COLLABORATIVE **N**ETWORK FOR **T**RAINING IN **E**LECTRONIC **S**KIN **T**ECHNOLOGY
(**FP7-PITN-GA-2012-317488-CONTEST**)

Towards Bendable Systems

5th February 2015

Fondazione Bruno Kessler Trento (Italy), via Sommarive 18 Povo Trento,

Aula 102, edificio Nord

General Program

12:50-13:00 **Welcome** (Ravinder Dahiya)

13:00-13:20 **Developing Flexible Thin Film Transistors using Si-microwires**
Saleem Khan, Fondazione Bruno Kessler, Trento

13.20-13.40 **CNT-Based Temperature Sensors**
Engin Cagatay, Technische Universitat Munchen, Munich

13.40-14.00 **Self-consistent Percolative Model for Random Networks of Carbon Nanotubes.**
Simone Colasanti, Technische Universitat Munchen, Munich

14.00-14.20 **Spectroscopic investigation of near infra-red emitting polymers for organic electronics**
Valentina Robbiano, University College, London

14.20-14-40 **Metal/organic patterned substrates for sensor and actuator integration**
Wenting Dang, Fondazione Bruno Kessler, Trento

14.40-15.00 **Flexible POSFET tactile chips**
Shoubhik Gupta, Fondazione Bruno Kessler, Trento

15.00-15.20 **Chemical and Physical sensors on flexible /conformable substrate**
Nivasan Yogeswaran, Fondazione Bruno Kessler, Trento

15.20-15.40 **Investigations of the fracture strength of thin silicon dies embedded in flexible foil substrates**
Nagarajan Palavesam, Fraunhofer

15.40-16.10 **COFFEE BREAK**

16.10-16.30 **System level Electrostatic Discharge (ESD) failure mechanisms on electronic skin**
Tekfouy Lim, Frauhnofer EMFT

16.30-16.50 **Silver nanowires (AgNWs) and multi-walled carbon nanotubes (MWNTs) coated electrodes for flexible and stretchable optoelectronic devices.**
Luca Santarelli, University College, London

16.50-17.10 **Dexterous Robotic Hands Learn To Recognize Complex Objects Via Robust Descriptors and Artificial Robotic Skin**
Mohsen Kaboli, Tecnische Universitat Munchen

17.10-17.30 **Physiological Mechanisms of Skin Nociception and Behavioural Responses to Pain**
Carlo Bagnato, Imperial College London

17.30-17.50 **A vibrotactile wrist interface for telemanipulation**
Matjaz Ogrinc, Shadow Robot Company

17.50-18.00 **CONCLUSION AND WRAP-UP**

Abstracts

For further information about the project, visit the website: http://www.contest-itn.eu/

Saleem Khan

Saleem Khan received his B.S degree in Engineering Sciences with specialization in Lasers and Optoelectronics from GIK institute of Engineering Sciences and Technology, Pakistan in 2007 and received his Master degree in Electronic Engineering from Jeju National University, South Korea in 2010. During his master course his research interests were in development of flexible thin film electronics on plastic substrates employing Electrohydrodynamic Inkjet system. The research work on Master's level included the development of inkjet nozzle head for getting fine patterns just in one step rather than many steps involved by using Lithography techniques. In manufacturing technologies the development of EHD inkjet head will have a valuable place as it is material efficient and low cost technology. A prototype thin film transistor has been successfully fabricated by following EDH technology during Master's research work. He joined GIK Institute as a Research Associate in Jan 2011, where he was mainly involved in assisting in various research tasks and teaching specialization courses of Semiconductor and Superconductor stream of final year students. He is currently a PhD student with the University of Trento and his research is based within the BioMEMS group at FBK (Fondazione Bruno Kessler), Trento, Italy under the supervision of Dr. Ravinder Dahiya. His research focus is development of fabrication route for flexible electronics using transfer printing of Si micro/nanostructures on plastic substrates

Developing Flexible Thin Film Transistors using Si-microwires

Development of a process protocol for fabrication of flexible thin film transistors will be presented using Si-microwires as semiconductor layer. Screen printing for metals layers, spin coating for dielectric, while Transfer printing is used for Si-microwires. Both top and bottom gated structures of thin film transistors are developed and characterized for reliable physical and electrical properties. Complete technology development for such devices and optimization for future circuits development is analyzed and will be presented in this presentation.

Cagatay Engin

CNT-Based Temperature Sensors

High-performance temperature sensors that utilize spray deposited carbon nanotube (CNT) films as the active sensing material are presented. In order to evaluate device performance, the change in device resistance with respect to change in temperature is monitored. Moreover, a comparative experiment is carried out in order to investigate the effect of CNT film thickness and device encapsulation on the characteristics of CNT-based temperature sensors.

