Learning in Bioelectronics

Cristian Ravariu
**Politehnica University of Bucharest, Faculty of Electronics, BioNEC Group*
Romania

1. Introduction

This chapter presents the mobile content evolution of a bioelectronics course, laboratory works, students impact and evaluation feed-back of a new discipline implemented since 2006 in a Faculty of Electronics from Romania. The BioNEC course, entitled Biodevices and Nano-Electronics of Cells, is dedicated to the Biosensors, Biosignals and Biomodeling, accordingly with the nowadays scientific trends. Placed at the cross-point between Biology-Medicine and Electronics Engineering, this course intends to familiarize the future engineers with the new products and applications in bio-engineering.

Electronics benefits on the largest nowadays interdisciplinary system (Nuxoll & Siegel, 2009). The relationship with biology was obviously from twenty years ago, when the integrated biosensors were firstly developed in a microelectronic foundry. In this way, news devices appeared like, IMmuno-FETs with Antibody membrane covering the gate metal, or ENzyme-FETs with a key enzyme entrapped in the Gate of a FET transistor, (Xu et al., 2006). The MOS technology down-scaling allows the integration on the same chip of the biological receptors with the adjacent electronics as Lab-On-Chip. These pieces are included in the "Biodevices" part of the course. The Biosensors act for in vitro analysis and the Implantable Devices act for in vivo applications. Also, in the last year were taken into account special macro-electrodes for non-invasive medicine or micro- electrodes for cells investigations. Among the south-eastern countries, Romania already presents a high morbidity of the metabolic diseases and diabetes over the european countries average, (Ionescu-Tirgoviste, 2007). Therefore, a special attention must be paid to the medical equipments of monitoring for the chronic diseases, (Pearlman et al., 2008).

The above discussion highlights the importance and the real possibilities to build up bridges among micro-nano-electronics, complex biosensors, neuroscience, prosthetics, tissue engineering, genomics, cellular electrophysiology, electrical trans-membranar transport, in an interdisciplinary system. Hence, the necessity of a bio-engineering course in a nowadays faculty of electronics is obviously, probably with the same intensity as in a Faculty of Medicine.

2. The bioelectronics links

The social studies predict an increment of the society mean age, especially in Europe. Therefore, there will be an important growth of the chronic diseases, consequently with an increased cost of the medical assistance. The health assurance companies and public sanitary services have noticed in the Price Waterhouse & Coopers Report "Healthcast 2010", three main directions: (1) Electronic Healthcare; (2) Genomic Perfection; (3) A rise of the individual access to the medical decisions and sanitary services via web and Telemedicine. On the other hand, the bioengineering systems must protect the peoples themselvs, respecting the medical ethics, the person privacy and security. Therefore a nowadays bioengineering course could be oriented to those manufactured tools that directly serves only to the medical act: medical tests, patient monitoring, drug delivery and not only to protect the assurance companies.

The chapter will answer to the following items:

1. The Bioscience overview: opportunities for different "Bio" Courses implementation, in the Engineering Faculties in agreement with the local research and industry branches and university profile.
2. The related disciplines for the implementation of a Bioelectronics Course in a faculty of Electronics.
3. Links for the BioNEC course in our faculty.
4. Evolution of the BioNEC content from a year to another.
5. Applications – labs and projects; our contributions.
6. The evaluation and the students feed-back.
7. The BioNEC research Group developing around this course.
8. Proposal for new directions in the Bioelectronics Learning.

These points concern the possibilities of a bioelectronics course implementation in others educational centres, adding together advantages and disadvantages, difficulties and suggestions.

Our learning contributions are: (a) new proposal - BioNEC course implementation - in a Faculty of Electronics is a successful contribution in the international context, taking into account that this acceptance arisen during the minimization of our, university degree from 5 years to 4 years and Master studies from 2 years to 1,5 years. (b) an adaptive content of the course was respected. (c) our net course contribution is related to Biosensors, Biotransistors, modelling of the electronic behaviour at cellular level, ionophore channels and nanopores simulations in Atlas software, non-invasive biosignal recording for cord, brain and others organs; all these sections don't overlap on others disciplines, neither on the classical Medical Electronics Department from our faculty (focused on apparatus, imagistic and bioinformatics).

Difficulties are: Poor endowment of the labs, lack of some apparatus (e.g. patch-clamp installation, etc). All the master students are engineers and have jobs simultaneously with courses. They cannot attend to all the courses and they came exhausted to assist the course after 18.00 p.m. An unsuccessful approach was to extend the bioengineering course to other Departments from Politehnica University of Bucharest, due to the lack of funds. The weekly schedule for BioNEC is 2 hours for course and 2 hours for applications – quite short to cover the Bioscience with its subsidiary Bioelectronics explosion form a year to another. Therefore the learning was more focused in the lasts years.

Unexpected pleasant reactions were related to the biological phenomenon, adjacent biochemistry, or cellular electrophysiology or medical terms, insertion for a better comprehension of a detection circuit or a biosensor technology. I was afraid to not be out of the Electronics Faculty requirements. But the students encouraged me to teach them about these complementary bio-medical aspects, where they have a high affinity for information. So, don't be afraid to teach biomedical knowledge in Technical Universities.

