MEMS and NEMS Research for Education

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ABSTRACT

Education in the branch of Microsystems is described in the paper. There are methods of education in the connection to research in the core of the paper. Methods are focused on active involvement of students in research work. Research student output are using in educational process. Individual tasks are parts of solutions of large research projects. Individual work contributes to their professional forming. The research in the area of nanoelectronics (MEMS and NEMS) is discussed. Several workplaces are used where students work on defined tasks. The use of special instrument, microscope and other nanotechnology workplaces in the different institutes is necessary. The education involves nanomaterials and smart materials for sensor and smart micro and nanosystems. Knowledges are become during research and individual student research work.

Keywords: Microsystems, education, MEMS, NEMS, smart materials, micro, nano

1 INTRODUCTION

MST represent an interdisciplinary area (typically interconnection of mechanical and electrical domains). Therefore analogy between quantities from various energy domains is implacable in models. Using analogy, non-electrical quantities can be converted to electrical ones. Solutions of electrical models are well elaborated and very good tools for modeling and simulation of their properties are developed. The integrated micro-sensors, micro-actuators and micro-systems are ever more being applied in various areas of common life – from the control of heating and air-conditioning in buildings to the constantly rising applications of micro-systems in medicine. Various analyzers are applied in environmental protection, based on special bio-chemical sensors. In parallel to the development of medical integrated systems there comes the need to follow their influence on the bio-system of the human body, etc. The micro-technologies are being augmented by the new nano-technologies (bringing new improved possibilities in developing device structures). They play an especially important role in the development of new materials and improvements of their properties.

The goal of the education process is research and education in the area of new types of intelligent integrated micro and nano sensors structures and actuators including electronic circuits for data signal processing and transfer. For the sensor realization are used micro technology resources together with nano technologies namely in the area of materials and chemical sensors and biosensors structures. Educational process includes modeling, properties simulation of RF MEMS and MEMS structure, development of active integrated strain gauges and wireless, Bluetooth and ZigBee data signal transfer, development of sensors using polymeric electronic, research of new opto-chemical sensors, development of micro and nano sensors for chemical and biochemical applications, build-in intelligence of integrated sensors systems, electro-magnetic compatibility in integrated circuits structures and bio-systems. The design, modeling, simulation, measurement and diagnostics in the laboratory are used for the pick-up student knowledges. The practical outputs of the student project are sensors and microsystems samples, instruments intended for biochemistry, medicine, living environment, food processing industry, and measurement and communication technology, models of sensor and structure. Some courses, that are introducing problems of nano and microelectronics, include in their practical part student research work. Students participate in solving partial task of larger research projects. Students present their research work results in the frame of individual courses, for examples: Sensors for electronics, Microelectronics, Micro and nanosystems, Physical electronics, etc. Interconnection of student education and research activities are depict on figure 1.

Talented students having interest in research work can work in specialised laboratories. These young researchers are in this way included in research teams and usually get small part of the project to solve [2]. For example, students can be invited into the laboratory of semiconductors in order to take a closer look with atomic force microscope (AFM). The microscope is used for three dimensional imaging of nano objects and surfaces in nano scale. The students can learn several AFM techniques that provide not only surface imaging (for example measurement of quantum dots InGa/GaAs can be demonstrated) in contact and semicontact regimes but also measurement of electrical properties of surface (spreading resistance, local distribution of potential), local anodic oxidation of material's surface, nanomanipulation etc. [1].

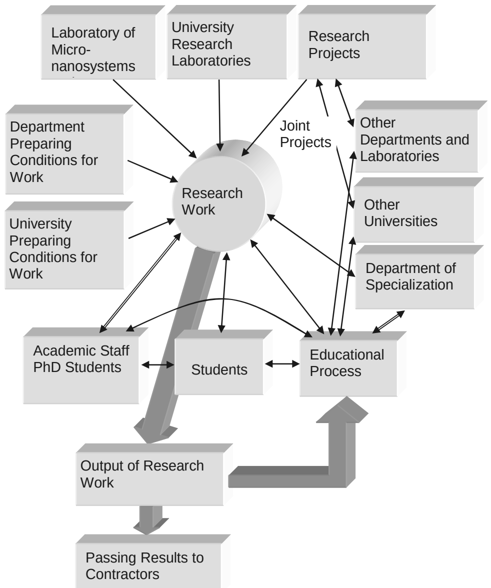

Figure 1: Interconnection of student education and research activities.

