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Vol. 16

AMORPHOUS SEMICONDUCTOR

TECHNOLOGIES & DEVICES

Editor Y. HAMAKAWA

OHM * North-Holland

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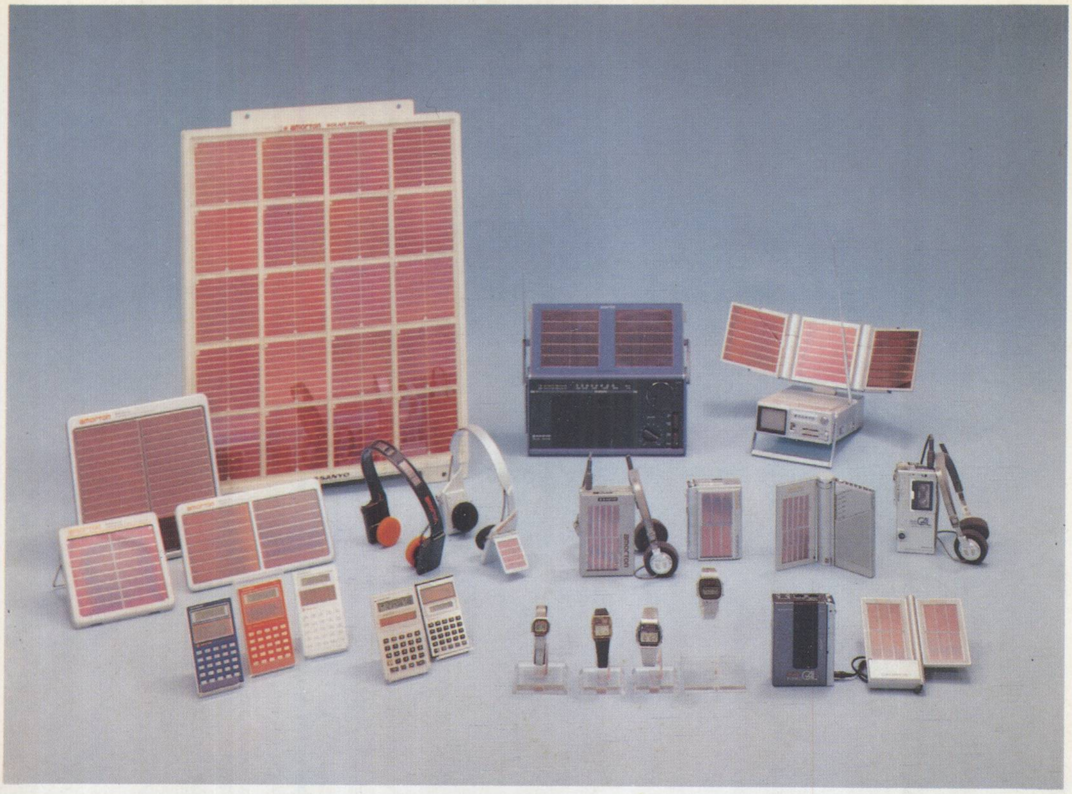
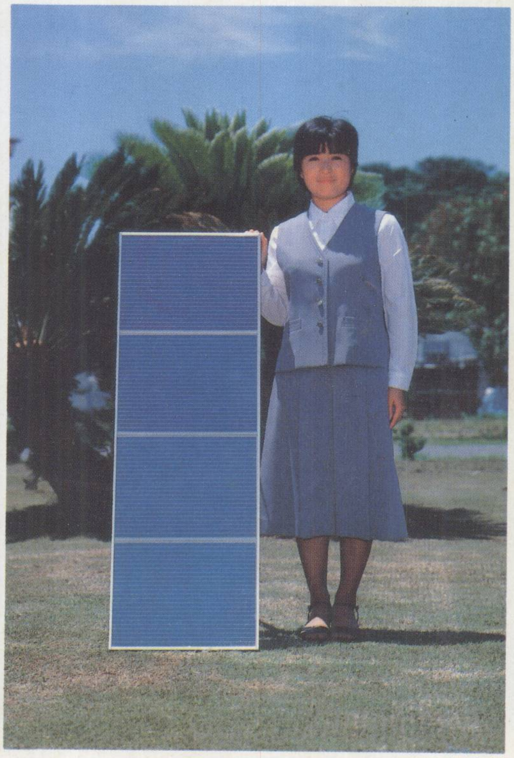
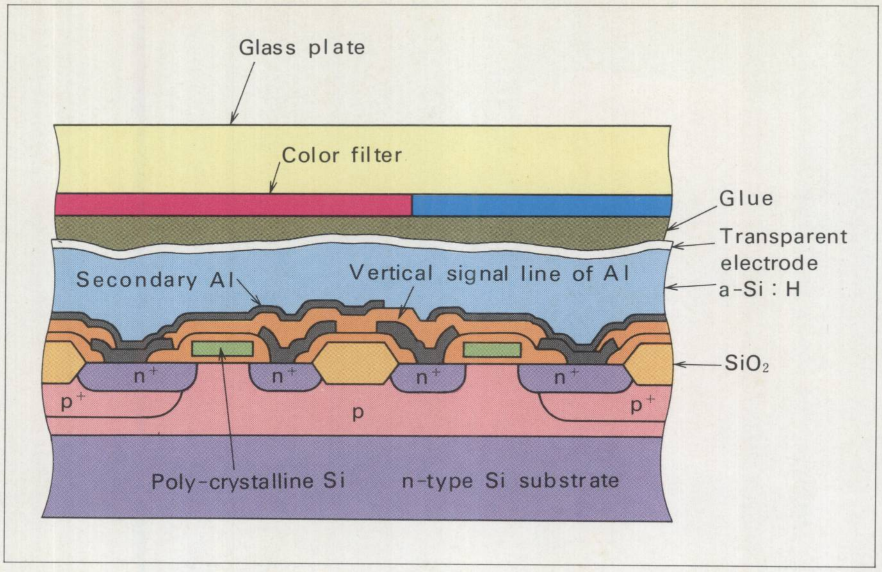