Simone Colasanti

Simone Colasanti is currently pursuing the Ph.D. degree with the Institute for Nanoelectronics, Technical University of Munich. He obtained his Master degree in Electronic Engineering at the University of Rome “Tor Vergata” in November 2012. His current research interests include the developing of theoretical models and simulation tools for electronics devices on flexible substrates which employ organic semiconductors and carbon nanotubes

Self-consistent Percolative Model for Random Networks of Carbon Nanotubes.

A new model for the simulation of randomly aligned networks of carbon nanotubes is presented. The model is based on a stochastic algorithm that can generate non-rigid solid objects in a three-dimensional space, emulating with high fidelity the typical fabrication processes of these devices. The properties of the nanotubes are extracted according to some probability distributions inferred from experimental measurements. The behavior of the network is simulated by coupling a SPICE program with an iterative algorithm that calculates self-consistently the electrostatic potential and the current flow in each node of the network.

Valentina Robbiano

Valentina is a second year PhD student at University College London (UCL). She obtained a Master degree in Material Science and Engineering at University of Genova. Her work is focused on the preparation and characterization of photonic systems suitable for flexible optoelectronic devices. This work will include different preparation methods of the systems as well as different optical-morphological characterization, such as polarized transmittance and reflectance angle resolved spectroscopy, steady-state and time-resolved photoluminescence spectroscopy and AFM.

Spectroscopic investigation of near infra-red emitting polymers for organic electronics

Wenting Dang

Wenting is the first year PhD student at University of Glasgow. She obtained the Master degree in Microsystems Engineering at University of Freiburg, Germany. Her work is focused on the stretchable electronics. This work includes the investigation of stretchable and conformable substrate, the integration of printing process and the integration of sensors/ electronics components on flexible/ stretchable substrates.

Metal/organic patterned substrates for sensor and actuator integration

Stretchable interconnects are realized by many groups with various geometries and structures. The schemes are mainly focused on metal wires (gold, copper) embedded with polymer substrate. However, delamination and cracks are often found after stretching due to the large difference of mechanical property between metal and polymer. In this case, carbon-polymer nanocomposites show their supreme combination of high electrical

conductivity and stretchability. In the presentation, previous studies on stretchable interconnects and carbon-polymer nanocomposites are summarized. Some recent research studies will be presented. The further studies are planned as well.

Shoubhik Gupta

Shoubhik is a first year PhD student in Department of Electronics and Nano-Scale Engineering, University of Glasgow, UK. He obtained his Bachelor's degree in Electrical Engineering from Indian Institute of Technology Kanpur, India in 2014 where he worked on Quantum-dot Cellular Automata technology and low power electronics. He worked quantum mechanical effects on junctional-less transistors during his final year project. He is the recipient of Nano-Undergraduate research Fellowship (NURF 2013) from University of Notre Dame, USA where he worked on modelling and fabrication of 2 dimensional MoS2 transistors.

Currently, he is working as a Marie Curie fellow at Fondazione Bruno Kessler, Italy on flexible POSFET for touch sensing in electronic skin under framework of CONTEST project. This work will be focused on transferring ultra-thin silicon membrane with POSFET fabricated over them to a flexible substrate.

His areas of interest are flexible electronics and quantum electronics.

Flexible POSFET tactile chips

The research on POSFET touch sensing devices will be advanced towards flexible tactile sensing chips. POSFETs and biasing circuitry will be developed on Si wafer, thinned down and then transferred to flexible substrates resulting in the flexible POSFET. In this presentation, I will be talking about state of the art of POSFET and diiferent thinning techniques in market and reported in literature.

Nivasan Yogeswaran

Nivasan Yogeswaran received his B.Eng. (Hons) degree in Electronic engineering from University of Surrey, UK where he specialised in devices. Following his undergraduate degree he pursued a masters degree in Nanoelectronics and Nanotechnology at University of Southampton, UK. Currently, he is enrolled as PhD student at University of Glasgow, UK. He is currently carrying out his research activities at FBK, Italy under the supervision of Dr. Leandro Lorenzelli, Dr. Ravinder Dahiya and Dr. Vincenzo Vinciguerra. His research work is focused on the development of physical and chemical sensors on flexible substrate for E-skin applications.

Chemical and Physical sensors on flexible /conformable substrate

Graphene is a carbon allotropes with fascinating properties with a wide range of potential applications including electronic, battery, transparent electrode, composites and sensors etc. Its superior electronic property and near ballistic transport could result it being a material of choice for future electronic applications in post silicon era. However, a feasible method suitable for industrial fabrication of graphene is yet to be reported. This presentation will provide an overview of various methods currently available for both

the synthesis and transfer printing of graphene. In addition, presentation will provide an overview of planned methodology for the design and fabrication of the graphene device.

