



THE PICOSEC  
MC-NET PROJECT



# Training on semiconductor devices, design and manufacturing

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*Catania, July 1<sup>st</sup>-2<sup>nd</sup>, 2013*

*Organization: STMicroelectronics*

## Program and Book of Abstracts

# Timetable

MONDAY	08:15-08:45	Registration	
	08:45-09:00	Welcome and Introduction to the Course	M. Mazzillo
	<b>Module 1 - Semiconductor Manufacturing Processes*</b>		
	09:00-09:30	Brief Introduction of STMicroelectronics and Microelectronics Historical Notes	G. Arena
	09:30-10:40	Semiconductors Processing and Devices Fabrication – part 1	G. Arena
	10:40-11:00	<b>Coffee Break</b>	
	11:00-12:30	Semiconductors Processing and Devices Fabrication – part 2	G. Arena
	12:45-14:00	<b>Lunch – Restaurant Il Cuciniere - Katane Palace Hotel</b>	
	<b>Module 2 - Electrical Testing, Assembly and TCAD Simulations*</b>		
	14:00-14:50	Electrical Parametric Testing	S. Sannella
	14:50-15:40	Electronic Devices Packaging	F. Ziglioli
	15:40-16:30	TCAD Process and Device Simulations	C. Miccoli
	16:30-16:50	<b>Coffee Break</b>	
	<b>Module 3 - Technology Development and Applications*</b>		
	16:50-17:40	STMicroelectronics Silicon Photomultiplier Technology	G. Valvo
17:40-18:30	Time-of-Flight PET Detector Development with SiPMs	S. Dolinsky	
20:30-22:30	<b>Social Dinner – Restaurant Cortile Capuana</b>		
TUESDAY	<b>Visit to 8" M5 Clean Room Facilities**</b>		
	08:15-10:45	First Group (19 Participants)	G. Vitale
	10:45-13:15	Second Group (19 Participants)	G. Vitale
	13:15-14:30	<b>Lunch – Restaurant Il Cuciniere - Katane Palace Hotel</b>	
	<b>Module 4 - Surface Analysis and Solids Characterization*</b>		
	14:30-15:30	X-Ray Photoelectron Spectroscopy (XPS) and Secondary Ion Mass Spectrometry (SIMS)	L. Renna
	15:30-16:30	Optical Microscopy, Fault Detection and Isolation Techniques	D. Mello
	16:30-16:50	<b>Coffee Break</b>	
	16:50-17:50	Samples Preparation and Transmission Electron Microscopy (TEM)	D. Mello
17:50-18:50	Focused Ion Beam (FIB) and Scanning Electron Microscopy (SEM)	D. Mello	
18:50-19:00	Concluding Remarks - Debriefing		

\* Katane Meeting Room, basement level, Katane Palace Hotel

\*\* STMicroelectronics - Catania site

# MONDAY

## Welcome and Introduction to the Course

Speaker: M. Mazzillo – STMicroelectronics



**Massimo Mazzillo** received the M.S. degree in physics with honors from the University of Bari, Italy, in 2002. Since 2002 he has been with R&D STMicroelectronics, Catania, where he currently works as staff technology development engineer at the development of silicon single-photon detectors for biomedical applications and high-energy physics experiments and silicon carbide photodiodes for ultraviolet light detection. His research interests also include the fabrication and characterization of advanced optoelectronic devices and organic biosensors. He filed 12 patents and authored more than 70 papers published in international journals and conference proceedings. He serves as Referee for the leading journals in the field of photodetectors and is member of STMicroelectronics Technical Staff.

**Abstract:** The fifth course organized in the frame of FP7 PICOSEC MC-Net Marie Curie project is focused on the design and fabrication of semiconductor devices. The main objective of the training is to get a short introduction to the techniques and fabrication processes for manufacturing semiconductor devices and analytical techniques used for their chemical and morphological characterization. During the course will be shown how a big semiconductor manufacturing company like STMicroelectronics produces devices on microchips and how the technologies to make devices evolve over time, learning about the various steps in making semiconductor integrated devices and circuits (ICs). The visit of STMicroelectronics-Catania site clean room facilities is included in the second day program to give to the participants the possibility to get directly in touch with the fascinating world of semiconductors.