▲Still expanding consumer electronics applications of a-Si solar cells.
(presented by Sanyo Electric Co.)

▲Role to role mass production in line system of a-Si solar cells.
(presented by Sharp-ECD Solar Inc.)



▲NEDO size ($40 \times 120\ cm^2$) amorphous silicon solar cell module produced by continuous mass production line.
(presented by Fuji Electric Co., Ltd.)



(a)

(b)

▲Monolithic tri-color a-Si : H image sensor stacked on silicon MOS (a) and its reproduced picture (b).
(presented by Hitachi, Ltd.)

Preface

The recent discovery of an existence of valency controllability in hydrogen passivated amorphous silicon strongly promotes the evaluation of amorphous semiconductor as a new electronics material. This new amorphous material is able to form both p-n and p-i-n junctions and it has excellent photoconductivity with a considerably high absorption coefficient. The foregoing characteristics coupled with massproduceability of large area non-epitaxial growth on any substrate material match very timely with the strong current need for the development of a low cost solar cell as a new energy resource. With the aid of the national project for renewable energy development, substantial progress in the amorphous silicon field has been seen in recent years in both basic physics and technology. These integrated new knowledges here opened some other new application fields such as TFT, electrophotography, three-dimensional integrated devices, and quantum well devices, etc., and has triggered to start many related R & D efforts in the broad areas of optoelectronics and electronics.

Recently, there have been a number of books published on the subject of the physics of amorphous semiconductors. However, there are still very few books on amorphous devices and technologies. The purpose of publishing this volume is to sum up the present status of the Japanese activities in the device field and their technological accomplishments and to stimulate scientists and engineers toward the advancement of this newly born electronics area, even though the basic features of this material have not yet been well identified.

