

all nuclei with higher proton numbers are also K -capturing or β^+ -active.

If now we have a stable nucleus (N, Z) for a certain odd value of the mass number, then $(N+1, Z-1)$ must be β^- -active and $(N-1, Z+1)$ either K -capturing or β^+ -active. From what has already been pointed out, it is clear that all nuclei on the higher neutron number side of (N, Z) will then be β^- -active and all nuclei on the higher proton number side of (N, Z) will be K -capturing or β^+ -active. Thus for a particular odd mass number we shall have only one stable nucleus, all other isobars being unstable.

Let us now consider what happens if the above argument is applied to the case of an even mass nucleus. For such nuclei we can distinguish between the even-even and odd-odd nuclei. Let (N, Z) be an even-even nucleus which is β^- -active. Then we have

$$B_N(N, Z) - B_{Z'}(N-1, Z+1) < M_N - M_H. \quad (8)$$

Now since,

$$B_{N'}(N+1, Z-1) = B_N(N, Z) - \delta + B_{NN} - B_{NZ},$$

$$B_Z(N, Z) = B_{Z'}(N-1, Z+1) + \delta - B_{ZZ} + B_{NZ},$$

we have

$$B_{N'}(N+1, Z-1) - B_Z(N, Z) = B_N(N, Z) - B_{Z'}(N-1, Z+1) - 2\delta + B_{NN} + B_{ZZ} - 2B_{NZ} < M_N - M_H, \quad (9)$$

because δ is positive and $(B_{NN} + B_{ZZ} - 2B_{NZ})$ is negative. Thus the odd-odd nucleus $(N+1, Z-1)$ must be β^- -active. But this same argument applied now to the even-even nucleus $(N+2, Z-2)$ leads to a different result. For $B_N(N+2, Z-2)$ and $B_{Z'}(N+1, Z-1)$ we write

$$B_N(N+2, Z-2) = B_{N'}(N+1, Z-1) + \delta + B_{NN} - B_{NZ},$$

$$B_{Z'}(N+1, Z-1) = B_Z(N, Z) - \delta - B_{ZZ} + B_{NZ}.$$

Thus we get

$$B_N(N+2, Z-2) - B_{Z'}(N+1, Z-1) = B_{N'}(N+1, Z-1) - B_Z(N, Z) + 2\delta + B_{NN} + B_{ZZ} - 2B_{NZ}. \quad (10)$$

Since δ is positive and $(B_{NN} + B_{ZZ} - 2B_{NZ})$ is negative, we cannot conclude from the above equation that the left-hand side will be less than $M_N - M_H$. It may or may not be, depending on the relative magnitudes of δ and $(B_{NN} + B_{ZZ} - 2B_{NZ})$. This shows that the even-even nucleus $(N+2, Z-2)$ may be stable in spite of the fact that the odd-odd nucleus $(N+1, Z-1)$ is β^- -active, and thus the existence of stable isobars for even mass nuclei becomes possible.

¹ H. A. Bethe and R. F. Bacher, *Revs. Modern Phys.* **8**, 83 (1936).

² K. Fuchs, *Proc. Cambridge Phil. Soc.* **35**, 242 (1939).

³ S. Jha and G. P. Dube, *Indian J. Phys.* **26**, 15 (1952).

Crystallization of Silicon from a Floating Liquid Zone

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CRYSTALLIZATION of silicon from a melt is of great interest as an initial step in the preparation of transistor devices. Since molten silicon is very active, there is no crucible material known of which one could be sure that no impurities are being introduced during the melting process. Fused silica, which is considered the best refractory material for melting silicon, is slightly reduced to silicon monoxide by the melt. The extent to which these reduction products affect the electrical properties of silicon is not known. This situation lends attractiveness to the method described below, which permits crystallization of silicon from the melt without having recourse to any crucible material.

The suspected high value of the surface tension of liquid silicon pointed to the possibility that a suitably large zone of molten silicon could be held stable between two vertically aligned, solid

rods, and this surmise was verified indeed by experiment. A piece of silicon which had the shape of a rod was held vertically and clamped at both ends. A heater element consisting of a short tantalum cylinder was mounted around the center portion of the rod. Heating this cylinder to incandescence caused a short section of the silicon to melt. The molten zone which developed and assumed the shape of a pear was held stable between the solid parts of the silicon rod by surface tension. The molten zone was then caused to travel slowly along the silicon rod by moving downwards or upwards the bracket to which the upper and lower clamps holding the silicon piece were attached. This constitutes a method of vertical zone melting with a floating liquid zone requiring no container for its support. The silicon rod shown in Fig. 1 was recrystallized by this method. Another possible appli-

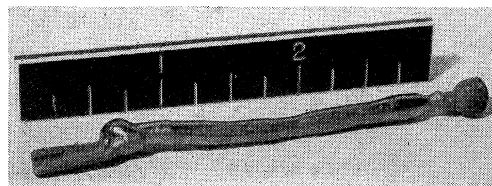


FIG. 1. Silicon recrystallized from a floating liquid zone. The comparison scale is in inches.

cation of this method is the growth of a single crystal from a polycrystalline mass. For this a seed crystal is placed against one end of the polycrystalline rod, and an initial floating zone of liquid silicon is formed at the joint. Then the seed crystal together with the silicon rod is slowly moved while the crystal grows from the melt and the floating liquid zone travels along the silicon piece. Thus the polycrystalline mass can be converted into a single crystal almost to its support.

The new method is not limited to silicon; it may find useful applications for a number of materials.

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Ferroelectricity in Oxides of Face-Centered Cubic Structure

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IN a recent letter¹ we reported on dielectric and x-ray observations on cubic cadmium niobate ($\text{Cd}_2\text{Nb}_2\text{O}_7$) and lead niobate ($\text{Pb}_2\text{Nb}_2\text{O}_7$) to which we ascribed the fluorite structure. B. C. Frazer of Brookhaven National Laboratory has pointed out to us that the structure of $\text{Cd}_2\text{Nb}_2\text{O}_7$ was studied by Byström² in 1944 who found it to be of the pyrochlore ($\text{NaCaNb}_2\text{O}_6\text{F}$) type. This structure type is face-centered cubic with dimensions double that of the fluorite structure. We have confirmed the presence of additional faint lines of a doubled cell for $\text{Cd}_2\text{Nb}_2\text{O}_7$.

The pyrochlore structure differs from the fluorite structure in the following ways:

There is a regular alternation of cations in the (fluorite) cation positions and a regular omission of one of the eight oxygens in a manner which leaves the larger cation surrounded by eight oxygens but reduces the coordination around the smaller cation to six. These six oxygens are equally displaced from the symmetrical fluorite positions towards the smaller cation.

We have now found a strictly cubic pattern of unit cell $10.561 \pm 0.001\text{A}$ for a lead niobate which is deficient in lead, approximating the composition $\text{Pb}_{1.5}\text{Nb}_2\text{O}_{6.5}$. The diffraction line in-

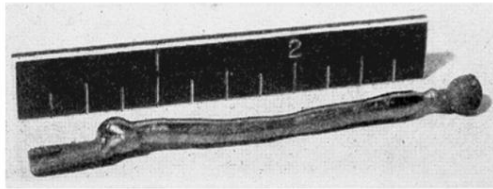


FIG. 1. Silicon recrystallized from a floating liquid zone. The comparison scale is in inches.