

Story of Atomic Layer Deposition by

# SVEN LINDFORS,

Chief Technology Officer and a Member  
of the Board of Directors of Picosun



"SUDDENLY, THERE WAS  
A GLOWING GOLDEN GROWTH  
COVERING THE GLASS TUBE."

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.





Mr. Sven Lindfors

**"I borrowed a bottle of hydrogen sulfide and, suddenly, there was a glowing golden growth covering the glass tube. We'd cracked it: this was the theory of advanced Atomic Layer Epitaxy taking physical form in front of my eyes."**

**Story of Atomic Layer Deposition by Sven Lindfors, Chief Technology Officer and a Member of the Board of Directors of Picosun.**

"We had numerous unsuccessful test runs behind us. **Dr Tuomo Suntola** knew that in order to proceed, we needed to advance from using pure chemical elements to an exchange reaction based on carrier gases and sulphides," says Sven Lindfors, at the time working as a key technician for Dr Suntola's team.

"Previously we had decided to try with hydrogen sulphide. At first, we tried to produce hydrogen sulphide in situ by heating up sulphur in a container with hydrogen. It was not very successful. It sort of came to my mind that you might be able to get your hands on some hydrogen sulphide by borrowing it from someone. The enterprising young man that I was at the time, I wasted no time putting the idea into practice."

**Sven Lindfors** went to KCL Keskuslaboratorio, a research company owned by the Finnish pulp, paper and board industries. "Wood processing deals with hydrogen sulphide," Sven explains.

KCL's Chief of Laboratory, **Mr Kaarlo A. Rainio** had a small container of the precious stuff. Sven signed a "secret and unofficial" agreement stating that he will return the bottle when asked to, but will not use up all contents. The two gentlemen signed the playful agreement as a "memento of this flexible and unofficial behaviour, the contents of which shall not be revealed to the employers of either party, except under extreme duress." The date of the agreement was August 24. 1978.

It was September 1. 1978. Sven Lindfors had attached the container to the reactor. At 13:30 p.m. he started with a single pulse of zinc chloride and a single pulse of hydrogen sulphide repeating the cycles for 20 minutes. "Suddenly there was a glowing golden growth covering the glass tube. We'd cracked it! Dr Suntola's great vision of the advanced Atomic Layer Epitaxy was taking physical form in front of my eyes," Sven Lindfors explains.

It took him a millisecond only to run to Tuomo Suntola's corner office and another millisecond for the two to run back to the small laboratory containing the reactor. A rather loud moment of jubilation followed.

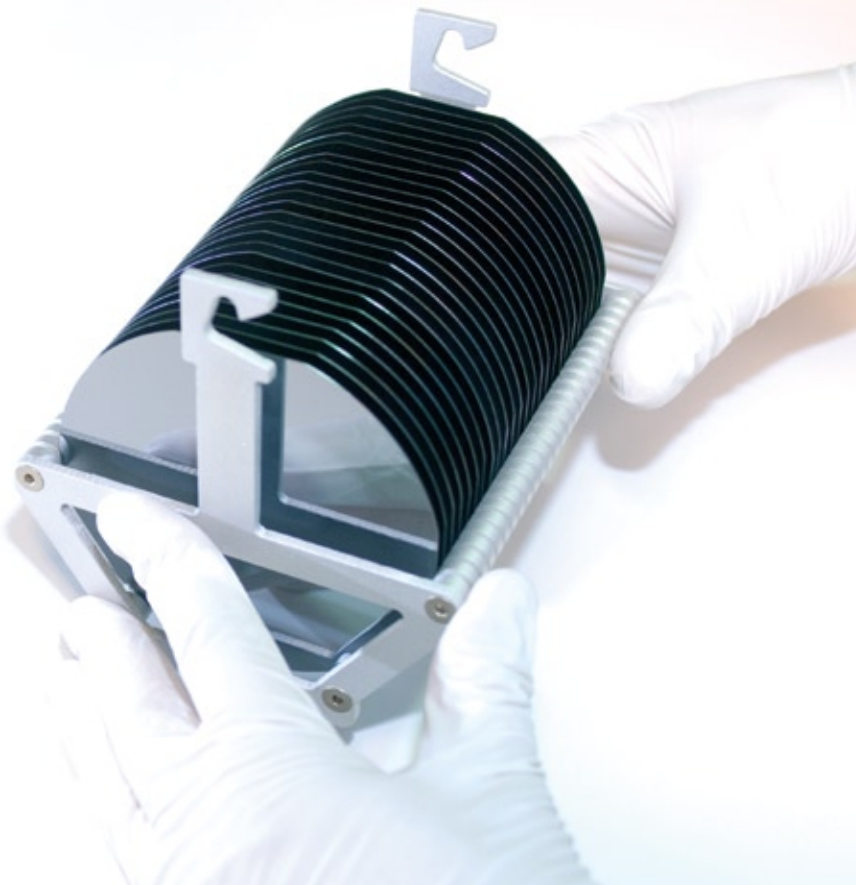
"The basic idea of using a carrier gas to enable the exchange reaction is still the firm basis of the Atomic Layer Deposition technology of today," Sven Lindfors explains. That September afternoon in 1978 Sven and Tuomo Suntola were both working for Lohja Oy Electronics developing electroluminescent display technology based on thin films.