3. The related disciplines and strategies

3.1. Adaptive course versus research branch

To implement a bioelectronics course, firstly must be evaluated the best direction in a university. Around an electronics materials group the following related disciplines are involved: micro and nanostructured materials, microfluidics, electrical charged fluids, biochemistry, electrochemistry, biophysics and biology with a good jointure to proteomics, biomaterials, biocompatibility. Around an electrical devices and circuit group another bioelectronics course could be succesfully promoted, with related disciplines like: microelectronics, micro-nano-technologies, electronic devices and circuits, related micromechanics (e.g. MEMS, NEMS), with good results in biosensors and biodevices.
Around an electrical signal processing group could be developed a bioengineering course using previous disciplines like: mathematical modeling, statistical methods, electronics apparatus, electrical biosignals analysis in order to process the recorded signals from cells, organs and body. A stong medical engineering group could develop, new electrophysiological methods, clinic or laboratory investigations, new diagnosis protocols, using links with diabetes science, gastro-enterology, neuroscience, pathologic anatomy, medical imagistics, tissue engineering, minimum invasion surgery.
For a general bioelectronics course implementation, some priors disciplines or chapters are imperiously necessary: physics, electrochemistry, mathemathics, signals theory, electronic devices, circuits, microelectronics technology. Then, depending on the course direction, others adjacent disciplines must be previously studied (e.g. a sensor course with MEMS elements must precede a biosensor and biodevice course).
A main problem must be highlighted: in a technical university usually is very difficult to introduce a pure biological discipline to precede the bioelectronical course. Therefore the fundamental biology knowledges accumulated from the high-school period are enough for beginning. We introduced all the related biological and medical knowledges inside the bioelectronics course in this way. Both technical staff of university and students requirements were satisfied.
All the developments in bioelectronics were based on the classical electrical models for the integrated structures functions. Unfortunately, some intermediates stages regarding the biological phenomenon comprehension were lost sake the financial reasons and time consuming. For instance the Huxley equivalent circuit with two simples diodes used to model the Action Potential, propagation through the neuron membrane can be now better replaced with others devices, as SOI-MOSFETs with under-threshold and over-threshold conduction regime, (Ravariu[a] et al., 2006).
Therefore, our BioNEC course wish to establish some physical models for all the non-linear components comprised in a biosensor that must be finally integrated in a global model, in the first part. In the second part, considering the previous models and accumulated experience, some extensions to medical applications are approached: electrical signals recording that accompany the internal organs or muscle contraction – an approach from macro to micro and nano scale.
The modeling of cellular or tissual electrophysiology was impossible due to the high complexity of the living being. Modeling means first of all measurements, then a deeply insight of the phenomenon to understand to whom physical, chemical or biological laws they submit. To directly translate the biological language into a mathematical one is difficult. The fuzzy approach of mathematicians provided stochastic database diseases-

symptoms-patients, unacceptable from individualized healthcare point of view. Therefore, we consider that a parallel aproach, using the experience from electronics, which started from the behavioral description of a digital system and descended step by step to circuit level, then to transistor level, up to physical phenomenon description inside the nanotransistors, can be a successful way in biomodeling, due to the well-known and reach experience accumulated in the electronic device area. The biomodeling utility can be expressed in some parameters extraction with high impact in the diagnosis and individualized treatments (the slope or amplitude of an ECG can be easily put in touch with a pathology). The gradual approach from BioNEC course: starting with the well-known MOS, SOI transistors models, continuing with the more complex integrated biosensors structures to highlight the concentration-current dependence, some extensions to the single cell modeling is possible (Ravariu[b] & Botan, 2008), e.g. the math model of the non-linear electrical conduction thru synapses, is a convincing argument to successfully move toward the cellular and tissual electrophysiology modeling.

3.2. Links for the BioNEC course in our faculty

In 2005 the announcement of a bioengineering discipline, entitled “3B course“, was proposed in our faculty and presented with the ocassion of ICL Conference, (Ravariu[c] et al., 2005). The electrical engineer students had the following related disciplines: electronic devices (pn junction, biodevices, contact metal-semiconductor, in II-nd year), physics (semiconductor physics, thermodynamic, cappilarity, in I and II-nd years), electrochemistry (Nerst relation, electrodes, in I-st year), programming (C++ language, in I-st year), microelectronic technology (depositions, diffusions, implantations, etching, in I-st and III-rd year), mathemathics (numerical methods, in II-nd year) and biology form the high-school.
The “3B” course was projected in a new manner: a course with an adaptive contents by the students feed-back; the contents must be adapted to the market and research trends. The evaluation consists in a homework with a high degree level for students. For instance, a student who studies at the communication department will be focused onto the bio-signals transmission or ECG-EEG parameter extraction. They will especially assist to those parts of the cours that covers the bio-signals collecting and processing. If a student is interested by the signal transmission at cellular level, his final work could be a software that simulates the inter-neuronal pulse propagation; he will deeply study the cellular electronic emerging toward neuro-electro- physiology.

