

Story of Atomic Layer Deposition by

DR. TUOMO SUNTOLA,

the Inventor of the ALD Method and a
Member of Picosun Board of Directors



"THEY JUST ASKED ME TO PROPOSE

SOMETHING"

Picosun Newsletter introduces the latest news of ALD manufacturer, Picosun. Newsletter comprises the comments of customers, character description of important people involved with Picosun's operation, new product releases and latest press releases.





Dr. Tuomo Suntola.

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"If there is one single secret behind the idea of Atomic Layer Deposition (originally Atomic Layer Epitaxy), it is not access to, but rather complete lack of adequate research equipment," says Dr Tuomo Suntola, inventor of the ALD method.

Back in 1973, Tuomo Suntola was hired by the Finnish medical instrument trading house Instrumentarium Oy (today a subsidiary of GE, General Electric). Instrumentarium had put up a subsidiary, Datex Oy, with the intention of becoming original design manufacturer of medical and hospital equipment instead of only importing such instruments.

Previously, Dr Suntola had developed Humicap, a revolutionary humidity sensor system for Vaisala Oy, global leader in atmospheric meteorological instruments. With significant product spinoffs, Humicap is still one of the most important product groups for Vaisala today. Suntola's work with Vaisala was key to him being asked to head Instrumentarium's research and development functions.

"Originally, Instrumentarium people just asked me to 'propose something'. One can safely say that my brief was adequately wide. I suggested to Instrumentarium that the use of flat screen displays might be worth aiming at as a business goal. They agreed," Suntola explains. "The question remained: how to achieve this."

"It took a couple of months before we had proper R&D equipment in place." This unfortunate delay turned into a very fortunate period of considerations. "We saw flat screen electroluminescent displays as a fascinating target — the key problem to be solved was the superb quality thin films needed in such a product. We spent hour after hour marinating ideas, tossing thoughts back and forth and putting our little grey cells to work filling the temporary void of hardware in the laboratory," Tuomo Suntola reminisces.

"I had a copy of the Periodic Table of the Elements hanging on the wall opposite to my desk. Whilst using it, focusing my thoughts by staring at it a lot during these first weeks, the basic idea of ALD just sort of emerged: should you wish to combine these elements they have qualities which actually automatically govern the growth mechanism exactly as you'd wish," Dr Suntola explains.

"Instead of forcing things, you allow the natural qualities of elements to do the work for you. It sounds simple enough today, but at the time this was unorthodox, to say the least," he says.

"In my case, the seeds for ALD can be traced back to my thesis in 1971, which I wrote on electronic phenomena in amorphous semiconductors. I noticed that the problem in obtaining well defined electrical properties in these materials was the unorganized structure characteristic to amorphous materials. If one wishes to achieve discreet electronic phenomena, the first thing one needs is well structured material. In order to achieve well structured material in thin film form, one needs to create growth conditions which allow material to reach its ordered form in situ," Suntola explains.

In hindsight, the path from that one single thought to the creation of ALD is rather straightforward.

Picosun Oy plans to publish a booklet, Story of the ALD, by the end of 2008. This is an excerpt of the manuscript under preparation.

Tuomo Suntola, (born 1943)

- Helsinki University of Technology, Electrical Engineering Department, M.Sc. (1967), Ph.D. (1971). Scientist at Finnish State Research Centre, VTT, (1968-1973). Development of Humicap humidity sensor for Vaisala Oy.
- Chief Scientist Instrumentarium Oy / Director of Display Division, Lohja Corporation (1974-1987): Development of Atomic Layer Epitaxy, ALE (Atomic Layer Deposition, ALD) for manufacturing of electroluminescent thin film displays.
- Managing director of Microchemistry Ltd, subsidiary of Neste/Fortum Corporation (1987-1997): Development of solar cell technologies. Extension of the use of Atomic Layer Deposition to the manufacturing of heterogeneous catalysts. Development of the ALD technology and equipment for semiconductor applications.
- R&D Fellow, Fortum Corporation (1997-2004), retired 2004.
- European SEMI AWARD 2004, for the development of the ALD technology to semiconductor applications, Semicon Europe 2004, Munich.
- Executive Advisor for Picosun (2004 – 2007). Since 2007 Member of the Board of Directors of Picosun Oy.