Today, some 30 years later, Sven Lindfors is the most experienced ALD reactor designer in the world. He is Chief Technology Officer of Picosun Oy, Finnish based ALD powerhouse. "Sven seems to know intuitively what works and what does not work in ALD reactor technology. I do not know another person with the same rare qualities," Tuomo Suntola, the inventor of the ALD technology says about his long-time friend.

Today, Sven has yet another breakthrough coming. This time his new ALD design will challenge the slow and difficult Chemical Vapour Deposition (CVD) production technology with a revolutionizing ALD batch-based reactor. "It is going to be extremely fast, cost efficient and easy to handle. Something completely different from the way thin film production technology has been done today," He says.

## Sven Lindfors, (born 1945)

- From 1961 to 1971, various technical development work at among others G.W.Berg Oy in Finland and Kistner Labtjänst Ab in Sweden.
- From 1971 to 1976, development and design of an automated chemical analyzer at Instrumentarium Oy / Datex Oy.
- Since 1976 technical design and testing of Atomic Layer Epitaxy reactor prototypes in Dr. Tuomo Suntola's group.
- From 1977 to 1987 at Lohja Oy Electronics as manager of processing equipment development. Designing and managing the R&D laboratory at Olarinluoma EL-production plant.
- From 1987 to 1997, at Microchemistry Oy as project manager on building new R&D laboratory facilities and designing MC-120 ALE reactor for thin film and powder coating applications (MC-120 renamed to F-120 by ASMM).
- From 1998 to 2004, at ASM Microchemistry as Senior Design Engineer.
- Since 2004 at Picosun Oy as Chief Technology Officer and a Member of the Board of Directors.



## CUSTOMER INTERVIEW

**Dr. Tech. Hannu Kattelus works as Research professor and Technology manager for VTT Technical Research Center of Finland. He received his Ph.D. degree in Electrical Engineering from Helsinki University of Technology in 1988. Dr. Kattelus has been granted 5 patents, and has authored or co-authored over 100 technical journal and conference articles.**

### ***What kind of research background do you have?***

I have mostly been working on various aspects of thin film technology and devices, including thin-film capacitors, surface acoustic wave devices, heat-reflecting window coatings and transparent conductors, diffusion barriers, III-V compound semiconductors, electroluminescent displays, active and passive integrated circuits, and MEMS.

### ***What are the focus points of your current research at VTT Technical Research Centre of Finland?***

We are developing microelectromechanical systems, most typically sensors and adaptive RF devices. Also, integrated optical and microfluidic systems are investigated. In MEMS we are focusing on surface micromachining technology.

### ***What goals would you like to achieve as a research group team leader?***

I want our group to develop sustainable technologies for the well-being of the society. I want our group members to be motivated with their work and enjoy what they are doing.

### ***How did you get interested of Atomic Layer Deposition?***

This is a long story. I heard about Atomic Layer Epitaxy (as it was called then) in the late 1970's, and got interested immediately. During my career I have used ALD in many phases: to develop III-V epitaxy, multicolor EL displays and nanolaminate capacitors in the eighties and early nineties. I have also had long intermediate breaks when I have not been using ALD in my projects.

