withstand the changes of environmental conditions such as temperature, stress, abrasion and liquids. Most window materials are lacking in these prerequisites.

What has been provided herein is an improved entrance window having distinct advantages over the others presently available in the art. The window material consists essentially of single crystals of semiconductor $CdAs_2$ having present therein an impurity concentration of less than 10^{16} net carriers per cc. The window or filter of the present invention possess excellent chemical stability, moisture resistance and physical durability. Furthermore the window exhibits a flat, high transmission spectral response over the range 1–25 microns. This characteristic may be utilized to detect unknown objects, such as missiles, submarines and the like, emitting infrared energy at any wavelength in that range.

An object of the present invention is to provide an improved entrance window for an infrared detection system.

Another object is to provide infrared filter comprising semiconductor cadmium diarsenide exhibiting a high, flat transmission over the range 1–25 microns.

A further object of the present invention is to provide a moisture insensitive, chemically stable, physically durable, infrared detecting window exhibiting a flat, high transmission response over the range 1–25 microns, said window comprising cadmium diarsenide single crystals having present therein an impurity content of less than 16^{16} net carriers per cc.

Still another object is to provide a semi-conductor element having a flat, high transmission response over the range 1–25 microns, said element comprising cadmium diarsenide having present therein an impurity content of less than 10^{16} net carriers per cc.

Yet another object is to provide apparatus for detecting the presence of foreign objects emitting infrared radiation in the range 1.3–30 microns, said apparatus comprising an entrance window through which said radiation may pass consisting essentially of crystalline $CdAs_2$ having present therein an impurity content of less than 10^{16} net carriers per cc. and an optical detector for said radiation.

Another object is to provide the above apparatus wherein the window material is oriented with its C-axis in the path of the infrared radiation.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

In the drawings:

FIGURE 1 is a graph of percent transmission (and reflection) vs. wavelength for the entrance window element of the present invention.

FIGURE 2 illustrates schematically infrared detection system capable of detecting emitted radiation at any wavelength within the range 1–35 microns.

The entrance window described herein consists essentially of semiconductor $CdAs_2$ containing an impurity content of less than 10^{16} net carriers per cc. The window element material may take the form of polycrystals or single crystals, optimum results, however are obtained in the form of single crystals.

The single crystals may be conveniently prepared by a pulling technique such as described in the paper by R. Gremmelmaier, in Zeitschrift für Naturwissenschaften, 11*a*, 511 (1956). The starting materials, cadmium and arsenic, are available commercially in high purity; however they may be pretreated to further increase their purity. For example, high purity cadmium, 99.999+%, available from the Consolidated Mining and Smelting Company, may be subsequently treated by vacuum distillation in a sealed tube. Similarly, arsenic, 99.999+%, purchased from American Smelting and Refining Company, may be further purified by sublimation in hydrogen at 950° C. The purified starting materials are then mixed in the stoichiometric ratio Cd:2As and sealed in a quartz crucible under an arsenic presure of about 0.5 atmosphere, using argon as an ambient gas. The reactants are then melted above 621° C. by the application of heat from an external source. Single crystals of $CdAs_2$ of tetragonal symmetry are then pulled from the melt using a seed crystal of the same material cut parallel to the crystallographic C-axis of the unit cell. Using this technique, well-oriented single crystals of $CdAs_2$ may be prepared with an impurity content of less than 10^{16} net carriers per cc.

The entrance window element of the present invention may be prepared using the crystal material prepared as described above. The window is prepared by cutting the crystal into parallel plates of any convenient thickness. The window should be oriented such that the incident radiation is directed along the C-axis of the crystal. Excellent transmission may still be obtained, however, with the infrared energy directed along the "*a*-axis" or along points between said axes.

Referring now to FIGURE 1 there is shown in graphic representation some optical properties of the filter element of the present invention. In particular it is seen from curve A that the element exhibits an exceedingly flat, high transmission response in the infrared range 1–25 microns, and usable transmission up to 35 microns, when the impurity content is about 10^{16} net carriers per cc.

In order to enable one skilled in the art to design and construct an optimum entrance window for a particular application, the following information and discussion is presented. In regard to the thickness of the entrance window it has been determined that the window material may be made of any convenient thickness without diminishing the high transmission response shown in curve A of FIGURE 1 for a thickness of 0.10 cm. This result follows from the fact that the transmission, T, is governed by the equation

$$T=\frac{(1-R)^2e^{-kx}}{[1-(R)^2]e^{-2kx}}$$

where k is the absorption coefficient, x is the thickness of the window material and R is the reflectivity. For single crystals of $CdAs_2$ containing less than 10^{16} carriers per cc., k approaches zero in the range 1–25 microns. Therefore, the transimssion, T, will depend only upon the reflectivity of the window.

The total reflection losses from the window is given in curve B. These reflection losses may be reduced to a minimum by coating the surface of the crystal with the so-called "blooming agents." A "blooming agent" may be defined as any material which decreases the reflection

loss and increases transmission without introducing spurious absorption peaks in the spectrum. For use in the window element described herein such a material must be transparent at the particular wavelength at which the entrance window is used, and preferably possess an index of refraction, *n*, which is the geometric means between the index of refraction of air, 1, and that of $CdAs_2$, 3.15. For maximum transmission the thickness of the coating should preferably be ¼ of the wavelength of the incident radiation being detected. Selection of a suitable material will vary with the wavelength region being detected. Suitable materials include silver chloride, potassium chloride, potassium bromide, and silicon monoxide.

In FIGURE 2 there is illustrated an infrared detection system for determining the presence of foreign objects which emit infrared radiation within the range 1.3–30 microns. The system comprises the entrance window element **1** described herein and an optical detection device **2** for recording the emitted infrared radiation. The window of the present invention finds particular usefulness in such a system in that it may be used to conclusively indicate the presence of objects which emit at any wavelength within the range 1.3–30 microns. Furthermore the high transmission response of this particular window element permits detection of objects emitting only weak infrared radiation.

What has been described herein is a new and improved semiconductor infrared window element exhibiting a flat, high transmission spectral response within the range 1.3–25 microns, and usuable transmission approaching 35 microns, consisting essentially of $CdAs_2$ crystals having present therein an impurity content of less than 10^{16} net carriers per cc.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. An entrance window having a flat, high transmission spectral response in the range 1.3–25 microns and a usable transmission approaching 35 microns, consisting essentially of semiconductor $CdAs_2$ having present therein an impurity content of less than 10^{16} net carriers per cc.

2. An infrared filter having a flat, high transmission spectral response in the range 1.3–25 microns and a usable transmission approaching 35 microns and an essentially complete absorption below and beyond said range, said filter consisting essentially of crystalline $CdAs_2$ having present therein an impurity content of less than 10^{16} net carriers per cc.

3. The claim according to claim 2 wherein the crystal has a coating material transparent in the range 1.3–25 microns and an index of refraction between 1 and 3.15 coated thereon.

4. Apparatus for determining the presence of foreign objects emitting infrared radiation at any wavelength in the range 1.3–30 microns comprising an entrance window through which said radiation may pass consisting essentially of crystalline $CdAs_2$ of tetragonal symmetry having present therein an impurity content of less than 10^{16} net carriers per cc. oriented with its C-axis in the path of the infrared radiation and an optical detector for said radiation.

5. A semiconductor element having a high transmission response in the range 1.3–30 microns consisting essentially of $CdAs_2$ single crystals having present therein an impurity concentration of 10^{16} net carriers per cc.

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