## Semiconductor Manufacturing Processes (Module 1)

Speaker: G. Arena – STMicroelectronics



**Giuseppe Arena** received the MS degree in Chemistry from the University of Catania, Italy, in 1991. In 1994 he joined STMicroelectronics' R&D department and in 1999 he was appointed Plasma Etch Development Section Head, acquiring also the responsibility of Lithography Development Group in 2001 and the advanced analysis group in 2006. In 2009 was appointed Technology Development Director. In this role he is involved in the development of new enabling processes/architectures and

modules for advanced devices in the technological areas of silicon based Power devices (MOSFETs, IGBTs, and customized ICs), compound semiconductors (SiC and GaN) and environmental sensors, healthcare, energy and smart miniaturized systems. He filed 13 patents and authored 15 papers published in international journals.

**09:00-09:30** **Brief Introduction of STMicroelectronics and Microelectronics Historical Notes**  
G. Arena

**09:30-10:40** **Semiconductors Processing and Devices Fabrication – part 1 (crystal growth and epitaxy, thermal oxidation, ion implantation and diffusion)** – G. Arena

**11:00-12:30** **Semiconductors Processing and Devices Fabrication – part 2 (thin film deposition, photolithography, plasma basics, etching and new trends in microelectronics industry)** – G. Arena

**Abstract:** Semiconductor technology is a very pervasive field, interesting several aspects of our life (communication, education, transport, environment, banking, industry, healthcare and medicine, leisure and entertainment, banking, research etc). Microelectronics is at the heart of economic life and it plays a strategic role also on the sustainable development trend, by the research on low-consumption devices, low-environmental impact processes, high-performances applications and miniaturization. Progresses in microelectronics strongly influence societal changes and lifestyle of people and they are at basis of the fully interconnected world. Semiconductor technology is a multidisciplinary field involving Physics of Semiconductors, Solid State Chemistry and Electronic Engineering. At the beginning of the lecture a brief history of microelectronics will be presented, highlighting the key success factors of this industrial field. A brief introduction on STMicroelectronics will be presented too and then, the basics of fundamental processes used for semiconductor devices fabrication will cover the most part of the presentation, answering, at the end, to the question on how a silicon chip is made and complementing with some cases study. The final part of the lecture will describe the new trends in microelectronics, including the miniaturization approaches, the use of new materials in hybrid smart systems and the replacement of silicon with new semiconductors for innovative applications.

## Electrical Testing, Assembly and TCAD Simulations (Module 2)

Speakers: S. Sannella, F. Ziglioli, C. Miccoli – STMicroelectronics



**Stefano Sannella** received the Bachelor's Degree in Electronics Engineering at the University of Catania, Catania, in 2001. Since 2003 he works in STMicroelectronics, in particular in Catania Manufacturing Site inside Device Engineering Group. He has covered different roles from Electrical Wafer Sort to Parametric Test analysis in different technologies (Memory Flash, VIPOWER, BCD6, BCD8, BCD8SP) to guarantee technology capability in mass production, to qualify new processes and to prevent and solve excursions. Actually he leads PT Data Analysis group inside SMART POWER Device Group that is the Parametric Test reference for internal and external customers of the main CTM technologies.

### 14:00-14:50 Electrical Parametric Testing – S. Sannella

**Abstract:** Parametric Test is the first electrical test on finished semiconductor wafer to check process integrity; it consists in verifying electrical functioning according to the models of the main elementary structures (resistances, capacitances, transistors...) in the device. Purpose of this presentation is to provide a brief description of how it works and is managed parametric test in semiconductor manufacturing.

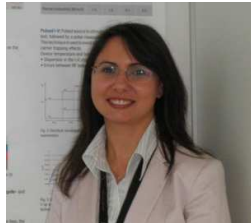


**Federico Ziglioli** received the Bachelor's Degree in Materials Engineering at Politecnico di Milano, in 2002. Since 2002 he works in STMicroelectronics, in Agrate, in the Central Packaging and Development group. He has followed the packaging development in particular for MEMS, accelerometers, gyroscope and medical device, from early prototyping to mass production. He filed 26 patents in the area of packaging and semiconductor assembly. Actually he is managing the industrialization of packages in the automotive field, and the advanced packaging R&D for new MEMS applications.