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

The often recognized benefit, i.e. possibility to deposit high quality conformal layers even at low temperature, is something I find very appealing.

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

In mid-nineties I was complaining to **Sven Lindfors**, now an employer of Picosun, that there are no convenient R&D ALD tools in the equipment market, only large batch reactors for displays or expensive 200 - 300 mm wafer clusters. Sven mysteriously replied: "just wait...". SUNALE™ ALD systems finally responded to this market demand. It is a tool capable of handling medium-sized MEMS wafers. ALD offers us new materials for making MEMS: aluminium and titanium oxide. It is possible to accomplish a lot already with these two materials.

### ***How actively is the SUNALE™ R-series ALD unit used at VTT premises?***

It is used on a daily basis. We have made well above 1000 depositions with our tool.

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

It fits to our cleanroom process line extremely well. It is used in a safe



*Dr. Hannu Kattelus, VTT Technical Research Center of Finland.*

way so that the operator doesn't need to get in close contact with the hot interiors of the reactor. Ease of use is on high level. Anybody with short experience can run the tool.

**What kind of impression have you gotten about our products?**

I have been fully satisfied with the tool.

**Have you been satisfied with Picosun equipment service?**

Yes I have. And our location in close connection to Picosun facilities has been a perfect match.

**How do Picosun ALD products differ from other ALD equipment on the market?**

I believe that it is an advantage that Picosun people have such a long experience of the technology. ALD is not just a modification of CVD but an unique approach. Newcomers will meet difficulties in understanding this.

**To whom would you recommend SUNALE™ ALD systems?**

We have been satisfied in using it in a wafer-fab environment to produce low particulate films of well-established ALD materials such as aluminium oxide or titanium oxide. I would truly recommend SUNALE™ ALD systems to people who are doing this kind of demanding wafer processing.

## Picosun issues stock incentive plan

**HELSINKI, Finland – November 20, 2008** – Leading Atomic Layer Deposition systems manufacturer Picosun Oy, Finland issued 200,000 new equity stocks as it made public a stock award plan for its employees and members of the Board of Directors. The total stock award plan represents eight percent of the present total equity of Picosun Oy.

"A fifth of the new stock was reserved for future key members of the staff, and the rest was subscribed to by current employees and members of the Board of Directors," says **Mr. Kustaa Poutiainen**, President and Chief Executive Officer of Picosun.

"So far, effects of the global economic crisis have not been felt at Picosun. We currently have a full dozen ALD reactors on our assembly line, and interest from both production and research clients world-wide has, if anything, increased," Poutiainen explains.

According to Mr. Poutiainen, the current stock award plan follows an internal corporate timeline which, in five years time, leads to an Initial Public Offering (IPO). "Next on the agenda is a venture capital investment aimed at fuelling our strong growth," he says.

## Today, Picosun's Kai-Erik Elers defends his PhD thesis on ALD

**HELSINKI, Finland – November 18, 2008** – Today at noon Finnish time, **Kai-Erik Elers**, Technical Applications Manager of the leading Atomic Layer Deposition (ALD) systems manufacturer Picosun Oy presents and defends his PhD thesis "Copper Diffusion Barrier Deposition on Integrated Circuit Devices by Atomic Layer Deposition Technique" at the Department of Chemistry of the Faculty of Science of the University of Helsinki.

Elers' dissertation studies the feasibility of new diffusion barrier processes for copper metallization and decreasing feature size of integrated circuit devices.



*Mr. Kustaa Poutiainen,  
President and CEO of Picosun*

Copper metallization comprises an entirely new process flow with new materials such as low-k insulators and etch stoppers, which are making the diffusion barrier integration demanding. Atomic Layer Deposition technique is one of the most promising techniques to deposit copper diffusion barrier for future devices.

"Motivation for my dissertation was based on possible business opportunities in the metallization market. When I started working on my thesis, it was expected that diffusion barrier processes used by the IC industry at the time were becoming inadequate. In 2006, Intel introduced the use of the ALD method for high volume manufacturing of transistors with high-k material. Evidently, the ALD technique had established its position in the IC production making it easier for new ALD processes to establish themselves." Kai-Erik Elers says.

