# KONAGAI Makoto
# "Pioneering Research on Solar Cells"

*(KONAGAI Makoto)*

## 1. Biography

**Birthday:** 1949-09-19

**Education:** Bachelor of Engineering,
Department of Electronic Engineering
Tokyo Institute of Technology (1972)
Master of Engineering,
Department of Electronic Engineering
Tokyo Institute of Technology (1974)
Doctor of Engineering,
Department of Electronic Engineering
Tokyo Institute of Technology (1977)

**Employment:** Research Associate, Tokyo Institute of Technology (1977)
Associate Professor, Tokyo Institute of Technology (1981)
Professor, Tokyo Institute of Technology (1991-March 2015)

**Present:** Professor, Advanced Research Laboratories, Tokyo City University
(April, 2015- )

**Major area:** Solar cell materials, Solar cells, Photovoltaic system

**Award:** PVSEC Award (PVSEC-11, 1999),
JSAP Fellow (Japan Society of Applied Physics, 2008)
The Commendation for Science and Technology by the Minister of Education,Culture, Sports, Science and Technology, Prizes for Science and Technology (2009)
Medal with Purple Ribbon (2013)
Hamakawa Award (2014)

**Other activities** Research Director
MEXT/JST FUTURE (**FU**kushima **T**op-level **U**nited center for **R**enewable **E**nergy research) Program, "Si Nano-Wire Solar Cells" (2012-2016)

Chairperson
JSPS (Japan Society for the Promotion of Science),
University-Industry Research Cooperation, 175th Committee on Innovative Photovoltaic Power Generation Systems (2014- 2020)

Chairperson
International Advisory Committee, International Photovoltaic Science and Engineering Conference (2004- present)

Member, Science Council of Japan (2012-2015)

## 2. Summary

KONAGAI has greatly contributed to the pioneering basic research and practical application of solar cell research and the development of the photovoltaic (PV) community as a driving force in academic and industrial fields. Research on solar cells began in 1972, just around the time of the first oil crisis, when there were concerns about oil depletion and the development of alternative energy sources for oil began as a national policy. In 1980, the New Energy and Industrial Technology Development Organization (formerly NEDO) was established, and with this as an opportunity, a contract project from the Ministry of International Trade and Industry to a university research institute began in the field of solar cell research. From 1980 to 2014, he has been conducting research under contract research from NEDO. In the 1980s, the solar cell industry was driven by consumer solar cells, which are mainly amorphous solar cells, and silicon solar cells for independent power supply systems. In 1990, the relationship between global warming and carbon dioxide emissions was discussed, and the introduction of renewable energy was indispensable for solving global environmental problems, so expectations for solar power generation are even higher.

Since 1980, he has been promoting research and development on solar cells with emphasis on silicon thin-film solar cells, $Cu(GaIn)Se_2$ thin-film solar cells and silicon heterojunction solar cells. Since the Great East Japan Earthquake on March 11, 2011, there has been a demand for accelerated development of photovoltaic power generation technology as an alternative energy source to nuclear power. KONAGAI participated in the Fukushima reconstruction project of the Ministry of Education, Culture, Sports, Science and Technology, and served as the representative of the consortium project "FUTURE-PV" in Koriyama City, Fukushima Prefecture (2012-2016).

## 3. Research Summary

### 3.1 Basic research on thin-film solar cells in the early days

In order to significantly increase the energy conversion efficiency of solar cells, KONAGAI focused on GaAs, and in the 1970s he achieved an energy conversion efficiency of over 20%. However, since GaAs wafers are extremely expensive, he proposed a technology called the "Peeled Film Technology (PFT)" that would reduce the price of GaAs solar cells by orders of magnitude. This technology was a key to lowering the price of GaAs solar cells, but in the 1980s, the oil crisis was averted, and research on GaAs solar cells changed to space applications. However, in the 2000s, there were calls for reductions in carbon dioxide emissions in order to mitigate global warming, and expectations for environmentally friendly solar power generation have risen again. Against this background, some companies have reached the practical use of 30-40% of multi-junction ultra-high efficiency solar cells using GaAs by adopting the "Peeled Film Technology" to reduce costs.