### 14:50-15:40 Electronic Devices Packaging - F. Ziglioli

**Abstract:** In electronics manufacturing, integrated circuit and discrete components packaging is the final stage of semiconductor device fabrication, in which the tiny chip of semiconducting material is encased in a supporting case that prevents physical damage and corrosion. The case, known as "package", is the interface between the semiconductor chip and the external world and is supporting the electrical contacts which connect the device to a circuit board. In a nutshell a semiconductor package is a metal, plastic, glass, or ceramic casing containing one or more semiconductor electronic components. This

lecture provides an overview of the key packaging design to aspects: topological, thermal, electrical, reliability and manufacturability. A part of the lecture focuses on extremely important and very diverse technology options (materials and processes) to package semiconductor chips in single-chip and multichip modules.



**Cristina Miccoli** received the MS Degree in Physics from the University of Catania, Italy, in 2006. In February 2010 she received the Ph.D. Degree in Physics from the University of Catania. Since 2007 she has been in STMicroelectronics where she now works in Technology CAD team inside the IMS CAD and Design Services. She collaborates with design teams and CAD developers/suppliers to validate, calibrate and support physical simulations, methods and models for the new devices and process steps. In particular, her main research topics include new physical models applied to new semiconductor materials, like GaN and AlGaN.

**15:40-16:30** **TCAD Process and Device Simulations** - C. Miccoli

**Abstract:** The success of microelectronics technology has been partly enabled and supported by sophisticated Technology Computer-Aided Design (TCAD) tools which are used to assist in Integrated Circuit (IC) development and engineering at practically all stages from process definition to circuit optimization. The main purpose of this training is to gain insights into technological simulations. After a brief introduction on simulation environment we will show you the process simulation flow (e.g. ion implantation, diffusion, oxidation, etc.) and also the device simulation set-up (drift-diffusion model, recombination and impact ionization models).

## **T**Technology Development and Applications (Module 3)

Speakers: G. Valvo (STMicroelectronics), S. Dolinsky (GE Global Research Center)



**Giusy Valvo** received the MS degree in Physics from the University of Catania, Italy, in 1996. Since 1997, when she joined STMicroelectronics as sensors designer, she has gained wide experience in the development of dedicated technologies for scientific grade silicon sensors, including analog Silicon Photomultipliers for medical applications and high energy physics experiments.

**16:50-17:40** **STMicroelectronics Silicon Photomultiplier Technology** – G. Valvo

**Abstract:** Solid state optical detectors are considered an attractive possibility to replace standard Vacuum Photomultiplier Tubes (PMTs) in many applications. More particularly, photodiodes working above their breakdown voltage in limited Geiger Mode have been demonstrated to offer outstanding possibilities in terms of high gain ( $>10^6$ ), fast timing response with low fluctuation ( $<150$  ps jitter) and sensitivity to extremely low photon fluxes. As of 2000 STMicroelectronics is involved in the design and manufacturing of Geiger Mode Avalanche Photodiodes (GMAP) in single pixels and arrays. In 2006 the GMAP technology was optimized to fabricate the first Silicon Photomultipliers (SiPMs) prototypes. SiPMs are currently finding wide utilization in many applications such as medical imaging and high-energy physics due to its high gain ( $>10^6$ ) at low operating voltage (typically a few tens of Volts), very fast timing response ( $\ll 1$  ns) and excellent single photon counting capability. STMicroelectronics SiPMs are currently available in N-on-P and P-on-N configurations for light detection in visible-near infrared and blue-near ultraviolet wavelength ranges, respectively. Their electro-optical performances in terms of high photon detection efficiency, low dark noise rate and cross talk set these devices at the state of the art in this field.



**Sergei Dolinsky** received the MS degree in Physics from the Novosibirsk State University, Russia, in 1984. His activity is mainly focused on nuclear detector development for High Energy Physics Experiments and Nuclear Medicine. In 2005, he joined GE Global Research, Niskayuna, USA, where he is leading the research of new technologies for PET applications. He has authored more than 60 papers in international reviewed journals.