It is our editors earnest hope that this annual review will be helpful to all researchers and engineers in this area, and that the contents will lead to further accelerative advances in this rapidly expanding technological field. In selection of the contents of this volume, many people have assisted the editorial board and have offered their support to the domestic amorphous semiconductor scientists. First we would like to express our sincere appreciation to the Ministry of Education, Special Research Project Office on "Amorphous Material & Physics", and also the Sunshine Project Headquarters Office for releasing their supported research data to the authors. At the publishers, we want to acknowledge Mr. S. Sato, Director of the publish-

ing office, who encouraged us to undertake this series of editions and Mr. M. Mori, Mr. Y. Moriwaki and Mr. K. Watanabe who handled the prodution of this book.

(Yoshihiro Hamakawa)

Toyonaka, Osaka, Japan
Full Cherry Blossom Time, Spring, 1984

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JARECT Vol. 16, Amorphous Semiconductor Technologies & Devices (1984), Y. Hamakawa (ed.)
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CHAPTER 1

INTRODUCTION

Yoshihiro HAMAKAWA*

As the introduction of this volume, the recent significant progress in the field of amorphous silicon and its alloys are examined with demonstrating the strong potential needs for a low cost solar cell in the photovoltaic project. Characteristic features as new electronic material are analyzed, and prospect of remarkable growth and application fields are also discussed together with the topics compiled in this edition. In the final section, brief remarks are made on the efforts paid by the editorial board for the seletion of topics in this rapidly expanding field. The organization and structure of the contents in this volume are also introduced.

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1.1 Remarkable Progress of Amorphous Silicon Technology

This year marks 10th anniversary of the sunshine project which has been organized in 1974 for the new energy resources to supply considerable portion of Japanese total energy demands by the year of 2000. Among a wide variety of the renewable energy technologies in the sunshine project such as solar energy, geothermal energy, coal gasification and liquefaction, hydrogen energy etc., the solar photovoltaics is growing to become the most promised technology for future energy resource, which is clean in nature, pollution free and abundantly available anywhere in the world or even in space as everybody knows. A significant evidence of this remarkable progress in the photovoltaic technology is more than one order of magnitude reduction of the solar cell price accomplished during these ten years. In fact, it was more than 100 $ /Wp of the module cost in 1974, and now has come down to 6~8 $ /Wp as shown in Fig. 1.1. The main reason of this cost down is due to a

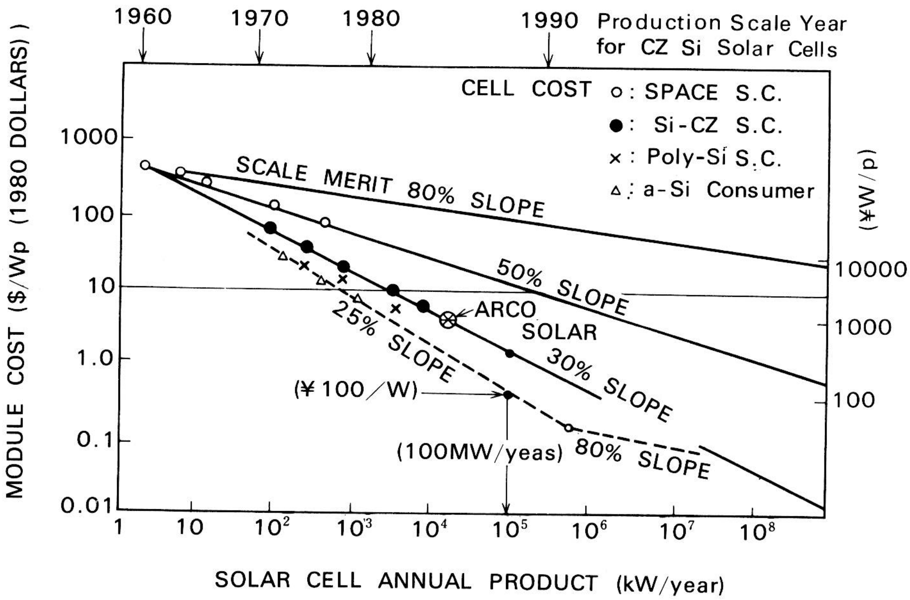


Fig. 1.1 Solar cell module cost vs mass-production scale, 30% slope lines of the scale merit match with Si-CZ solar cell and 25% for a-Si solar cell.