"My goal was to study one specific area of ALD for possible integration into industrial manufacturing processes. ALD represents a feasible diffusion barrier process as an alternative to the existing choice of industry (Physical Vapour Deposition). However, aspect ratio requirements have remained moderate in copper metallization making it possible to extent the use of current technology. It will be interesting to see in which application ALD barriers for the copper metallization will be used first," Elers says.

Kai-Erik Elers' dissertation can be downloaded from <http://ethesis.helsinki.fi>.

## Nordtest to distribute Picosun's SUNALE™ Atomic Layer Deposition (ALD) systems in Italy

**HELSINKI , Finland and SERRAVALLE SCRIVIA, Italy – October 17, 2008** – Leading global Atomic Layer Deposition systems manufacturer Picosun Oy, Finland and Nordtest srl, a leading Italian high-tech equipment distribution company have entered into co-operation in distributing Picosun's SUNALE™ Atomic Layer Deposition (ALD) systems and equipment in Italy.

"Italy is one of key markets in Europe when it comes to highly specialized industries with clear potential in adapting their production for use of ALD techniques. It is an immense pleasure for me to welcome Nordtest srl as the latest member of the global network of Picosun Partners," says **Juhana Kostamo**, Managing Director of Picosun Oy.

"We at Nordtest strongly believe that the main trends in technology and industry in the coming years will be best served through material modifications and improvement as a central milestone in these processes. Atomic Layer Deposition has specific features and advantages which make it preferable to other, more established processes," says **Dr Maurizio Bruni**, Managing Director of Nordtest.

"In western industrialized countries large amount of research, technical development, small scale and high added value production is taking place and more will grow in the coming years. We are specifically looking to this type of customers as our most promising marketplace for Picosun products in Italy," Dr Bruni adds.

Nordtest has its offices and laboratories at the small town of Serravalle Scrivia, strategically located along the A7 motorway connecting Genoa and Milano, serving the industrial heartland of Northern Italy. Nordtest has attended the needs of scientific institutions and high tech industries in Italy since 1989.

Dr. Kai-Erik Elers



## Picosun and Euris together at Semicon Europe 2008

**HELSINKI, Finland and GRENOBLE, France – October 7, 2008** – Finnish based Atomic Layer Deposition (ALD) reactor manufacturer Picosun Oy, and Euris Sarl, a French based semiconductor equipment distributor will both be present at the 2008 Semicon Europe trade fair, taking place from 7 to 9 October at the Stuttgart Trade Fair Centre in Stuttgart, Germany. Euris recently joined the network of Picosun Partners marketing Picosun's SUNALE™ range of ALD reactors in France, Germany, Ireland and the United Kingdom.

"We have finalized training Euris' sales force and they have expressed their complete confidence in being able, with Picosun products, to successfully introduce world's leading ALD equipment in these key markets," says **Kai-Erik Elers**, Technical Applications Manager of Picosun.

"I am very much looking forward to fruitful discussions with present and future clients in Stuttgart," Kai-Erik Elers says. He will personally be present at Euris' stand (stand # 452) supporting the sales staff of Euris.

Euris is a leading European semiconductor equipment distribution company with sales and services support offices located in Germany, France, UK and Italy. In Germany, Euris GmbH has offices in Tübingen and Dresden.

## Picosun and Honoprof enter into co-operation in distributing Atomic Layer Deposition (ALD) systems in China

**HELSINKI, Finland and BEIJING, China – August 28, 2008** – Leading Atomic Layer Deposition systems manufacturer Picosun Oy, Finland and Beijing Honoprof Sci. & Tech Ltd, a leading Chinese high-tech equipment distribution company announced entering into co-operation in distributing Atomic Layer Deposition (ALD) systems and equipment in China.

"China is one of the fastest growing markets for Atomic Layer Deposition systems and equipment, specifically for Picosun's highly successful line of SUNALE™ ALD process tools. We welcome Honoprof Sci. & Tech as a key member of the global network of Picosun Partners," says Picosun's Managing Director **Juhana Kostamo**.