3.3 A course motivation

This “3B“ course in conjunction with electrochemistry is easily associated to an electrical engineering specialization due to the implementation of these integrated biodevices in a microelectronics foundry. Another reason is the electrical behavior at the cell level: all cells are electrically charged in cytoplasm and present trans-membranar ionic conduction. The third reason consist in the trends for the electronical devices and sensors toward mixed bio - electrical devices. These tendencies are clearly shown in the changes of topics at a traditional Conference of microelectronics from USA : IEEE Nanotech – MSM *in 2000*: Semiconductors and Microelectronics, Advanced Packaging and Interconnects, MEMS, Smart Sensors and Structures, Advanced Lithography and Photonics, Biotechnology, Microfluidic Systems, Environmental Monitoring and *in 2005*: Quantum Effects, Quantum Devices (Ravariu[d], et al., 2005), Spintronics, Advanced Packaging and Interconnects, MEMS, Smart Sensors and Structures, Advanced Lithography and Photonics, Biotechnology, Genomics & Proteomics, Microfluidics & Lab on Chip, High Throughput Screening, Point of Care Diagnostics, Molecular Modeling, Protein Engineering, Structural Biology, Bioinformatics. A similar deviation occured with the ICNT – International Conference on Nanoscience and Technology from 2006 to present, (Ravariu[e] et al., 2006).

4. Evolution of the BioNEC mobile content

The BioNEC course is dedicated to the Biosensors, Biosignals and Biomodeling aided by electrical engineering. Placed at the cross-point of Biology and Electronics Engineering, this course, was firstly named "the 3B Course", but lately was accepted with the BioNEC acronym. Till now the BioNEC course keept his promise to be an interactive, an adaptive learning environment, which can be extended in the next future toward the great public, removing the psychological walls among a biologist, an engineer or others specialists.
In order to simplify the term, in the following discussion we will refer by the notations BioNEC1, BioNEC2 and BioNEC3 to the BioNEC course learned in the university year 2006-2007, 2007-2008 and respectively 2008-2009. In all these three years, the course schedule has 2 hours weekly, during 14 weeks. The main course sections are:
Chapter 1. Introduction in bioengineering.
Chapter 2. Biosensors.
Chapter 3. Biodevices.
Chapter 4. Biosignals.
Chapter 5. Nano-Electronics of Cells.
The first chapter had the following evolution:
- BioNEC1 describes the chemical and physical signal reception in the living beings as: "From the living cells to the biosensors principles". The motivation is related on the wealth course content about biosensors in the first year, besides to a pedagogical method to draw attention to something new, never before studied in a technical faculty. After one year, the space devoted to biosensors decreases and this presentation, strictly related to the reception and receptors, was moved at the second chapter beginning.
- BioNEC2 replaced the first chapter content with "News challenges in Bioengineering". The aim was to describe the entire topics of bioelectronics with its latest challenges, to capture the student's interests, to demonstrate them the large spectrum of interest in the nowadays academic space and to show them what slice of domain we are learning in our BioNEC course. On the other hand, I let them to elect a project them from the entire domain of bioelectronics in order to test their preferences and interests.
- BioNEC3 generalized the first chapter content to "Bioscience sections". I consider to introduce at the first course as much as possible material about the entire bioscience because the links among biology and sciences increase so much in the lasts years, so the BioNEC course with 2 hours x 14 weeks becomes insignificant. Therefore, I use the opportunity of the first course at least , to connect the students to the huge Bioscience domain, starting with Bioelectronics, Biomechanics and Bioinformatics enveloped in Bioengineering and continuing with the Biochemistry and Biomaterials, Biophysics and Biotechnology, and finishing with the extensions of the medical sciences toward technique, like medical imagistic, nano-cellular imagistic using AFM, neuroscience, nano-tools for manipulation in

genomics or proteomics, electrophysiology – from body to cell, prosthesis and in vivo devices, minimal invasion surgery, tissue engineering, nanomedicine.

In the second chapter the biosensors were studied; this activity will continue to rest in the top of the interests because our master study direction is about "Microsystems" and comes from the "Micro- Opto- Nano- electronics" specialization direction. The semiconductor technologies, the etched architectures in silicon, MOS devices, nanomaterials and microsensors are disciplines previously studied.

However, some deviations occur from a year to another. BioNEC1 approach: Biosensors – definitions & classes; transducers; receptors; small scale integration on biochip; specific technological steps for the biosensor manufacturing; transducer function modeling - from a chemical signal into an electrical signal; many examples of biosensors. An excess of information occurs about many types of transducers: optical, thermal, electrochemical, mechanical, biological intact in Ist year. The time constrains make me to remove the technology for biosensors that passed to another separate discipline, to include here the mechanism of reception in biosensor borrowed from living cells, and only to mention all the transducers and receptors types with a wealth examples of biosensors in BioNEC2. In this case too, the quantity of information was exaggerated. I consider that the deficiency comes from the axiomatic aspect of the course. All assertion must be admitted. The time for explanations, for links with the related disciplines was completely insufficient. Therefore, in the place of a wealth documented chapter about biosensors, without comprehension fundament, in the BioNEC3 stage I opted to restrict the Chapter 2 only to the electrochemical transducers, with a deeply insight on the metal-solution contact, which they never studied before in the Electronics Faculty. The focusing on the electrochemical transducers is justified because they represent the majorities transducers, encountered in conductometric, amperometric or potentiometric biosensors.