2 STUDENT'S RESEARCH ACTIVITIES IN EDUCATION

Students' involvement in research activities is performed in many ways that differ in a number of basic factors. Students are free in their decisions; they are not forced to participate in this work. However, it is recommended to do so. The research activities, projects and students' research activities are discussed on many levels, namely in education, during discussions with students, etc. Students get extended information about potential involvement in research activities. In curricula, there is a number of specialized courses utilising principle of project-oriented education. In these courses, the students get frequently task specifications that represent partial projects being parts of larger research projects. Topics of Master theses are usually based on actually solved projects in the Department. However, there is a disadvantage of long realization time of such a task. Nominal interval from defining topic of the Master thesis to its finishing is two years, but in recent years relatively many students ask for postponing the delivery. On the other side, if the student is good and teacher's supervision works well, the results acquired in the thesis may be usable in research projects. Efficiency of results applicability is very heterogeneous, in average it can be estimated to be up to 30 per cent. Here we are facing the problem that not all students have the sense of responsibility to deliver good work. There are students who just try to do their work "somehow" – to satisfy the basic requirements with as little effort as possible.

3 STUDENT'S RESEARCH ACTIVITIES IN EDUCATION

They acquire this knowledge in several ways, namely studying specialised courses, studying literature and active knowledge acquisition outside university. Let us mention an example of knowledge acquisition in the area of nanoelectronics, quantum electronics, microelectronics, or micro-nanosystems, fundamentals of micro and nanosystems (principles of operation of nanotubes, nanowires, nanoFET, semiconductor elements, circuits, electronic blocks and measurement methodology) are included. Courses constitute basic knowledge in the area of nanoelectronics, nanotechnology, electronics and microelectronics. They prepare students for further study of Micro and Nanosystems. Basic study levels are illustrated in figure 2. In the courses, laboratory equipment for microsystem design and diagnostics is used. Structure of micro-nanosystem courses is in figure 3.

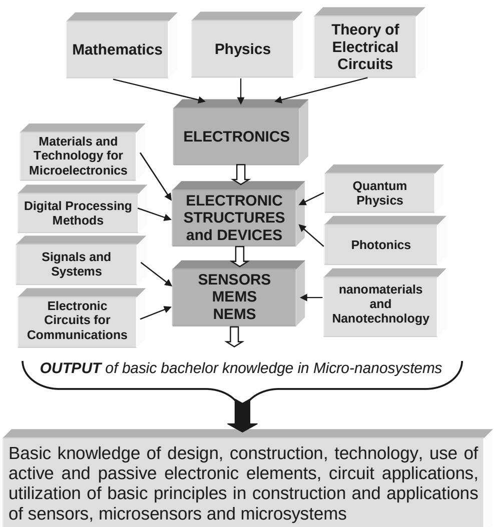

Figure 2: Basic courses supporting further education in micro-nanosystems.

Different themes are using as support of education in that subjects. Many themes relate to design of new types of smart integrated microstructures of microsensors, microactuators, including electronic circuits for processing and transmission of sensor signals meant for applications in environmental protection, biomedical applications, measurement techniques and other areas. For example some themes: Fast RF MEMS microwave signal switch (modeling of mechanical and thermal properties of the structure, use of equivalent electrical parameters to be created models, use of the CoventorWare program), RF sensor micro- and nano-structure for measurement of microwave radiation absorption. Sensor system with active integrated strain gauge, Integrated sensor structures with wireless data transmission, Polymer electronic structures and their applications in sensors, etc.