"Honoprof is a perfect match in our policy of first class service for first tier customers, world-wide. Through the successful hosting of the Olympic Games China has drawn the attention of the whole planet to herself by showing that the country is raising fast to become one of the leading nations of the world, also in terms of high technology," Kostamo says.

"Nanotechnology is very hot in China. The Chinese government has invested gigantic amounts of funds and resources in universities, research institutions and related applications. Next phase will be to commercialize nanotechnology," says **Stephen Liu**, Managing Director of Honoprof.

"Picosun is not only a leading supplier of ALD systems, but also has a powerful ALD team and possesses the richest ALD knowledge in the world. We are happy to work with Picosun and introduce the best in ALD to Chinese researchers and engineers," Stephen Liu says.

Honoprof Sci. & Tech is a leading supplier of instruments and systems for R&D in the field of surface chemistry and film deposition in the Chinese market. In addition to the main office in Beijing, Honoprof has offices in Shanghai, Guangzhou, Wuhan and Chengdu.



## Picosun and EURIS announce their co-operation in distributing Atomic Layer Deposition (ALD) systems in Europe

**HELSINKI, Finland and GRENOBLE, France – August 27, 2008**

– Leading Atomic Layer Deposition systems manufacturer Picosun Oy, Finland and EURIS Sarl, a leading European semiconductor equipment distribution company have entered into co-operation in distributing Atomic Layer Deposition (ALD) systems and equipment in Germany, France, UK and Ireland.

“Europe is one of three key markets for Picosun’s highly successful line of SUNALE™ ALD process tools. We already have a number of first tier customers in various countries in Europe, but co-operation with EURIS will multiply our presence in Germany, France, UK and Ireland,” says Picosun’s Managing Director **Juhana Kostamo**.

“Our policy of working together with the best in every field of our activities is strengthened through EURIS’ becoming part of the global network of Picosun Partners,” Kostamo says.

“Nanotechnology is going to transform every area of technology and science. Germany, France, UK and Ireland are at the forefront of micro-, and nanotechnology, both in research and industrial applications,” states **Guy Salabert**, President of EURIS.

“EURIS is very pleased to distribute the systems and equipment of Picosun, a clear leader in ALD technology. We trust the high quality manufacturing standards of the equipment, and praise superior ALD process knowledge behind Picosun’s success. We forecast a strong mutual success for this co-operation,” Guy Salabert says.

EURIS is a leading European semiconductor equipment distribution company with sales and services support in Germany, France, UK and Ireland.

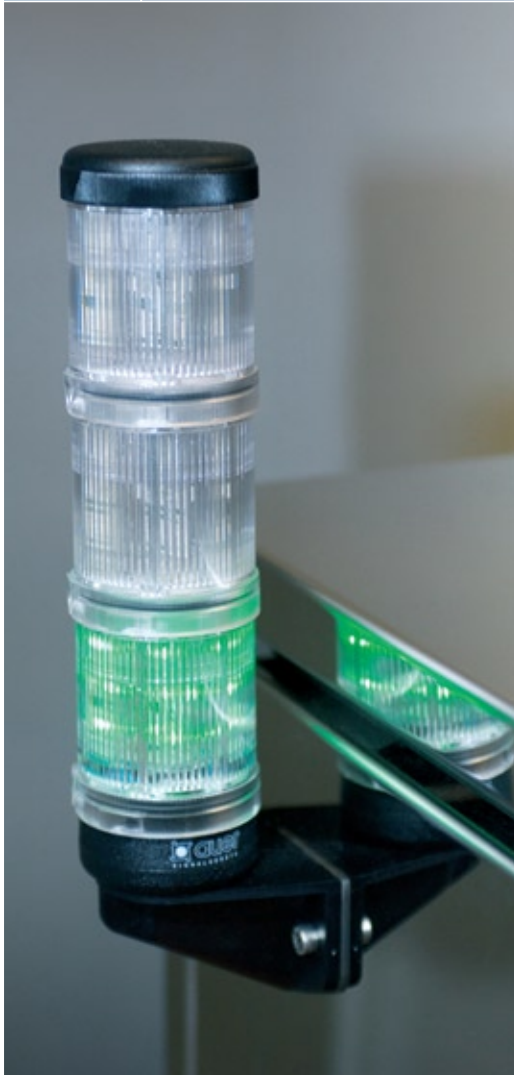
## Picosun registers record sales for its SUNALE™ ALD reactor systems