In the BioNEC1 stage, the third chapter contains elements about Bio-FETs Family, implantable devices, example of MEMS devices manufactured in the Si-technology (Grundbacher et al., 2009). In the first year the target was to disseminate as much as possible the Bio-FET devices to convince the audience about the possibility to apply the classical knowledge about MOSFETs to unsuspected applications from bioelectronics. As a fact, the, Ion Sensitive-FETs, Membrane-FETs, IMmuno-FETs, ENzyme-FET, Microbial-FETs, DNA-FETs were briefly depicted. The didactical materials concerning the implantable devices, prosthesis, insulin micropump were poorly. Thus, these devices were removed in BioNEC2. All the Bio-FETs transistors were equally approached in the IIst year with the same consequent disadvantage: crowding of information lead to low efficiency in learning. The BioNEC3 course rename the Chapter 3 from "Biodevices" to "Bio-FETs" and was focused mainly on ISFET, ENFET and those Microbial-FETs that involve just a metabolic ion detection with electrodes. In this way, the Chapter 3 becomes related to the Chapter 2 and is approaching the most encountered biodetection method that use the Field Effect Transistor with the analyte transformation into ions easily to be indexed in the gate space of a MOSFET. A short presentation of the kinetic modeling of an enzyme assisted reaction provides the key element to understand the BioFET principle that is missing in an Electronics Faculty curriculum.

The Chapter 4 started in the BioNEC1 case with the Biosignals transmission at cellular level. At that time, the notion of signal in biology was introduced as a variation of a chemical concentration versus time. At the beginning of the chapter 4, in the first year, the evolution of the matter from inorganic stage to the self-organized stage inside cell was introduced. This presentation had a good impact among engineers accustomed with Si and C as semiconductors, to discover the new alphabet of the living matter formed by 20 essentials amino-acids from C, O, N and H elements. This presentation occurs in every handbook of medicine at the beginning. Unfortunately the main enemy was the time. For this reason BioNEC2 and 3 can't sustain this presentation. The resting transmembranar potential (RP) and the cellular membrane depolarization up to the action potential (AP) as a consequence of an external stimulus recognition was learned. Starting from the cellular electrical signal studied at BioNEC1, the electrophysiological signals at the body level were added in BioNEC2, only as project theme and in BioNEC3 as theory, too. The cropping of ECG, EEG, EMG signals, cutaneous recording, modeling of the normal or deviated signals, specific amplifiers and filters used in electrophysiology and signal processing techniques were introduced in the BioNEC3 stage.

The Chapter 5, entitled "Nano-Electronics of Cells", intends to bring closer the extension of nanoscience from biology to engineering. Finally this chapter offer solutions, explanations and tools for the future medicine in its effort to observe the diagnosis and to start the body restoration from the cellular level.

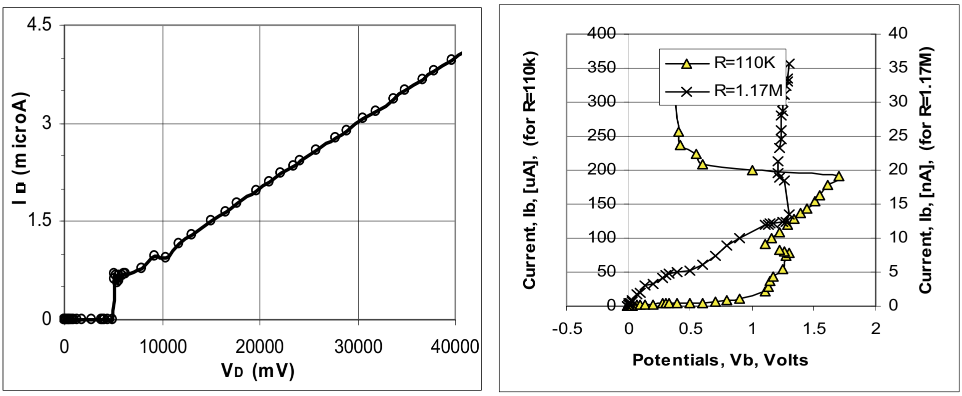
BioNEC1 spoke about nano-structures inside the cell, electronics phenomenon at membrane level and ionophore nano-channels. BioNEC2 enhanced the content with the trans-membranar electrical conduction modeling by Huxley circuit, simulations and modeling of the biosignal propagation, applications for the neuronal cell. This chapter had the maximum mobile content, in respect with the latest news collected from the web sites and accordingly with the encouragements constantly received from students. BioNEC3 comes with a new excitable cell for study: beta cell from the endocrine pancreas, responsible for the diabetes installation. Here the stimulus is biochemical (glucose) and the reply is electrical as in the neuron case: an action potential that depolarizes the membrane from -70mV to -30mV.

In both years, at the beginning of the BioNEC course, the students asserted a better affiliation to the Biosensors and Bio-FETs, probably due to a better relationship of these chapters with previous disciplines. Also in the firsts 1-2 courses they were very reserved versus the Chapters 4 and 5. But every year, the Cellular Nano-Electronics and intercellular biosignals produced the maximum impact on the students at the end.