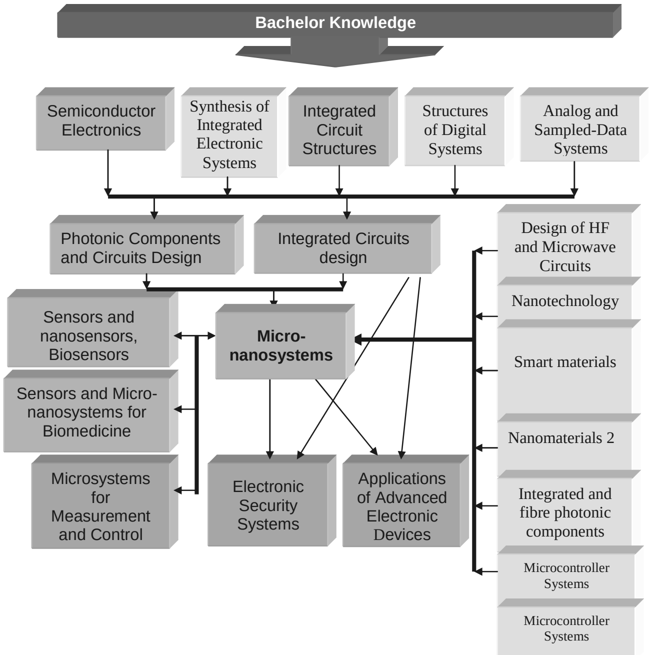

Figure 3: Concept of basic master microsystems courses.

The aim of the student project is the design, development, simulation and optimization of the properties of basic electronic structures, shape, signal processing, etc. The creation of models of the mechanical and thermal behavior of the structure, their application in the CoventorWare simulator. Comparison of models fit to prepared samples. Theme of Effects of integrated circuit architectures on biological environment is very suitable for the solving of the minimization of risks (of unwanted interaction) between the architecture of microelectronic devices and systems, and the biological environment.

4 WORKPLACES DETERMINED FOR STUDENT RESEARCH WORK

Workplace disposes of ECAD design center equipped with many workstations with implemented world software standards, like CADENCE and CoventorWare, etc. Software serve for design, modelling and simulation of integrated circuits and micromechanical microstructures are used. Technology service allows us usage of different IC technologies. The laboratory of diagnostics and microsystems is determined for measurement and testing of realized microstructures, both on-chip and encased samples of microsystems and microsensors. The laboratory is equipped with a number of instruments. Optical microscope workplace is used for inspection of micromechanical structures. The microscope is equipped with documentation subsystem for creation of graphical records that is composed of serial interface, camera for movement sensing under the objective and sublimation printer for printing quality images of microsystem structures. For processing of graphical information from the microscope, a PC for image saving and software for graphics processing is used. The workplace is completed with reproduction equipment. Monitors are used for displaying manipulation with samples, monitoring moving events in microsystems, and demonstrations for students. A recorder is used for recording these events. Workplace for temperature measurements is intensively used for research activity, mostly microsensor calibration. The core of the workplace for development of temperature microsystems with high resolution and accuracy determined especially for biomedical purposes is represented by exact temperature calibrator 140SE-RS. The core of the workplace for high-speed collection of sensor data is represented by portable high-speed multichannel digitizer OMB-WAWEBOOK-512 with OMB-WBK20 interface that is determined for fast multichannel collection of sensor data and their evaluation on a connected PC. The workplace for biochemical measurement on microsystem structures is determined for testing of properties of biochemical microstructures, realized on semiconductor base (e.g. pH measurement at ISFET structures). The workplace of surface assembly allows manipulation and soldering of microelements and realization of professional electronic modules. It is a supporting workplace that is used for realization of additional works during development of measuring systems and devices for diagnostics and measurement.

5 FLOW OF THEME SOLVING

Many levels of the model are using as support of education approaches to complex problem solving may differ and depend on nature of solved MST [3]. System model (model realizing system function) may have several levels that are placed in different MST levels. Model on the level of energy domain can be used to consider MST operation in different energy domains. Equivalent models between energy domains can be used for many applications. Models are based on equivalence of discrete elements and their behaviour described by mathematic expressions in various energy domains [4]. The best-known equivalence is utilized between electrical, mechanical and thermal domains. In these domains individual equivalences are elaborated well – table 1.