Nagarajan Palavesam

Nagarajan Palavesam received his B.Eng. degree in Electrical and Electronics Engineering from Anna University, India and International M.Sc. degree in Nanotechnologies for Integrated systems from Polytechnic University of Turin, Grenoble Institute of Technology and Swiss Federal Institute of Technology (Lausanne) respectively. He worked at IBM Almaden Research Center, USA for his Master Thesis where he analyzed the use of Conductive Polymers to reduce Image Placement errors in E-beam lithography. He has received several Scholarships such as Alta Scuola Politecnica, Compagnia di San Paolo-Politecnico Project and EDISU Piemonte Merit and International Mobility Scholarships. Since August 2013, he is a Marie Curie Early Stage Researcher at Fraunhofer EMFT, Germany and he is concurrently working on his PhD thesis under the supervision of Prof. Karlheinz Bock at Dresden University of Technology. His current research interests include flexible electronics, development of new packaging and integration technologies for electronic components on flexible/stretchable foil substrates and their reliability testing.

Investigations of the fracture strength of thin silicon dies embedded in flexible foil substrates

Mechanical stress induced by mechanical and thermal loading on thin silicon devices breaks the devices at a certain load called the fracture or breaking strength of the device. The displacement experienced by the dies, due to bending, at fracture strength is called the fracture displacement. The strength properties of thin, bare silicon dies have already been reported by several groups. This work extends the study further to demonstrate the improvement in the fracture strength of thin silicon dies, of three different thicknesses (30, 65 and 130 µm), when integrated inflexible foil substrates. The fracture strength of the dies was measured using uniaxial (3-point-bending test) and biaxial (Ring-ball test) bending tests. Experimental results of the fracture strength of thin, bare silicon dies were in good agreement with simulation results obtained from Finite Element Analysis (FEA).Experimental results showed that there was an increase of the fracture strength up to about 190% and an increase in the curvature of bending up to about 85% when silicon dies were integrated in flexible foil substrates. This increase in the fracture strength and curvature of bending can be useful in designing and manufacturing more mechanically robust flexible electronic devices.

Tekfouy LIM-Experienced Researcher at Frauhnofer EMFT

Tekfouy Lim received the BSc. degree in Electrical and Electronics Engineering and the MSc. degree in radio frequency and millimetre wave engineering from the University of Lille1, France, in 2007 and 2009 respectively. He completed a Ph.D. degree in radio frequency and millimetre wave engineering from the

University of Grenoble, France, in 2013. His current research interests include radio frequency and millimetre wave circuits design and ESD protection design.

System level Electrostatic Discharge (ESD) failure mechanisms on electronic skin

The IEC standard is the electrostatic discharge (ESD) standard test on system level. The IEC standard is a system level test that replicates a charged person discharging to a system in a system end user environment. The purpose of the system level test is to ensure that finished products can survive normal operation and it is generally assumed that the user of the product will not take any ESD precautions to lower ESD stress to the product. In an electronic skin application, an efficient ESD robustness has to be provided for a normal functionality. This presentation is about the first investigations performed on a CellulARSkin multi-cells patch.

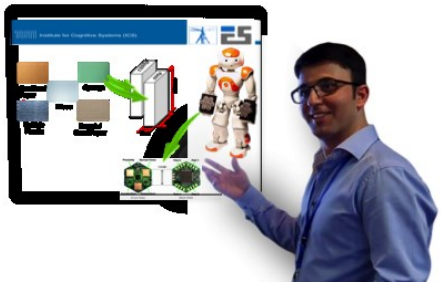
Luca Santarelli

Luca Santarelli is a first year PhD student. The research he is doing is part of the project “Initial Training Network CONTEST (COllaborative Network for Training in Electronic Skin Technology)” and he is funded by a Marie Curie Early Stage researcher (ESr) scholarship. Born in Lanciano (Italy) the 10th June of 1984, he received a BSc degree in Biomedical Engineering in 2007 at the University of Pisa with the dissertation “Design and implementation of a development platform for serial communication devices built for technical aids for disabled people”. He obtained his MSc in Electronics Engineering in June 2013 at the University of Pisa with the dissertation “Construction of a scanning thermal atomic microscope (SThM) for nanopatterning of advanced functional materials”. From September 2012 until May 2013 he did an internship at University College London (UCL) funded by the European Erasmus Placement project. In September 2013 he has started his PhD program in the department of Physics at UCL and Prof. Franco Cacialli supervises him. Luca’s research is mainly focused in: Development and characterization of organic devices, such as p-LED, solar cells and sensors, made onto flexible and stretchable supports; Investigation into properties of electrodes made by carbon nanotubes;Thermal and optical lithography of polymer semiconductors through a Scanning Thermal Microscopy (SThM) and a Scanning Near-field Optical Microscopy (SNOM).