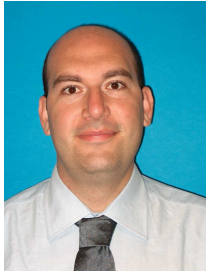
**17:40-18:30** **Time-of-Flight PET Development with SiPMs** – S. Dolinsky

**Abstract:** Positron Emission Tomography (PET) is a functional imaging modality that is primarily used for cancer diagnosis and staging. GE Healthcare manufactures PET scanners based on Time-Of-Flight technology for general purpose whole body imaging. A typical PET detector consists of high stopping power scintillator to convert the energetic 511 keV annihilation photons into light, which are then detected by a photo-sensor. The vacuum PMT based detectors have been used in PET scanners for over 20 years, and significant optimization for performance has been done over this period. Recent advances in solid state photo sensor technologies developed for a variety of applications have led to emergence of new Silicon Photo Multipliers (SiPM) as a potential replacement for vacuum PMTs. We have constructed TOF PET-MR detector ring based on SiPM photosensors. High uniformity was achieved for both energy and timing resolution. System energy and timing resolutions were 10.8% and 374ps.

## TUESDAY

### Visit to 8" M5 Clean Room Facilities

Speaker: G. Vitale – STMicroelectronics



**Giovanni Vitale** received the High School Certificate (Diploma) as Electrical Engineering Technician Diploma degree from the E.Morselli Institute in Gela, Italy, in 1992. Hired in ST in March 1996 as Manufacturing Operator, he was involved in the start-up of Module 5, the first 8" ST plant in Italy. After 7 years spent in Manufacturing department, as Protocol manager and then as Supervisor of Manufacturing and OEE data (OEE stands for Overall Equipment Efficiency), he joined the Organizational Development Team, where he worked for the following 5 years, and then Manufacturing Quality department, always in charge of Sustainable Excellence activities. He is currently in charge of FMT R&D IMS & APG CTM Sustainable Excellence activities within Catania Manufacturing Operations. In this role, and throughout a 17 year experience, he has been able to introduce ST and Catania Site to more than 22.000 visitors coming from all over the world.

**08:15-10:45** 1st Group (List of the names at the last page) – G. Vitale

**10:45-13:15** 2nd Group (List of the names at the last page) – G. Vitale

**Abstract:** ST Catania plant originated in April 6th 1961 as ATES (Aziende Tecniche Elettroniche Semiconduttori – Electronics Semiconductor Companies) within the group IRI-Finmeccanica. Further to various corporate restructuring and the merge in 1987, the plant became part of STMicroelectronics, former SGS-THOMSON, born from the merge of the Italian SGS with the French Thomson. Today

STMicroelectronics in Catania counts 4000 employees and is the first Company in Sicily and the second in the South of Italy for the number of employees. The educational level is very high: 35% of employees have a university degree and 63% a High School Diploma. The average seniority on the job is 20 years. 27 % of Engineers is dedicated to Research & Development and release around 10% of 1100 patents/year of ST World Wide; 53 % is employed in the manufacturing of





advanced devices; 20% is enrolled in all the other Corporate Processes and Roles. The Site occupies a surface of 183,520 m<sup>2</sup>: 59,362 m<sup>2</sup> are covered areas; 21,702 m<sup>2</sup> dedicated to class 1 and class 10 clean areas for the manufacturing of around 12.000 wafer out equivalent (8" - 20 Mask Levels).

## Surface Analysis and Solids Characterization (Module 4)

Speakers: L. Renna, D. Mello – STMicroelectronics



**Lucio Renna** received the M.S. degree in Chemistry and the Ph.D in Material Science from University of Catania, in 1999 and 2007 respectively. Since 1999 he joined STMicroelectronics, where he currently works in R&D department. During his experience in STMicroelectronics, he gained multidisciplinary competencies in the development of integrated devices for bio-diagnostic applications and chemical surface functionalization for molecular electronics and biosensors and since 2011 is member of technical staff at STMicroelectronics. His research activity is documented by more than 40 publications and patents.