Mechanical	Thermal	Electrical	
Mass M $F' = M\frac{d(v)}{dt}$	Capacitance C $Q' = C\frac{dT}{dt}$	Inductor L $V' = L\frac{d(i)}{dt}$	Capacitor C $i' = C\frac{d(V)}{dt}$
Spring k $F' = k\int v\cdot dt$	Capacitance C $T' = \frac{1}{C}\int Q\cdot dt$	Capacitor C $V' = \frac{1}{C}\int i\cdot dt$	Inductor L $i' = \frac{1}{L}\int V\cdot dt$
Damper b $F' = bv$	Resistance R $Q' = \frac{1}{R}(T_2 - T_1)$	Resistor R $V' = Ri$	Resistor R $i' = \frac{1}{R}V$

Table 1: Mechanical, thermal, and electrical analogies.

Material and structure models describe properties of intelligent materials and structures are utilized. Then modeling their properties as input parameters for higher-level models is necessary. Physical models are necessary to utilize new materials and new structure properties. Ideative model is used by the student at first, model creates an ideative model of a MST with input information, output functions, and inner logical functions. Soft model of MST using PC and libraries of electronic components and blocks. Realization of HARD model is a successive step and is used for verification of basic functions of the designed SOFT model. It is possible to use available elements for realization of the HARD model. This model illustrates characteristics and behaviour of the designed MST model. It is instructive for education, it is possible to demonstrate its behaviour and basic characteristics. There are close connections between SOFT and HARD models. The students can develop a real functional model. Design of MST is the most difficult part and follows after previous steps. Micro-models are developed from these macro-models according to the rules for design of integrated MST (technology, materials, software, etc.). Macro-model properties are compared with simulated and modeled properties of real MST. For these purposes, suitable tools are utilized (CoventoWare, CADENCE, etc.). Students usually design very simple MST; more complex models are realized in the frame of Master or PhD theses. Individual models and their interconnections are illustrated in figure 4. [4].

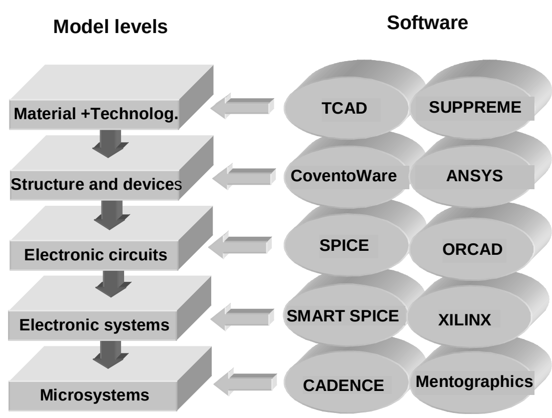

Figure 4: Flow of model levels.

When developing a system for pressure measurement, wireless information transmission and information processing, interconnection scheme (figure 5) can be used. Structure of integrated one-chip LC circuit realized on Si substrate is shown in Figure 6. In the middle part of the structure there is a capacitor with flexible membrane.

The capacitor measures external pressure. Integrated inductor is a part of integrated LC circuit. Inductor is produced by evaporation of metal spiral around capacitor. Besides L and C parameters, the structure displays a number of parasitic parameters caused by construction. Model on material and structural level can be used for modeling of basic properties of the structure as well.

6 CONCLUSIONS

Contributions of students' involvement in research activities: Motivation increase, Extension of specialised knowledge, Linking theory and practice directly during study, Students are often source of new ideas, ways of problem solving, unconventional approaches to solving given problems, Students see direct link between educational process and research work, Acquisition of deeper knowledge, Students become research team members, Mutual cooperation of students. New approach - a new method for education in the area of nanotechnology, narrow connection research and education, use of the nanotechnology equipment (AFM, nanolitography, etc.), The effort is targeted at the connection of the research an education of students in the university, connection different workplaces from the different institutes with branch of nanotechnology and nanoelectronics including nanomaterials.

7 ACKNOWLEDGEMENT

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