Feb. 19, 1963 R. KAPPELMEYER 3,078,151

APPARATUS FOR DRAWING SEMICONDUCTOR BODIES FROM A MELT

Filed Sept. 25, 1959

Fig.1

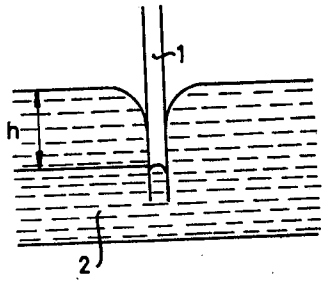


Fig.2

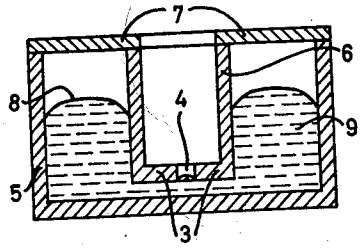
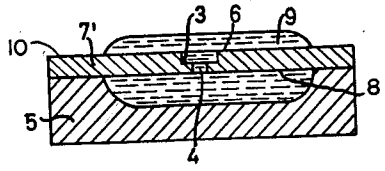


Fig.3



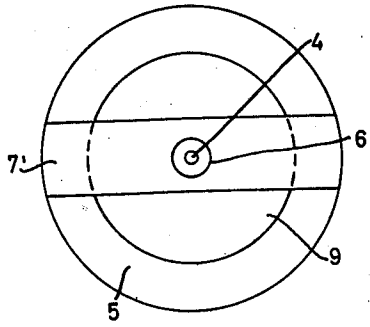


Fig. 4

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APPARATUS FOR DRAWING SEMICONDUCTOR BODIES FROM A MELT

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3 Claims. (Cl. 23—273)

This invention is concerned with drawing rodlike semiconductor bodies, especially thin rodlike substantially mono-crystalline semiconductor bodies, from a melt contained in a crucible.

The various objects and features of the invention will appear from the explanations rendered below in part with reference to the accompanying drawing, wherein

FIG. 1 illustrates as an aid to the understanding of the invention capillary phenomena produced upon dipping a tubular body into a non-wetting liquid;

FIGS. 2 and 3 illustrate in cross sectional views crucible devices which are particularly favorable for practicing the invention; and

FIG. 4 shows a top elevational view of the crucible device according to FIG. 3.

The invention is based upon the known phenomenon of capillary action. If a body, especially a tubular hollow body (capillary) **1** is, as shown in FIG. 1, dipped into a non-wetting liquid **2**, the liquid within the tubular body is depressed downwardly, such action being referred to as capillary depression. The liquid appears in the capillary relative to the surrounding liquid lower by the amount *h*. The liquid level within the capillary depends in addition to the border surface tension and density of the liquid only upon the diameter of the tubular body. The smaller the cross section of the capillary, the more will the liquid be depressed downwardly, that is, the liquid level within the capillary will be lower with decreasing cross section of the capillary. The height of the liquid level within the capillary does not depend upon the height of the level of the liquid surrounding the capillary.

In accordance with the invention, the material required for the formation of the desired semiconductor rod is drawn from a point in the semiconductor melt which is below the highest surface parts thereof, a member provided with an opening formed therein being for this purpose dipped into the melt and the material for the semiconductor rod being drawn through such opening. Accordingly, into the semiconductor melt is dipped a member which may be shaped as desired, it being merely essential that such member is provided with an opening which is so small that capillary forces can become operative. The semiconductor rod is drawn through such opening.

The advantage resulting from the invention resides in obtaining with substantially constant drawing speed a fixed location for the transition zone, liquid-solid-(solidification zone), which is independent of the top level of the melt in the crucible. It follows, therefore, that the supply of molten material does not require accurate dosing during the drawing operation.