CUSTOMER INTERVIEW

Dr. Ronald Grundbacher works as a Senior Research Scientist in ETH Zürich, Center for Micro- and Nanoscience. He received his Ph.D. degree in Electrical Engineering from the University of Illinois in Urbana-Champaign in 1997. Dr. Grundbacher has been granted 7 patents, and has authored or coauthored over 60 technical journal and conference articles.

What kind of research background do you have?

PhD. research focused on GaAs- and InP-based HEMT (high electron mobility transistor) process and device development. Afterwards I worked 8 years in the aerospace industry in Los Angeles, California at TRW and Northrop Grumman Space Technology. There I worked on the research and development of HEMTs for millimeter wave applications for space satellite and ground-based applications.

What are the focus points of your current research at ETH Zürich?

I am interested in investigation of ALD materials for use in transparent thin film transistors (TTFTs). PhD. students in our group use the ALD deposited material to form insulating membranes used in building MEMS pressure sensors and as passivation layers in nano electromechanical systems (NEMS) and MEMS. Several other groups from the physics and chemistry department use the ALD in their quantum transport and catalyst research.

How did you get interested of Atomic Layer Deposition?

Several PhD. students in the group were using the ALD method in their research. They were collaborating with a group from the US. We were interested in procuring an ALD and I helped in the effort. It was at this time that I became more familiar with and interested in ALD.

What would you see as the key advantages of ALD compared to other thin film methods?

Conformal coating of non-planar surfaces, pin-hole free layers, control of deposition at monolayer / sub-nanometer scale and excellent uniformity.

What role does SUNALE™ R-series ALD system play in your research activities?

It plays a key role for the deposition of insulating and semiconducting oxides in several projects. Furthermore, it is essential for a project in which there is a need to deposit single or several monolayers of aluminum oxide or titanium oxide.

What do you regard being the most positive aspects of SUNALE™ R-series ALD tools?

Ease of use, both software and hardware. Reliable tool. Repeatable, uniform deposition characteristics.

What kind of impression have you gotten about Picosun and our products?

I have a positive impression of Picosun. The product is well engineered and constructed. When we have questions, whether related to the ALD tool itself or related to deposition of material, we receive expert support and advice from the Picosun team.

Have you been satisfied with Picosun equipment service?

Yes. Service has been well-supported and has been carried out by competent, knowledgeable Picosun engineering staff.



Dr. Ronald Grundbacher and SUNALE™ R-150 ALD process tool in ETH Zürich, Center for Micro- and Nanoscience.

Picosun's SUNALE™ ALD reactors to three leading American universities

BOSTON, USA – June 3, 2008 - At the 2008 NSTI Nanotechnology Conference and Trade Show held in Boston, Massachusetts, Finnish Atomic Layer Deposition (ALD) reactor manufacturer Picosun Oy today announced three new orders for its flagship SUNALE™ R-series Advanced ALD research reactors from three leading U.S. universities.

"Picosun personnel possesses over 200 years of combined ALD experience. Company CTO Sven Lindfors has been designing ALD reactors continuously since 1975, and the actual inventor of the ALD method, Dr. Tuomo Suntola serves as Member of the Board of Directors of Picosun. With its unrivalled experience Picosun has been one of the best kept secrets of nanotechnology in recent years, but customer interest is now raising it to the forefront of the ALD explosion," says Dr. **Charles L. Dezelah**, General Manager of Picosun's U.S. operations.

"I am extremely happy of the speed with which Picosun's North American business has taken off," Charles Dezelah says. "Picosun's U.S. office was opened less than a year ago. We have already installed ALD reactors at several customer locations in the U.S. Names of our three new customers will be published once their reactors have been installed and approved for use."