5. The applications: lab and project

The applications consists in three laboratory works and three project meetings, the seventh metting being reserved for lab evaluation. The laboratory precedes the project and is destinated to closely accompany the course with some, experimental and simulation demonstrations. The experimental part is related to some previous experiments, coupled with knowledges borrowed form the "Electronic Devices" laboratory.

The first lab consists in the electrical characteristics measuring, for some biodevices with neurotransmitter solutions, Figure 1.a., in the same manner as for the pn junction. Figure 1.b reveals a new result for a two terminal biodevice with a hormonal solution (methyltestosterone). The non-linearity observed at this device is obvious. Another aspect is the curves reproductibility that is higher for methyltestosterone, versus neurotransmitters like adrenaline, (Ravariu[f] et al., 2007).

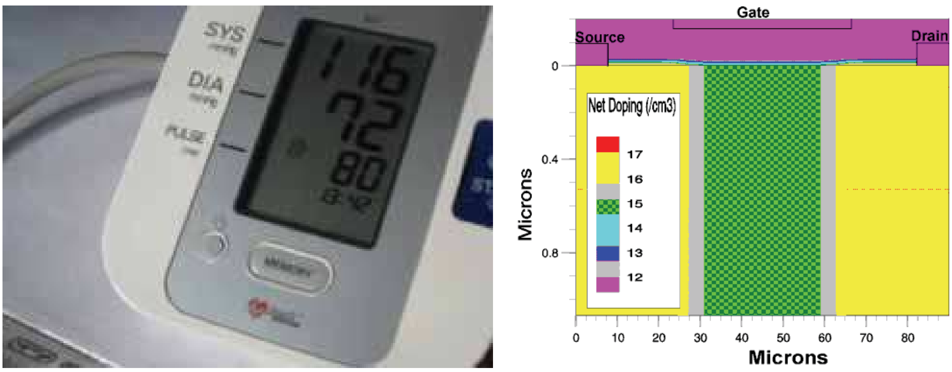


(a) (b)

Fig. 1. The current-voltage response of a test biodevice with: (a) oily testosterone solution; (b) adrenaline aq. solutions for a series resistance R=110kΩ or R=1.17MΩ

In the second lab the students learn to use some basic sensor and have to navigate on web in order to be familiarized with products, companies, and latests news in biosensors.

At the beginning of the second lab they learn to use a tensometer, Figure 2.a, with the normal and limit range for the human blood pressure or pulse, besides to a glucometer that includes a glucose biosensor as tester.



(a) (b)

Fig. 2.(a) The blood pressure measuring. (b) The doping concentration in a simulated BioFET

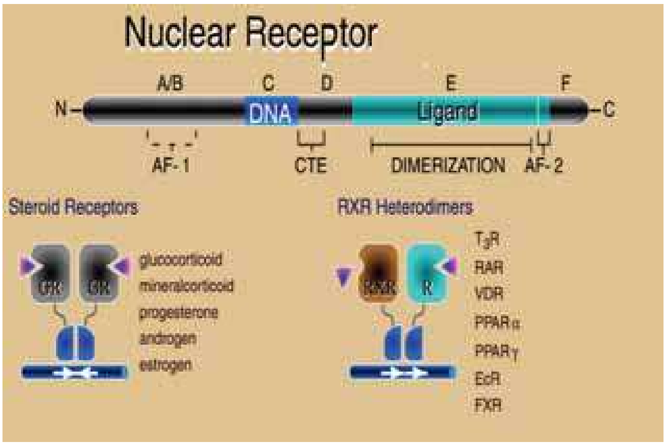


Fig. 3. Nuclear receptors are a class of proteins found within the interior of cells that are responsible for sensing the presence of steroid or thyroid hormones

In this picture for instance, the systolic pressure is 116mmHg, the diastolic pressure is 72mmHg and the puls is 80 / 1 min. Then will find out the work principle for some biosensors (metabolism sensors, afinity sensors, immuno sensors, microbial sensors). Every student will be deeply focused just on one type of sensor at the end of the lab. For instance the BioFET analysis can't be performed with the university endowment, and a theoretical study is poorly. Therefore some examples revealed on simulations become useful, Figure 2.b, because appeals to the visual memory – one of the most efficient gate of learning.
The scope of the internet navigation isn't only scientific, but in order to confront the results, to find out the latest news and products, to fill the market tendencies and to establish possible contacts with others research groups. This domain implies strong cooperation from different areas.
The third lab is destinated to the nano-electronics of cells. The students can select one theme at the beginning of the lab and the work is individual. This method has two aims: (1) to let a, large domain to be investigated in a short time on many directions, thinking that the students will discuss about their interesting informations after the classroom and (2) to find out the students interests in this huge domain, thinking that they have a keen filling of the academic trends, jobs opportunities, news in a domain. In this way, we hope to enhance next year the BioNEC course and labs by the students feed-back.
In the third lab they independently study about the signal transmission in cells, second messengers, endocrine, paracrine, juxtacrine biosignals; they can see some short films, microscopic images and they save in their file the results.
As an example, a student provides a wealth material about the nuclear receptors (Gronemeyer et al., 2004) – specific for steriods and lipophilic substances that penetrate the bilipidic cellular membrane, Figure 3.
The practical skill are continuing to be developed within the project. The students have the opportunity to select every theme that belong to Bioelectronics with the teacher supervision. The project subjects changed from a year to another. The themes were selected in the field of sensors, test biodevices, short software for diagnosis, or investigations in medicine (Ravariu[g], 2008).