### 3.2 Research and development of high-efficiency amorphous Si solar cells

From 1980 to 2000, while promoting national projects, he contributed greatly to the development of basic technology for improving the efficiency of current silicon thin-film solar cells. In 1984, he found for the first time in the world that the conversion efficiency of amorphous solar cells was limited at the p/i interface, and proposed inserting a graded buffer layer at the interface as a solution. The buffer layer technology in amorphous solar cells has already been widely put into practical use. On the other hand, since the device physics of amorphous solar cells is significantly different from that of conventional silicon solar cells, he has developed the world's first detailed simulation method that considers the localized states and tail states. Since then, the simulation method that follows this trend has been developed by research institutes around the world, and many groups are now releasing it as free software.

### 3.3 Research on high-efficiency optical confinement type thin-film solar cells

As for the development of peripheral technologies for silicon thin-film solar cells, the development of transparent conductive films for $SnO_2$ and ZnO is evaluated as a world-leading pioneering research. In particular, optimum texture morphology of the transparent conductive film is indispensable for optical confinement, and the relationship between the texture morphology and cell characteristics was reported for the first time in the world. In 1991, he developed a low-temperature deposition method for a ZnO transparent conductive film having a textured morphology by the MOCVD method and demonstrated it in an amorphous solar cell. ZnO is regarded as the favorite of transparent conductive films for thin-film solar cells.

### 3.4 Research on next-generation compound thin-film solar cells

In 1985, he started research on $Cu(InGa)Se_2$ (CIGS) for solar cell application for the first time in Japan. In the early stages of his development, he proposed and developed the Encapsulated Selenization method and the gas phase selenization method, but his greatest contribution was the development of a Zn-based buffer layer without Cd. In particular, after the publication of a paper on CIGS solar cells using ZnInSe and InSe as buffer layers, the development of Zn-based buffer layers became active worldwide. Although not necessarily the same technology, Solar Frontier manufactures CIGS solar power using a Zn-based buffer layer.

### 3.5 Research on innovative solar cells

Based on more than 40 years of experience in solar cell research and numerous achievements, he made two epoch-making proposals and conducted research using a large-scale industry-academia collaborative consortium. One of them is the concept of thin-film full-spectrum solar cells, and the second is nanowire solar cells. For the former, a new method called spectrum splitting has been devised

to achieve an energy conversion efficiency of 30% or more. On the other hand, regarding the latter, in 2012, the "Nanowire Solar Cell" proposed by him was adopted as the Fukushima Reconstruction Project of the Ministry of Education, Culture, Sports, Science and Technology aiming at the energy conversion efficiency 30%. In order to achieve the target efficiency, research activities were carried out under the cooperation system of industry, academia and government.

### 3.6 Researchmap, KAKEN, etc. database

**Researchmap**

https://researchmap.jp/read0008282

420 papers published, 523 international conferences, 17 publications such as books

689 oral presentations, etc.

**KAKEN**

https://nrid.nii.ac.jp/ja/nrid/1000040111653/

32 research projects

## 4. Remarks

KONAGAI has not only been actively engaged in research, but has also made a great contribution to education and management at universities. Under the guidance of KONAGAI, 52 people have obtained a doctoral degree, of which 21 are international students.

Off-campus, he was President of the Japan Society of Applied Physics (2012-2013). In 2004, he established the "The 175$^{th}$ Committee on Next Generation Photovoltaic Power Generation System" as the Japan Society for the Promotion of Science, Industry-Academia Collaboration Research Committee, and served as the chairman for 16 years. He contributed to the formation of the photovoltaic community in Japan. In addition, based on these activities, the Japan Photovoltaic Society was established in 2020.

## 6. REFERENCES

[1] M. Konagai, M. Sugimoto, K. Takahashi,
"High efficiency GaAs thin film solar cells by peeled film technology"
J. Crystal Growth, 45 (1978) pp. 277-280, Number of citations: 345

[2] W. W. Wenas, A. Yamada, K. Takahasahi, M. Yoshino and M. Konagai,
"Electrical and optical properties of boron-doped ZnO thin-films for solar cells grown by metalorganic chemical vapor deposition",
J.Appl.Phys., 70 (11) (1991) pp.7119-7123, Number of citations: 338

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