Picosun and Tohoku University announce their co-operation in Atomic Layer Deposition

HELSINKI, Finland and SENDAI, Japan – April 17, 2008 - Picosun Oy, Finland and Tohoku University, Japan announce their collaboration in the field of Atomic Layer Deposition (ALD).

"We are proud that Tohoku University has joined our ALD network by choosing Picosun as their ALD tool provider. Our co-operation will lead to new results in implementation of ALD in nanotechnology applications and further strengthen the market position of our SUNALE™ ALD process tools in Japan", stated **Juhana Kostamo**, Managing Director of Picosun Oy.

"Picosun possesses 30 years experience in ALD technology. Picosun's ALD tools are technologically-sophisticated and Japanese customers are now convinced that Picosun's ALD tools are the best in the market. More and more customers in need of high-quality ALD tools both in industry and academia are now choosing Picosun as their partners. We are proud of distributing Picosun's ALD tools in Japan", stated **Hiroshi Sato**, General Manager of Altech Co., Ltd.

"In semiconductor spintronics, gate controlled spin manipulation and its device application are one of the important technologies for realizing spin based functional devices. Al₂O₃ formed by SUNALE™ ALD R-75BE reactor system enables us to realize pin-hole free and thinner gate insulator on top of semiconductor two dimensional electron gas and shows excellent device characteristics", stated Prof. **Makoto Kohda** of Tohoku University.

Tohoku University was founded in 1903 as the third Imperial University in Japan, following Tokyo and Kyoto. Its Graduate School of Engineering dates its roots back to the early 1920s. Professor **Junsaku Nitta's** Quantum and Materials Science laboratory studies a new paradigm,



electronics based on the spin degrees of freedom of the electron requiring a way of controlling electron spins in semiconductor channels by using gate bias voltage.

Altech, since its foundation in 1976, has been operating successfully as a leading trading company for specialized industrial machineries. In the 30 years of operation, Altech has tried their best to provide globally acknowledged top-class machinery to top-class clients. Altech's current range of supply includes nano technology related equipments, covering the field of life science to semiconductor electronics.

Picosun hires additional key personnel

HELSINKI, Finland - March 5, 2008 - Picosun Oy, Finland, an international manufacturer of Atomic Layer Deposition (ALD) equipment announces hiring new key personnel.

Technician (dipl.) **Hannu Tervo** has been appointed as Senior Mechanical Engineer. He has more than 20 years of experience in CAD-based mechanics design work with leading Finnish and international companies, including experience with thin film process module design. Mr. Tervo joins Picosun's research and development team.

B.Sc. (engineering) **Olli Vuolanto** has been appointed as Facility Manager. He has extensive experience in designing and managing the building of advanced clean room microelectronics production facilities and production equipment. Mr. Vuolanto is responsible for creating an ALD reactor production and laboratory facility for Picosun.

M.Sc. (technology) **Otto Laitinen** has been appointed as Marketing Manager. Mr. Laitinen has several years of experience in ALD and other thin film deposition methods in international companies in Finland and abroad. Mr. Laitinen has joined Picosun in August 2006, initially as an ALD Technology Specialist. He is responsible for Picosun's marketing operations.

Executive Vice President and Chief Communications Officer **Pekka Reinikainen** of Picosun's parent Stephen Industries Inc Oy has taken over responsibilities as Chief Communications Officer of Picosun Oy. Mr. Reinikainen has extensive international communication experience, including having worked as Head of Public Information for the Organization for Security and Co-operation in Europe (OSCE) in Kosovo, and with the International Red Cross, where his latest appointment was in Geneva, Switzerland as project manager responsible for marketing communication activities supporting the organization's 400 million Swiss Franc annual appeal for international assistance.

Picosun and B.G. Technical Support announce their co-operation in distributing Atomic Layer Deposition equipment in Israel

HELSINKI, Finland and REHOVOT, Israel - January 9, 2008 - Picosun Oy, Finland and B.G. Technical Support Ltd. have entered into co-operation in the distribution of Picosun's ALD products in Israel.