big scale merit of solar cell production with increasing about two order of magnitude of the annual productions in recent few years as shown in Fig. 1.2.[1]

As it has been pointed out elsewhere[2] that cost reduction of the solar cell module is prime importance to succeed in the photovoltaic project. Therefore tremendous amount of R & D efforts have been paid in the wide areas of technical fields from solar cell material, cell structure, mass production processes to photovoltaic systems. As the results, it could be expected that there are roughly two steps of technological innovations for further solar cell cost reductions as shown in Fig. 1.3. One is low cost substrate preparation technologies

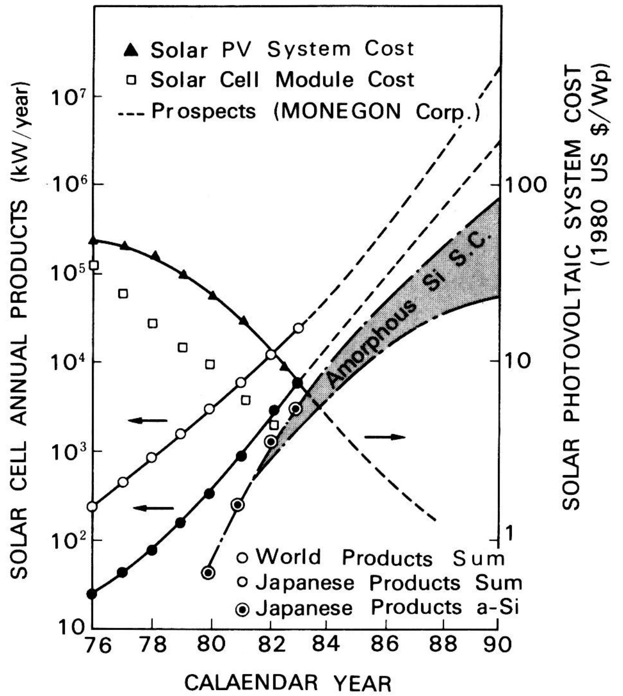


Fig. 1.2 Growth of world and domestic annual production of solar cell module and prospect of module cost.