Since the diameter of the drawn rodlike member is determined by the distance of the solidification front from the surface of the melt, it is necessary to provide at the corresponding area measuring feeler means for the diameter regulation. According to the invention, such feeler means may be fixedly built in. For example, an inductive measuring feeler may be used for measuring this distance, utilizing thereby as a measuring value the abrupt resistance change occurring in the case of germanium and silicon upon transition from the liquid to the solid state.

A further advantage of the invention resides in the fact

that the temperature gradient in the melt remains during the drawing substantially constant.

As has already been explained above, the height *h* is with given diameter of the capillary or opening a constant function. Accordingly, when the capillary or the part provided with an opening is dipped deeper into the liquid or semiconductor melt, the liquid level in the capillary or opening will rise. In accordance with the invention, the part provided with the opening is dipped into the melt to a depth, such that the semiconductor material, owing to its surface tension, does not normally automatically pass through the opening which is for this purpose made correspondingly small. The opening thereby serves as upper limit of the rod diameter. The invention may be advantageously employed for the drawing of thin crystal rods.

FIGS. 2, 3 and 4 show particularly advantageous crucible devices for practicing the invention. There are two concentric firmly interconnected crucible parts **5** and **6**, the part **6** being provided with an opening **4** formed therein, through which the semiconductor rod is drawn.

The crucible shown in FIG. 2 comprises two parts **5** and **6** which are firmly interconnected by the part **7**. The inner crucible part **6** has at the bottom **3** thereof a hole **4** formed therein through which the desired semiconductor rod is drawn from the melt **9**. Provided that the melt does not wet the crucible, which is the case with germanium in a graphite crucible or silicon in a quartz crucible, the melt level **8** may be in view of the capillary depression considerably above the level of the bottom **3** of the inner part **6**. A rod may be continuously drawn from the melt upwardly through the opening **4**. The melt level within the opening **4** is thereby independent of the height of the melt level **8**, making it possible to supply during the drawing operation semiconductor material to the crucible part **5** without regard to any accurate dosing.

A suitable measuring feeler for regulating the diameter of the drawn rod is provided in the opening **4** and fixedly connected with the corresponding crucible part **6**. The interconnecting part **7** may be disposed so as to be easily removable or, alternatively, it may be provided with openings for inserting semiconductor material during the drawing operation.

In the arrangement according to FIGS. 3 and 4, the connecting part **7'** and the inner crucible part having the opening **4** are made of one piece which is firmly connected, for example, screw connected with the outer crucible part **5**, covering only part of the outer part **5**. An opening **4** is again formed at the bottom **3** of the inner crucible part for drawing the semiconductor rod therethrough. A measuring feeler is again positioned in the opening **4**. The melt **9** extends for several millimeters upwardly beyond the plane **10**, that is, beyond the plane of the margin of the outer crucible part.

Thin germanium crystal rods with diameters from 1–2 millimeters have been drawn particularly with the aid of a crucible arrangement made according to the invention and corresponding to the arrangement illustrated in FIGS. 3 and 4.

Changes may be made within the scope and spirit of the appended claims which define what is believed to be new and desired to have protected by Letters Patent.

I claim:

1. In the art of drawing relatively thin substantially monocrystalline semiconductor rods from a semiconductor melt, a crucible device containing such melt, said crucible device comprising firmly interconnected outer and inner parts, said inner part having a bottom wall disposed substantially below the upper edge of said outer part and containing a capillary opening fixedly disposed in said melt at a level lying below but otherwise inde-

pendent of the highest surface level of the melt, said opening having a size sufficiently large to permit the continuous drawing of semiconductor material therethrough to form a semiconductor rod of predetermined size and at the same time of a size sufficiently small to prevent, by capillary action, upward flow therethrough of semiconductor material when the opening is disposed at normal operating depth in the melt.

2. A crucible device according to claim 1, wherein both said crucible parts are made of graphite for the processing of a germanium melt.

3. A crucible device according to claim 1, wherein both said crucible parts are made of quartz for the processing of a silicon melt.

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