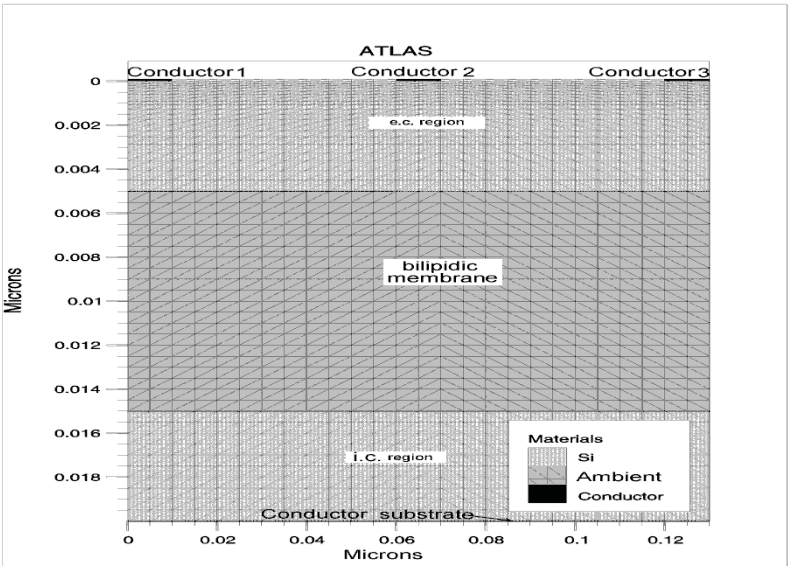


Fig. 4. Variant of membrane in vicinity of the e.c. and i.c. environment, beside mesh

As a first example is given a device simulation software available for biostructures analisys. Some simulations in the semiconductor devices environment software are available to test the potential distribution over the bilipidic membrane under Resting potential or Action Potential. In order to simulate the membrane as insulator, surrounded by the intra-cellular i.c. and extra-cellular e.c. environments with semiconductive properties, the structure from figure 4 can be adopted. The membrane was defined in the statements:

region,, num=1, y.min=0.005 y.max=0.015 material=ambient (lipid)

material permittivity=4.8 region=1

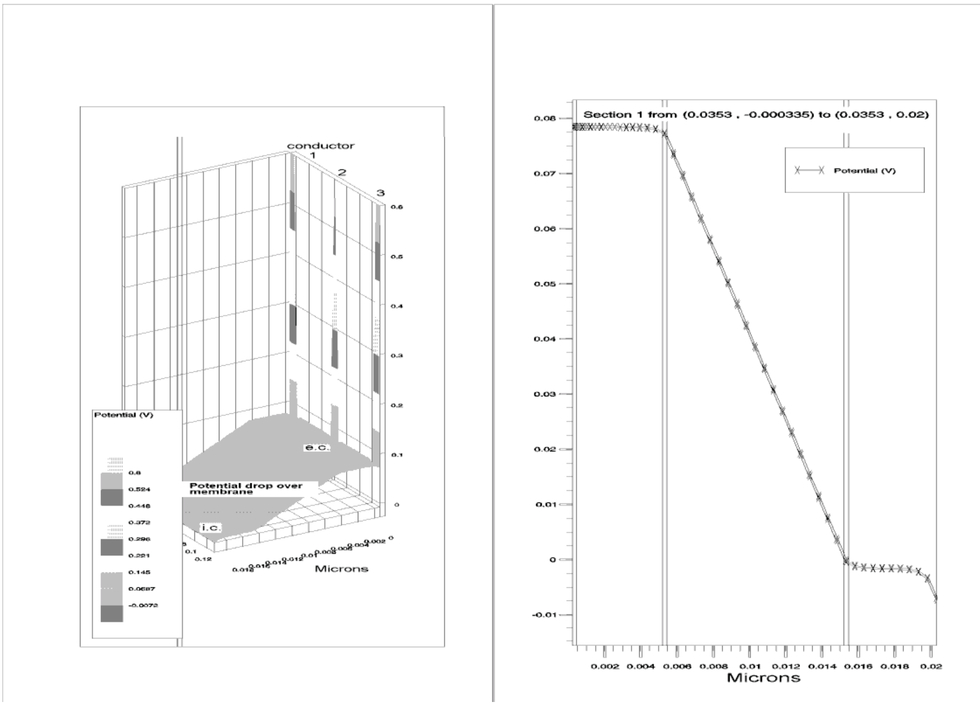


Fig. 5. Distribution of potential 2-D (left) and 1-D (right), when the Resting Potential PR = -0,078mV is spreading from the e.c. environment, toward the bilipidic membrane, up to the, i.c. environment

The Atlas library offers a finite list of semiconductors. Therefore, the i.c. and e.c. environments were simulated by Silicon layers with doping concentration about $9x10^{19}cm^{-3}$, accordingly with the K^+ concentration ~ 150mM, that means $150x10^{-3}$ mol/dm^3= $6,023x10^{23}$ x 150 x 10^{-3} ions / 1000 cm^3 = $9x10^{19}/cm^3$ positive electrical charges per 1 cm^3, equivalent with $9x10^{19}cm^{-3}$ holes concentration in semiconductor:

dopin uniform conc=9e19, p.type reg=2

Three electrodes are defined instead of three adjacent ionic channels: conductor 1, conductor 2, conductor 3, against the conductor substrate, Figure 4 and 5.
The electrical potential distribution is numerical computed by the Poisson equation solving, Figure 5. This figure reveals the additional effect of the contact metal-semiconductor, besides to the transmembranar potential drop.
These simulations can reveal the dielectric properties of the membrane in absence of some adequate endowments tools.