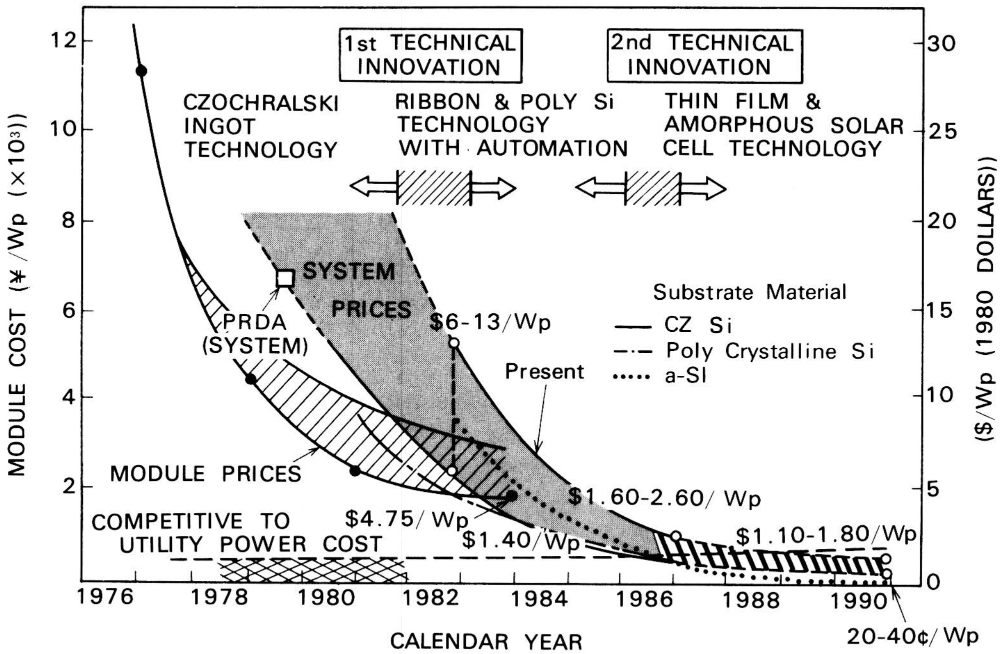


Fig. 1.3 Cost transitions of solar cell module and photovoltaic system with prospective technological innovations.

applicable to well developed single crystalline silicon solar cell fabrication process. In this category, low cost polycrystalline,[3] and ribbon crystal[4] solar cells are in progress.

Another innovation expected is an advanced cell fabrication technology involving not only the substrate growth but also the junction fabrication and other multi-layer processing such as antireflecting coating, electrode contact with interconnection by successive vapour phase depositions. Really, this advanced processing has been realized in the amorphous silicon solar cell fabrication as shown in Fig. 1.4. In the case of amorphous silicon solar cells, the active layer can be deposited on any inexpensive substrate with low temperature process less than 250~350°C. As has been pointed out in the early stage of the work,[5] junction formation can be easily made in the same reaction chamber by mixing of substitutional impurity gases into SiH_4 or SiF_4. Moreover, the interconnection of cells can be made simultaneously in the process of a-Si film deposition with a conventional integrated-circuit mask technology. Combining the advantages with this technology, automatization of a mass-production line could be easily accomplished and direct scale-up can be expected with a all-dry processes as shown in Fig. 1.4. Utilizing the concept of non-

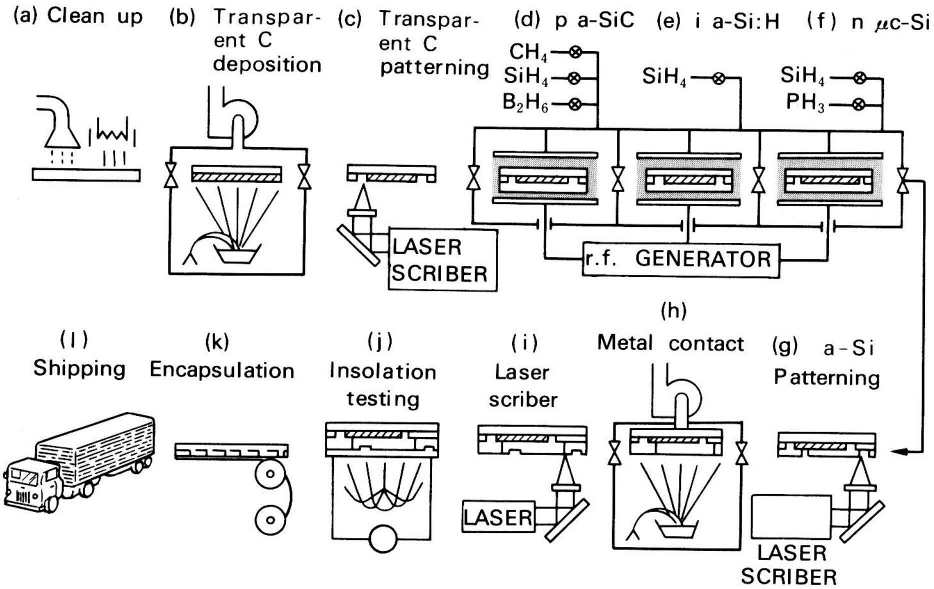
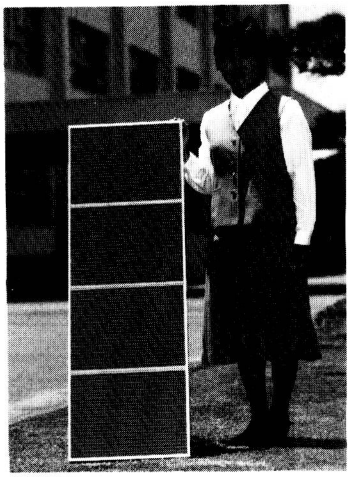


Fig. 1.4 A production sequence of a-Si solar cells having the advantages of; 1) good mass produceability, 2) large area film formation with nonepitaxy, 3) all dry process, and 4) large scale merit.

