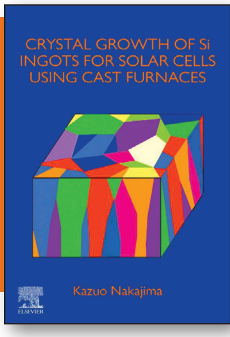


Crystal Growth of Si Ingots for Solar Cells Using Cast Furnaces

Kazuo Nakajima

Elsevier, 2020
390 pages, $133
ISBN: 9780128197486

Often, the goal of crystal growth research is to produce the highest structural perfection and lowest residual impurity concentrations possible. This is expensive, so a more practical approach, to keep the cost low, is to produce crystals that are not perfect but are good enough. This book describes the process innovations developed to grow such multicrystalline silicon ingots for fabricating economical solar cells. Although primarily for specialists interested in silicon solar-cell production, this book offers an original perspective that would be of universal interest to all researchers involved in crystal growth.

A long minority carrier lifetime is necessary for efficient crystalline solar cells. To achieve this, the silicon's dislocation density must be low, as the dislocations create recombination centers that reduce lifetimes. Dislocations arise to relieve stress in the silicon from the interactions of crystal grains as they form, temperature gradients, and the forces exerted by the crucible as the liquid silicon freezes and expands. Grain boundaries relieve stress. Consequently, judiciously introducing grains with different orientations (i.e., producing polycrystalline silicon) is beneficial, as it lowers the dislocation density, resulting in more uniform properties and lowers the material cost.

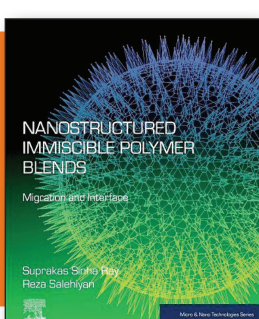
This book details the process strategies to control grain size, predominant crystal orientation, and dislocation densities in cast multicrystalline silicon ingots. It begins by describing silicon's important fundamental properties, including its solid–liquid phase behavior, types of defects commonly present (grain boundaries, twins, and dislocations), and the sources and effects of impurities. The electrical and optical properties important for solar cells are quantified.

The various casting processes and their respective advantages and disadvantages are described. In conventional casting, molten silicon is directionally solidified by imposing a temperature gradient on the melt. The resulting silicon ingot has nonuniform properties due to grain expansion as the silicon freezes. In contrast, in the dendritic cast method, an initial rapid crystallization at the bottom of the crucible produces a nucleation layer that results in greater crystal grain alignment throughout the ingot. In the high-performance cast method, small, randomly oriented crystal seeds are placed at the bottom of the crucible to initiate the growth. This results in an ingot with smaller grains, but with less stress and more uniform properties throughout. The mono-like cast method uses large silicon single crystals to initiate growth of the ingot, producing much larger and more oriented crystals. In the noncontact crucible (NOC) method, the ingot is removed from the melt before freezing occurs at the crucible walls in order to avoid the stress that this causes.

Nakajima ends the book by describing the future technologies being researched to improve the quality of cast silicon ingots. Reducing temperature gradients in the NOC method reduces dislocations and point defects, leading to higher solar-cell efficiencies. Techniques to grow square crystals instead of round ones will make it easier to completely cover an area with less loss of material.

This book provides excellent coverage of the science and technology that has gone into improving multicrystalline silicon for solar cells. The figures clearly illustrate important concepts. The references are up to date (through 2018) and extensive. Despite the many years of research that has gone into silicon solar cells, this book demonstrates that innovation is still possible to produce better quality materials.

***Reviewer: James H. Edgar**, Distinguished Professor, Kansas State University, USA.*



Nanostructured Immiscible Polymer Blends

Suprakas Sinha Ray and Reza Salehiyan

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This book covers the developments in fundamental aspects as well as applications in the area of immiscible polymer nanocomposites during the last five years. The large number of figures, images of materials, equations, and references are helpful for the reader to gain a comprehensive view of the topic. The authors depict the great potential of nanomaterials in constituting multifunctional immiscible polymer nanocomposites and the underlying mechanisms.

The introductory chapter discusses immiscible polymer blends and the factors governing their rheological behavior and compatibilization. Nanostructured materials are introduced, and developments in the area of polymer nanocomposites are briefly discussed along with the scope of the book.

Chapter 2 begins with the definition of nanomaterials based on different standards