### 14:30-15:30 X-Ray Photoelectron Spectroscopy (XPS) and Secondary Ion Mass Spectrometry (SIMS) – L. Renna

**Abstract:** The role of surface analytical techniques is fundamental in Integrated Circuits technology, in that most of physical and chemical processes involved in their developments regard surface (e.g. ion implantation and diffusion, thin film polymers, surface oxidation, plasma processes, etc.). In this presentation an overview about Secondary Ion Mass Spectrometry and X-ray Photoelectron Spectroscopy techniques will be accomplished. Example applications will be also described not only related to the “conventional” IC’s processes, but also to research aspect related to the control and modification of surfaces at monolayer level.



**Domenico Mello** received the MS degree in Physics from University of Lecce, Italy, in 1996, discussing research thesis on transmission electron microscopy, and the Ph.D degree in materials science, in 2001, discussing a thesis in surface analysis and ion implantation. In 2000, he joined STMicroelectronics, Catania, Italy, where he lead the Physics Laboratory Group. His activity is mainly focused on chemical and morphological characterization for process steps and failure analysis. He has authored about 30 papers on international reviewed journals.

**15:30-16:30** **Optical Microscopy, Fault Detection and Isolation Techniques**

D. Mello

**16:50-17:50** **Samples Preparation and Transmission Electron Microscopy (TEM)**

D. Mello

**17:50-18:50** **Focused Ion Beam (FIB) and Scanning Electron Microscopy (SEM)**

D. Mello

**Abstract:** The materials analysis requirements for microelectronics development and manufacturing are becoming increasingly sophisticated with decreasing geometries and greater diversity of the materials used in the new generation of semiconductor devices. The evolution in technology presents growing challenges to materials scientists and development engineers working in the field of microelectronics. As a consequence of the device miniaturization and introduction of new semiconductor materials (SiC, GaN), it's necessary to characterize features of ever decreasing size with respect to morphology. In these lectures the fundamentals of optical and electron microscopy (both scanning and transmission) will be given. The optical microscopy is commonly used for the visual inspection of semiconductor devices. Optical microscopes are used to obtain an enlarged image of a small object, utilizing visible light; in general they consist of a light source, a condenser, an objective lens, and an ocular or eyepiece, which can be replaced by a recording device. The electron microscope is a type of microscope that uses a beam of electrons to create an image of the specimen. It is capable of much higher magnifications and has a greater resolving power than a light microscope, allowing it to see much smaller objects in finer detail. The original form of electron microscopy, Transmission electron microscopy (TEM) involves a high voltage electron beam emitted by a cathode and formed by magnetic lenses. The electron beam that has been partially transmitted through the very thin (and so semitransparent for electrons) specimen carries information about the structure of the specimen. Unlike the TEM, where the electrons in the primary beam are transmitted through the sample, the Scanning Electron Microscope (SEM) produces images by detecting secondary electrons which are emitted from the surface due to excitation from the primary electron beam.

**18:50-19:00** **C**oncluding Remarks – Debriefing

## Additional Information

**Coffee Breaks:** Katane Palace Hotel courtyard - Ground Floor

**Lunches:** Restaurant Il Cuciniere, Katane Palace Hotel – Ground Floor

**Social Dinner:** Restaurant Il Cortile Capuana, Via Capuana 104, Catania.

**Name lists of the group 1 and 2 for the visit to 8” M5 clean room facilities:**

### **1<sup>st</sup> Group (08:15-10:45)**

**Rita Giuffredi**, Pawel Modrzynski, Farah Ben Mimoun, Rui Silva, Ricardo Bugalho, Viesturs Veckalns, Carlos Gaston Zorraquino, Aliakbar Ebrahimi, Daniele Cortinovis, Sara Faraj, Chen Xu, Chen Huangshan, Alejandro Gil Lopez, Vera Stankova, Tobias Harion, Wei Shen, Rosana Martinez Turtos, Aron Czerkaszkzy, Amit Shah.

### **2<sup>nd</sup> Group (10:45-13:15)**

**Ferenc Nagy**, Alexandros Rapidis, Matthieu Vangeleyn, Etienne Auffray, Mithra Nemallapudi, Katayoun Doroud, Crispin Williams, Edoardo Charbon, Esteban Venialgo, Marco Pizzichemi, Zheng Liu, Stefan Gundacker, Sergei Dolinsky, Raffaello D’Alessandro, Cristina Mattone, Romina Rega, Abigail Cutajar, Massimiliano Colarieti Tosti, Hans Cristian Schulz Coulon.