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APPARATUS FOR PRODUCING CRYSTALLINE SEMICONDUCTOR MATERIAL

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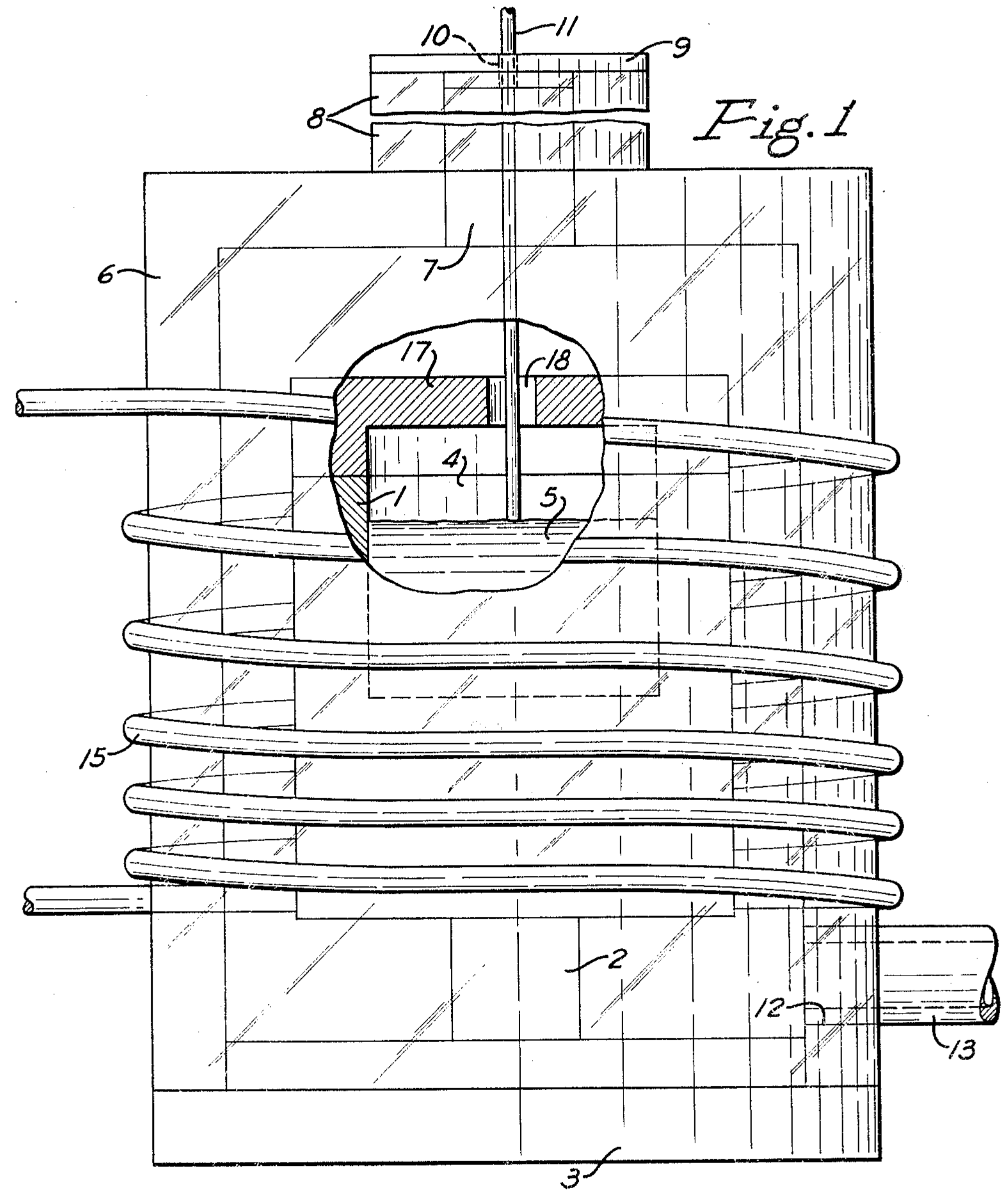

Fig. 1

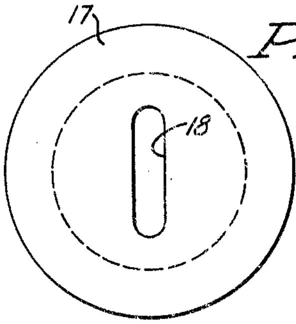

Fig. 2

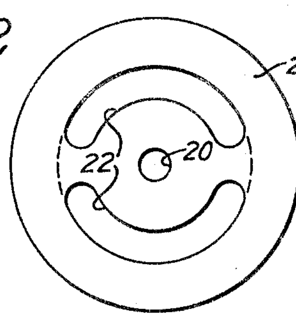

Fig. 3

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APPARATUS FOR PRODUCING CRYSTALLINE SEMICONDUCTOR MATERIAL

Walter J. Smith, Pitcairn, Donald R. Hamilton, Monroeville, and Jacob J. Coleman, Braddock, Pa., assignors to Westinghouse Electric Corporation, Pittsburgh, Pa., a corporation of Pennsylvania

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2 Claims. (Cl. 23—273)

This invention relates to apparatus for growing ribbons and other shapes of crystalline semiconductor material from a melt in a heated crucible.