**Otaniemi Campus, ESPOO, Finland – August 13, 2008** – Following roaring success at AVS ALD 2008, the 8 th International Conference on Atomic Layer Deposition held in Bruges, Belgium in early July, Picosun Oy, the Finnish Atomic Layer Deposition (ALD) reactor manufacturer reports record sales for its SUNALE™ ALD reactor systems. “In the course of one single week in July we closed four new deals for our ALD systems, a record week sales achievement for the company so far,” says **Juhana Kostamo**, Managing Director of Picosun.

“All the sales were for new clients,” Kostamo says. Picosun’s record sales include three crown jewel corporate customers from Asia and Europe, and one leading university from Asia.

“I have often said that our strategy of building a firm foundation on first class products and first tier customers telling others of the quality of the Picosun Package is going to be a formula for unprecedented success. I am happy to say that we are now seeing this prediction take physical form,” Mr. Kostamo says.

“At this point we are unfortunately unable to reveal the names of our new clients. When their SUNALE™ reactor systems have been installed and approved for use, we can revisit this topic,” Juhana Kostamo promises.





## Picosun package gather big interest at ALD 2008 Conference in Bruges, Belgium

**Otaniemi Campus, ESPOO, Finland – July 4, 2008** – AVS ALD 2008, the 8th International Conference on Atomic Layer Deposition held in Bruges, Belgium, became a convincing step forward for Picosun Oy, the Finnish Atomic Layer Deposition (ALD) reactor manufacturer. “We registered an impressive increase in people’s interest in the Picosun Package, the combination of hardware, software, training, consulting and service solutions offered by the company,” says **Juhana Kostamo**, Managing Director of Picosun.

“As a direct result of our performance during the Conference, we received some three dozen extremely serious enquiries from the scientific community, research institutions and various business enterprises,” Juhana Kostamo says.

“I have often said that our strategy of building a firm foundation on first class products and first tier customers telling others of the quality of our package is going to be a formula for unprecedented success. I am happy to say that we are now seeing clear signs of this,” Mr. Kostamo says.

During the ALD conference, Picosun Oy re-introduced the inventor of the ALD method, Doctor **Tuomo Suntola**, to a whole new generation of ALD -enthusiasts. Picosun also successfully introduced world’s most experienced designer of ALD systems, **Mr. Sven Lindfors**, to the wide global ALD community. Today, Suntola is Member of the Board of Directors and Lindfors is Chief Technology Officer of Picosun.

“People at the conference were actually asking autographs from Dr Suntola and Sven Lindfors. And, indeed, they are the stars of the ALD world, dating their unique co-operation back to the earliest days of the method,” says Juhana Kostamo.

Daniel Lewis Ray, from the University of Colorado at Boulder, recently praised Dr. Suntola as the inventor of the ALD method back in 1974 in his spotlight article at [www.nanowerk.com](http://www.nanowerk.com), and went on to say: “Despite being invented more than three decades ago, the technique of atomic layer deposition is continuing to advance and it promises to hold the key to perhaps hundreds of future advancements. From the creation of new or more effective chemicals to the development of mechanically driven computers, everything suggests that ALD’s role in nanotechnology and nanoscience will only continue to grow.”

PRESS  
RELEASES



*Juhana Kostamo,  
Managing Director of Picosun.*



## Picosun re-introduces Tuomo Suntola, inventor of ALD at ALD 2008 conference

**BRUGES, Belgium – June 30, 2008** - At AVS ALD 2008, the 8th International Conference on Atomic Layer Deposition held in Bruges, Belgium, Finnish Atomic Layer Deposition (ALD) reactor manufacturer Picosun Oy today re-introduced Dr **Tuomo Suntola**, Finnish scientist who received the European SEMI award in 2004 for inventing the ALD method, to a whole new generation of ALD-enthusiasts.