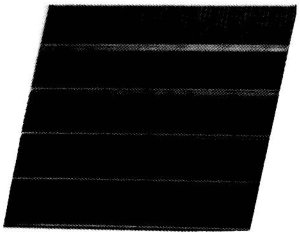
epitaxial deposition technology, it could be possible to reduce BOS (balance of system) costs in photovoltaic arrays by the hybridization of already-built units. Solar roofing tile and sticker from solar cell might be useful to realize this concept. Fig. 1.5 shows an example of various a-Si solar cells deposited on glass,[6] ceramics,[7] Kapton films[8] and stainless steel.[9]

An increase of cell efficiency is also directly connected to the cost down project. In the amorphous silicon solar cell project, tremendous efforts to improve the cell efficiency

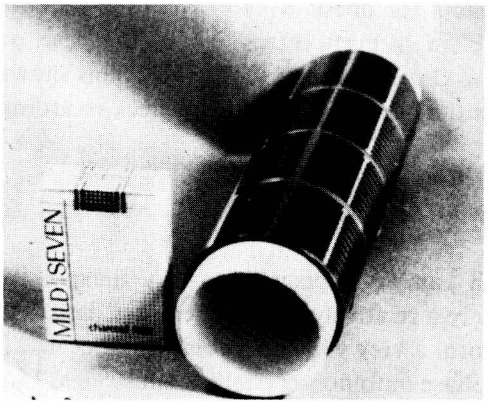
(a) a-Si solar cell roofing tile (presented by Sanyo Electric Co.)



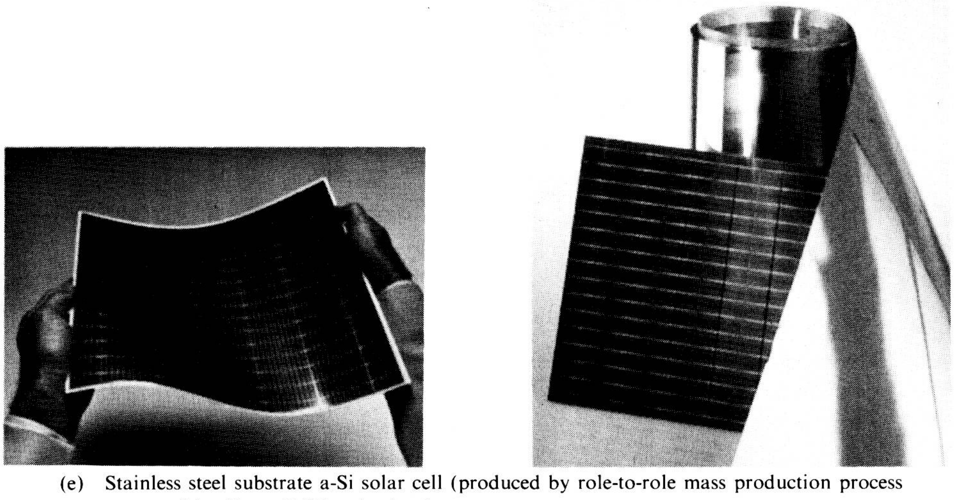
(b) NEDO size module (presented by Fuji Electric Co.)



(c) Ceramic substrate a-Si solar cell (presented by Kyocera Co.)



(d) Polymer film substrate a-Si solar cell (produced by Teijin Co.)



(e) Stainless steel substrate a-Si solar cell (produced by role-to-role mass production process presented by Sharp-ECD solar Inc.).

Fig. 1.5 a-Si solar cells deposited on various inexpensive materials.