Silver nanowires (AgNWs) and multi-walled carbon nanotubes (MWNTs) coated electrodes for flexible and stretchable optoelectronic devices.

We report on electrical, morphological and optical properties of AgNWs and MWNTs thin films coated over different substrates (glass, polyethylene terephthalate (PET), polydimethylsiloxane (PDMS)) obtained via spray-coating and vacuum-assisted filtration techniques. We investigated the suitability of these thin films to obtain stretchable and flexible optoelectronic devices. Amazing sheet resistance values in AgNWs coated films (≈ 32 Ω/sq) have been found, whereas MWNTs films feature values between 1.4 KΩ/sq and 1.6 KΩ/sq. Work function values of 4.8 eV in AgNWs thin films and 4.54 eV in MWNTs films have been obtained. The light transmittance at 550 nm for AgNWs films has been found between 70% and 50%, instead for MWNTs films between 30% and 35%. We also analysed work function tuning effects induced by spin-coated polyethilenimine (PEI) on AgNWs coated films, obtaining a reduction of almost 1 eV in all films so treated. AgNWs thin films coated electrodes are promising for optoelectronic applications, instead MWNTs coated films, featuring a high sheet resistance and a low

light transmittance, are not the ideal for such applications. Nevertheless, MWNTs films are interesting for other flexible and stretchable electronic devices, such as CO2 or O2 gas sensors.



Mohesn Kaboli

Mohsen Kaboli received his BSc. degree in Electrical and Electronic Engineering and his Msc. degree in Signal Processing and Machine Learning from the Royal Institute of Technology (KTH University) in Stockholm – Sweden in 2011. In 2012 he was awarded the research scholorship from the swiss national science foundation for 18 months in order to continue his research in the field of robot learning at EPFL university / Idiap Lab in Switzerland. Since April 2013, he is working as a research assistant and PhD candidate at the Institute for Cognitive Systems (ICS) at the Technical University of Munich (TUM) in Germany. His research interests are robot learning , artificial robotic skin , and signal processing.

Dexterous Robotic Hands Learn To Recognize Complex Objects Via Robust Descriptors and Artificial Robotic Skin

In this talk I will present new Transfer Learning methods for the recognition and categorization of complex in hand object properties such as surface texture using a multi-modal artificial skin mounted on finger tips of a dexterous robotic hand. In addition, I introduce novel biologically inspired feature descriptors, which are useful for providing high-level information to robotic learning systems.

Carlo Bagnato

Carlo Bagnato received his BSc in Bioengineering from Polytechnic of Turin, and his MSc in Neuroengineering and Cognitive Sciences from University of Genoa. Now he is an Early Stage Researcher and PhD student under the supervision of Professor Etienne Burdet at the Human Robotics Group, Imperial College London. He is currently working on bimanual and human-human collaborative motor control, and he is investigating the neural mechanisms of tactile sensing. In particular, his research studies focus on the nociceptive component of touch, and he carries out experiments to develop computational models of pain mechanisms.

Physiological Mechanisms of Skin Nociception and Behavioural Responses to Pain

While pain is often debilitating and intolerable, failing to notice injuries and illnesses can have severe adverse consequences and may even be life threatening. In my research I investigate pain mechanisms in humans in order to implement artificial pain mechanisms on robots and improve their performance. In this talk, I will present a study that I am currently conducting on brain correlates of pain, and discuss how I investigate the influence of pain on motor processes.

Matjaž Ogrinc

Matjaž was awarded his University Diploma in Electrical Engineering from University of Ljubljana in November 2012. He spent two years working at JSI's Humanoid and Cognitive Robotics Lab, where he also finished his diploma project on humanoid robot balance control. He joined Shadow Robot Company in August and began his postgraduate study at Imperial College in October 2013. His research interests are tactile sensing and rendering, adaptive control and sensory substitution in telemanipulation.

A vibrotactile wrist interface for telemanipulation

The talk will introduce a novel technique for creating haptic stimuli using a series of vibrating motors (tactors). To ensure the quality of the proposed method we investigated the perceptual limitations imposed by human psychophysics and tactors' dynamic properties. Results of the conducted psychophysical studies were employed to design a vibrotactile wrist interface with better haptic feedback properties considering human perception and hardware limitations. This work suggests several application areas, such as telemanipulation and navigation, in which the proposed vibrotactile travelling wave and developed wrist interface will benefit compared to existing haptic feedback techniques.