“Dr Suntola has not been actively participating in ALD events during the past few years. That is why there is a complete generation of people working with ALD who have not had a chance to meet him in person before. He has, however, served as Executive Advisor to and, since 2007, Member of the Board of Directors of the Finnish ALD Powerhouse Picosun. Picosun has been one of the best kept secrets of ALD, but the silence around the company has now been lifted,” says **Juhana Kostamo**, Managing Director of Picosun.

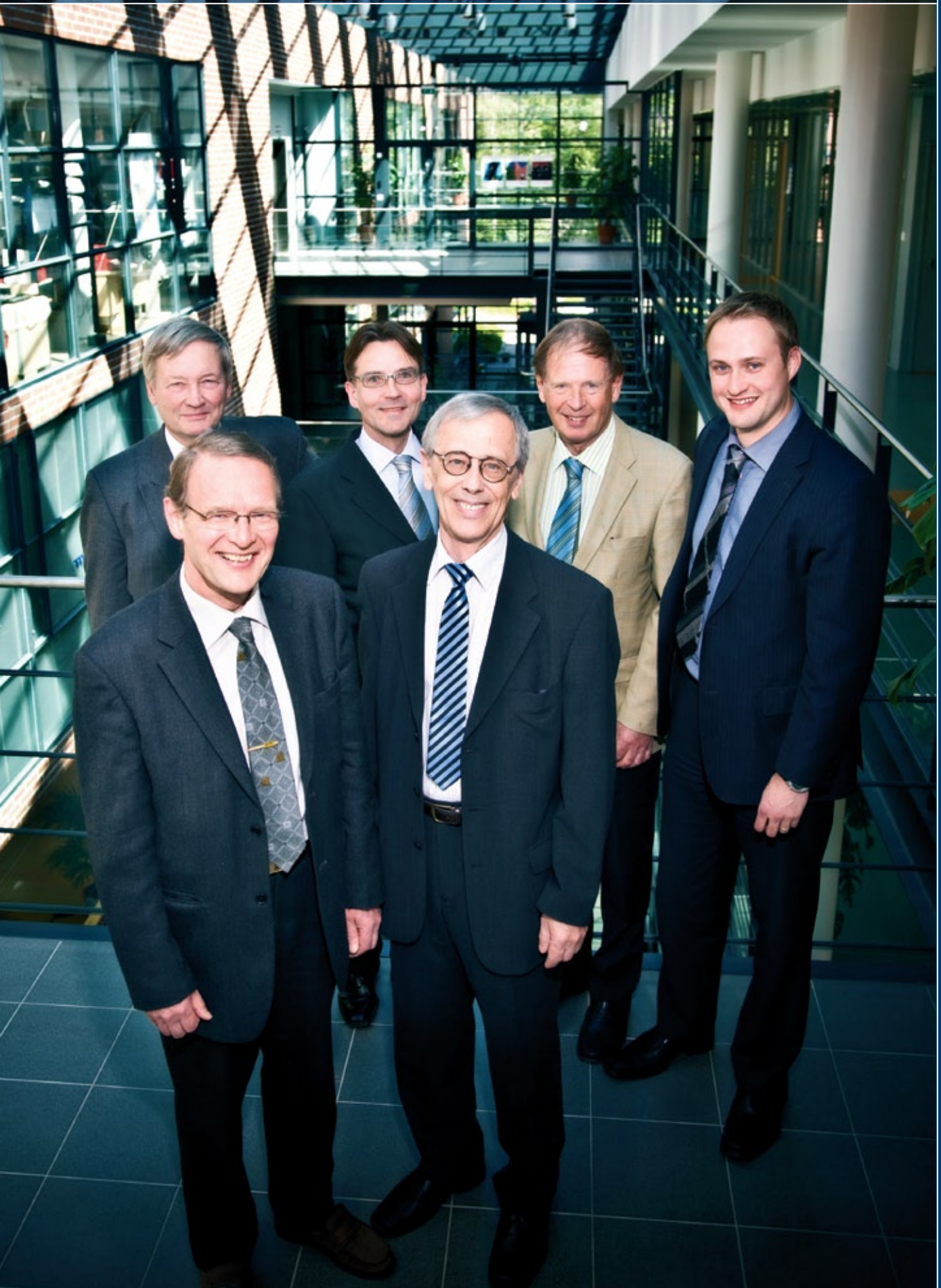
“We have used the past four years to build a platform from which we will reach the top of the ALD world. We now have un-matched products both for R&D and production, the quality of which is not defined by empty advertising phrases but unparalleled hard measured facts from actual equipment used by some of the world’s leading universities and research institutions. We now also have first actual user long-term measured results from our new SUNALE™ P-series production reactors confirming that we have, indeed, products which master the most important thin film deposition equipment requirements – uniformity, repeatability and particle performance – with flying colours,” Juhana Kostamo explains.