Fig. 6. First window opened by the patient, Step 1; at the end must "Continue"

As an alternative example, figure 6 presents the first window opened by a software, regarding a web-assisted diagnosis page, useful for human medicine, (Ravariu[h] et al., 2008). In order to produce a web Virtual E-Healthcare point, the following tools for a web application were used by students: PHP, MySQL, JavaScript, HTML and CSS.

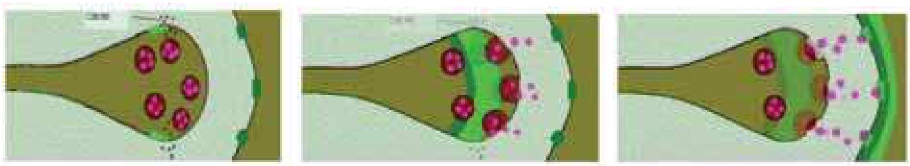


Fig. 7. Intermediates steps for the inter- neuronal electrical pulse transmission

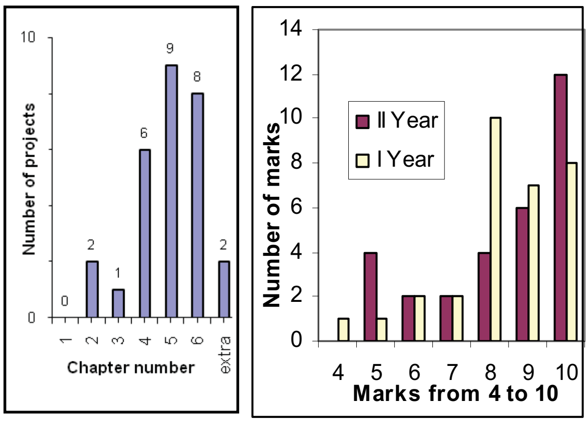
Another example, given by a student project from BioNEC2 stage, is representing an animation soft-ware for a better biological phenomenon learning in the nerves terminations. When the action potential – green zone – open the Ca-channels, the neurotransmitter exocytosis occurs, Figure 7.
These fields are preserved in the BioNEC3 stage, but the preffered topic is destinated to electrophysiology, starting with the electrical conduction in neurons and synapses level, noise rejection, filters used in physiological measurements.

6.The evaluation

The finnal mark represents an average between the score obtained at a final theoretical test (50%) and the score from the lab and project (50%). Sometimes, the project score was additionally awarded with some specials results as papers or communications of their materials in journals and conferences. In the theoretical test, the students have at least one free subject from one chapter. For instance, if the imposed subjects cover the Biosignals and Biodevices chapters, the free subject can be selected from Biosensors and Nano-electronics of cells.

6.1 The impact among students

At the beginning of the course, the students asserted a better affiliation to the Biosensors and Bio-FETs, due to a stronger relationship of these chapters with previous knowledge. Figure 8. a comparatively presents the preferences among topics from the selected subjects at the Project Homework of our students from BioNEC1 and BioNEC2 generation. Obviously, the Cellular Nano-Electronics produced the maximum impact on the students, (Rusu et al., 2008).



(a) (b)

Fig. 8. (a) The number of projects affiliated at some BioNEC topic (see the Chapter 1…5 contents at section 4 in this chapter). (b) The obtained marks

6.2 The evaluation results

The final score of evaluation consists in two percents: the project homework bring 40% and the writing exams 60%, Figure 9.b. We take into account the life problems of our students and let them to select the preferred domains in homework. Due to the free-choose subject from exam that doesn't cross with the imposed others, we had the opportunity to observe from their feed-back, the deficiency and strong points of the course. Strictly from the BioNEC course contents, the main deficiency is a quite exhausting approach. Therefore, more focused subjects were teaching in IInd year. The main attraction is the Cellular NanoElectronics. With the occasion of this part, they discover many bridges between biology and electronics, invisible at the beginning. For instance they don't expect to meet electrical conduction with a threshold electric field (~10^7V/m on a 7nm bilipidic membrane) to transmit the incident stimulus in the excitatory cells, likely in MOS devices. The electronics absolvent's rapidly find out the common language with nano-biology.

7. The BioNEC research group and perspectives

Around the BioNEC course, a research platform was developed, as a BioNEC group in the Faculty of Electronics. Besides to the Politehnica team, some external partnerships reinforce the research capacity, (Ravariu[i] et al., 2008). We discover a huge interest among the clinicians to find out the latest news in technique. In the Annual Congress of the Romanian Medical Association, they made us a constant chapter: biotechnologies, where they annually invited students from BioNEC course to present them some technical novelties.
Inside of this BioNEC group, some new tools to investigate some biological medium were developed: nanoporous material for new metabolic biosensors, the analysis of the non-linear responses of biosensors with tools borrowed from microelectronics – Non-Linear Electrical Conduction Theorem, a biodevice for neural cells investigations, specific biosensors technologies, (Ravariu[j] et al, 2006), (Babarada, F. & Ravariu, C., 2004).