Conventional apparatus is available for producing a solid crystal from a molten pool of suitable material. Such apparatus includes means for contacting the surface of the melt with a previously prepared crystal or seed and then slowly withdrawing the seed. The seed pulls after itself a portion of the melt which solidifies on the seed, so a crystal of indefinite length can be produced. In growing crystals the thermal gradient at the surface of the melt is important. Unless it is controlled properly the result can be the growth of thick, rough crystals or even no growth at all. Heretofore, the melt has been contained in an uncovered crucible. The melt surface radiates heat at a rate depending on its emissivity and temperature, and the thermal gradient at the melt surface and just within the melt will be equal to the radiation loss per unit area divided by the thermal conductivity of the melt. In many cases, such as in the growth of silicon dendrites, this thermal gradient is unsuitably high, so that when dendrites of great length are grown, they deteriorate in time to an unsatisfactory condition. That is, they become thick, rough and have macroscopic pits and hillocks on their surfaces.

It is among the objects of this invention to provide apparatus for producing crystalline semiconductor material that does not deteriorate materially, that can be formed in indefinite lengths, and that retains its original thickness and smoothness. A further object is to provide such apparatus, in which supercooling of the melt is controlled.

The invention is illustrated in the accompanying drawings, in which:

FIG. 1 is a side view of apparatus constructed for our purposes;

FIG. 2 is a reduced plan view of the supercooling control member on the crucible; and

FIG. 3 is a plan view of a modification.

Referring to FIG. 1 of the drawings, a crucible **1** of well-known construction for growing dendrites and other crystalline semiconductor materials is made from graphite or the like and may be mounted on a center post **2** projecting up from a base member **3**. The upper part of the crucible is provided with an upwardly opening recess **4** to contain the material **5** from which a crystal is to be formed. The crucible is mounted in a furnace of any suitable construction, the one shown being a cylindrical furnace **6** formed from quartz or the like to provide ample visibility into its interior. The top of the furnace is provided with a small central opening **7**, from which a tube **8** extends upwardly. The upper end of the tube is closed by a cover **9** that has a central opening **10** just large enough to receive a rod **11** or other suitable elongated member to which a suitable seed is attached and by which a crystal can be drawn from the crucible. The side wall of the furnace is provided with an opening **12** connected to a pipe **13**, through which an inert gas can be delivered to the inside of the furnace or the air exhausted from the furnace.

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The crucible is heated most suitably by a radio frequency coil **15** encircling it. This coil may be either inside or outside of the furnace, outside being preferred. The turns of the coil are closer together at the bottom of the crucible than at its top so that there will be a thermal gradient present in the crucible-melt system to insure that the surface of the melt and the melt just below its surface will be the coolest points of the melt. Also, this thermal gradient maintains the bottom part of the melt, which is in contact with the crucible, at a temperature higher than the melting point of the melt, whereby the melt is prevented from freezing at the bottom.

Another feature of this invention is that the desired thermal conditions for continued crytsal growth are produced by reflecting some of the heat from the surface of the melt back to that surface in order to reduce the thermal gradient in the melt and thereby control supercooling of the top of the melt. This is accomplished by a supercooling control member **17** that is placed on top of the crucible to cover it and hold in the heat, whereby to provide as large a supercooled area of the melt around the growing crystal as is possible. To permit the growing crystal to be removed from the crucible, the top of the control member is provided with a center opening **18** for rod **11**. This opening should be as small as possible but, as shown in FIG. 2, it is preferred to make it in the form of a slot extending part way across the control member so that an observer can see down into the crucible through either end of the slot. This control member **17**, which does not interfere with continuous extraction of the crystalline material, controls supercooling of molten material in the crucible by reducing the thermal gradient at the top of the pool. For best results, it also is desirable to heat the control member, and this can be done by extending the heating coil around it as shown.

In the modification shown in FIG. 3, the central opening **20** in the supercooling control member **21** to permit withdrawing the crystal from the crucible is small and circular, but the control member also is provided with a pair of arcuate slots **22** spaced uniformly from its center and opening into the crucible. These slots not only provide sight openings through the control member, but they allow more heat to be radiated from the area of the melt beneath the slots in comparison with the area of the melt directly beneath the unslotted portion of the control member. This results in a higher temperature at the edge of the crucible for the same supercooling at the center, thus decreasing the tendency for the melt to freeze at the melt-crucible interface.

For a more detailed explanation of the process of growing dendritic crystals from a supercooled melt reference should be had to U.S. Patent 3,031,403, the assignee of which is the same as that of the present invention.

According to the provisions of the patent statutes, we have explained the principle of our invention and have illustrated and described what we now consider to represent its best embodiment. However, we desire to have it understood that the invention may be practiced otherwise than as specifically illustrated and described.

We claim:

1. In a furnace for the preparation of crystalline semiconductor material from a supercooled melt, a crucible for containing the melt, a member disposed over and covering the top of said crucible, said member having a central opening and arcuate openings spaced uniformly about said central opening, and a heating coil disposed about said crucible, said heating coil having its upper turns spaced farther apart than its lower turns.

2. In a furnace for the preparation of crystalline semiconductor material from a supercooled melt, a crucible for containing the melt, a member disposed over and covering the top of said crucible, said member having a central opening through which a seed is passed to contact the melt, arcuate openings in said member, said arcuate members being disposed uniformly about said central opening, said arcuate members serving to control the thermal gradients near the surface of the melt and a heating coil disposed about said crucible, said heating coil having its upper turns spaced farther apart than its lower turns.

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NORMAN YUDKOFF, *Primary Examiner.*