*Dr. Tuomo Suntola*



*Best Wishes for Year 2009!*



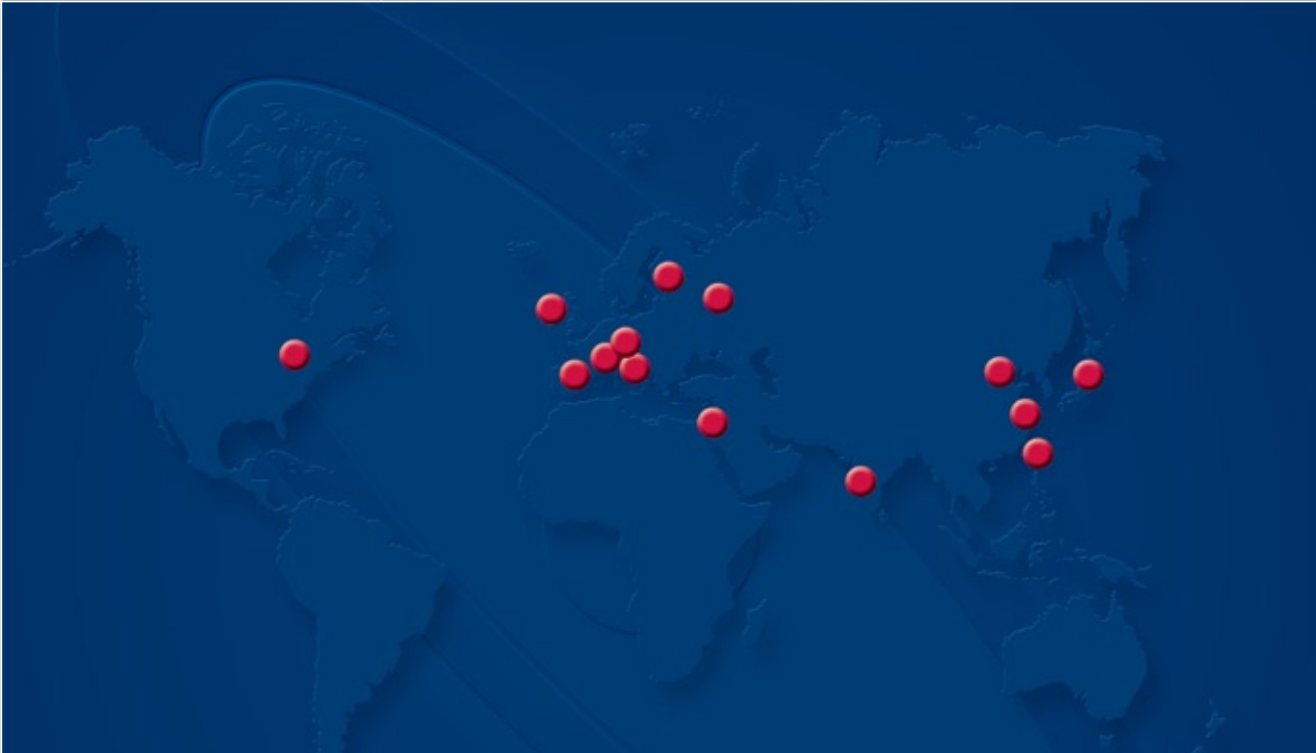


*SEMI organisation President and CEO Stanley T. Myers presents the European SEMI 2004 award to Dr. Tuomo Suntola at Semicon Europa 2004 exhibition in Munich.*

## 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 people 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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### Regional sales

See [www.picosun.com/contact/](http://www.picosun.com/contact/)  
for details of regional sales offices.