"ALD reactor market in Israel is growing rapidly. We are positive that our co-operation with B.G. Technical Support Ltd. will yield new orders and secure the best possible service for our customers in Israel.", stated **Juhana Kostamo**, Managing Director of Picosun Oy.



"We feel that Picosun's ALD products have a unique technology and are the best in the market. Customers in Israel who wish to have high-quality ALD layers shall choose Picosun and BG-Tech as their partners" stated Hezi Grossman, CEO of B.G. Technical Support Ltd.

Novel batch ALD reactor design wins new orders for Picosun

HELSINKI, Finland – December 12, 2007 - Finnish Atomic Layer Deposition (ALD) equipment manufacturer Picosun Oy report on their novel SUNALE™ PicoBatch ALD tool. First SUNALE™ PicoBatch ALD system has been accepted for production at a customer site. The tool is used for coating a batch of 25 wafers simultaneously.

"We are very pleased to introduce to the market our novel small-footprint SUNALE™ PicoBatch ALD reactor. I am positive that this tool will win several additional orders for Picosun Oy in the near future", states the inventor **Sven Lindfors**, CTO and Founder of Picosun Oy. "The reasonable price level of this unique production tool will surprise our customers positively". The test results reported by our customer are very satisfying as well as the production capacity increase.

Picosun provides sophisticated tools for ALD, allowing studies on Single-wafer, Minibatch, or Maxibatch processes within the same tool. The SUNALE™ PicoBatch ALD tool can be used for pilot production studies and extended to stand alone production for Atomic Layer Deposition. Loading of the batch can be done manually or automatically with preloaded holders and a Robotic handler.

SUNALE™ P-series ALD reactors are optimized for ALD especially for micro- and nanotechnology production purposes. The SUNALE™ PicoBatch ALD reactor is also well suited for decorative and protective coating of 3-dimensional devices.

SUNALE™ P-series ALD reactors can be equipped with ventilated Picosolution™ liquid source cabinet, ventilated Picogases™ gas cabinet and proprietary new type Picosolid™ and Picohot™ sources for low vapor pressure precursors.

SUNALE™ PicoBatch ALD tool has a footprint of less than 1 square meter, and is able to coat 25 – 50 pieces of 4-inch wafers in a single run. The SUNALE™ PicoBatch ALD tool can be upgraded to take a batch of up to 8-inch wafers. Repeatability of Al₂O₃ process of 0.3% 1sigma and uniformity of 0.6% 1sigma have been demonstrated at the customer site. Added particle count of 4 pieces larger than 0.2 micrometers per a single 50 nm film deposition run, including loading and unloading has been achieved. Extremely fast cycle times enabled by efficient purging of the reaction chamber, easy and fast maintenance, low precursor, gas and power consumption combined with a very high uptime through reliable industrial software and electronics lower the cost-of-ownership of the SUNALE™ PicoBatch ALD tool far below the usually accepted level.





SEMI organisation President and CEO Stanley T. Myers presents the European SEMI 2004 award to Dr. Tuomo Suntola at Semicon Europa 2004 exhibition in Munich.

PICOSUN – THE ALD POWERHOUSE

Picosun is an international equipment manufacturer with a world-wide sales and service organization. We develop and manufacture Atomic Layer Deposition (ALD) reactors for micro- and nanotechnology applications. Picosun provides its customers with user-friendly, reliable and productive ALD process tools, which offer unique scalability from research to production. Picosun is based in Espoo, Finland and has its US headquarters in Detroit. SUNALE™ ALD process tools are used by leading scientific institutions and companies across Europe, America and Asia.

Picosun has expertise that has been attained from over three decades of ALD reactor manufacturing in Finland. Dr. Tuomo Suntola, the inventor of the ALD method in 1974, is a Member of the Picosun Board of Directors. Our CTO Sven Lindfors has continuously designed ALD systems since 1975. Combined, Picosun characters share over 200 years of ALD experience and have contributed to more than 100 patents on ALD. Our long history and comprehensive background establishes Picosun as the optimal partner for your ALD technology needs.



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