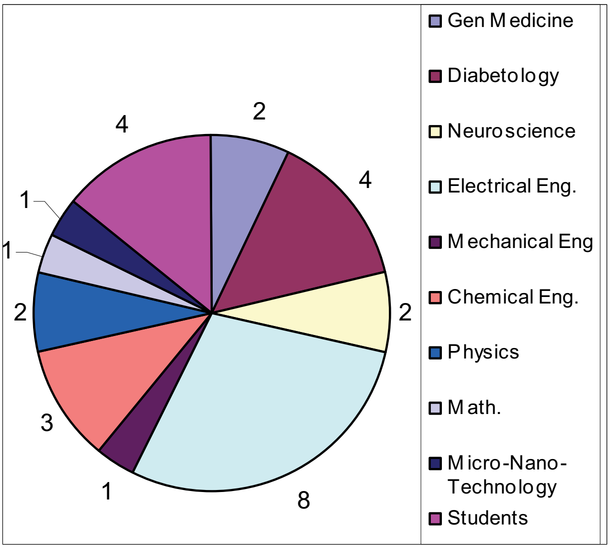


Fig. 9. The domains covered by specialists as percent area

The human resources in the BioNEC research platform consist in : 2 correspondent members of the Romanian Academy, 1 professor, 3 associated professors, 1 Principal Researcher I, 3 Principal Researcher II, 4 Scientific Researchers, 1 resident physicians, 1 young researcher debutant, 7 PhD students, 3 students, 2 masters students. They have the affiliation: P1 – Politehnica University Bucharest, P2 – Institute of Microtechnology, P3 - Institute V. Babes of anatomo-pathology, P4 – University of Medicine and Pharmacy Carol Davila Bucharest, P5 – private company. Figure 9 presents the complementary specialities covered by the persons with the BioNEC group affiliation.
International cooperation in research is stimulated in the BioNEC platform, by immediate links with similar area research centers: Carinthia University of Applied Sciences, Villach, Austria, Dept. of Medical Physics, School of Medicine Patras, Greece, EPFL Lausanne Swiss, Cambridge University, UK, multiple medical research internationals institutes of Diabetes.

The research directions available for the entire BioNEC platform are: monitoring in electrophisiology, cellular siganal recording and processing, Langerhans islands isolation for characterization and transplants, intercellular communications, biomodeling in living structures, contributions in neuroscience, e-healthcare and the list is opened.

8. Conclusions

Which are the targets of a Bioelectronics course? Firstly, a quantitative investigation in medicine, new tests, new medical protocols for diagnosis. Secondly, to prepare our students for the next future, that belongs to a convergence among sciences.

On the other hand, the internationals reports alert us that in the next years the medical assistance responsibility will move toward patients. Hence, the Learning process must be extended from the universities boundary toward the great public – the main beneficiary in the future.

A Bio-electrical engineering course was presented: BioNEC - Biodevices and Nano-Electronics of Cells. The course content is adapted accordingly with the students interest (e.g. market trends, possible jobs, academic area, some companies development). In the future, this course can be a started point for a large people scholarship.

The modern medicine is resting slave to a qualitatively description till nowadays. To succesfully pass toward a quantitative approach implies a strong collaboration with a physicist group. From electronics and electrochemistry, the bioscience gains the experience and those tools necessary to model the biological phenomenon; but their efficience must be immediately verified, in a collaboration with physicists and patients.

9. References

Eric, E. Nuxoll & Ronald A. Siegel. (2009). BioMEMS devices for drug delivery. IEEE Eng. in Medicine and Biology Magazine, Vol. 28, No. 1, Jan/Feb 2009, pp.31-39, DOI 10.1109/MEMB.2008.931105

Xu, Y; Xia, S; Bian, C & Chen, S. (2006). A micro amperometric immunosensor for detection of human immunoglobulin. Science in China Series F: Information Sciences, Science Press, Springer-Verlag GmbH, Vol. 49, No.3, June, pp. 397-408, ISSN 1009-2757

Ionescu-Tirgoviste, C. (2007). Diabetes, House Publ. Ilex, Book, pp.10-15, Bucharest, Romania, ISBN 973-709-313-4

Pearlman, J.; Cooper, R.A.; Krizack, M.; Lindsley, A.; Wu, Y.; Reisinger, K.D.;, Armstrong, W.; Casanova, H.; Chhabra, H.S. & Noon, J. (2008). Lowe-limb prostheses and wheelchairs in Low-income countries. IEEE Eng. in Medicine and Biology Magazine, Vol. 27, No. 2, Nov/Dec, pp. 12-23, DOI 10.1109/MEMB.2008.931105

Ravariu[a], C.; Rusu, A. & Ravariu, F. (2006). Interface electric charge modeling and characterization with <delta> - distribution generator strings in thin SOI films. Microelectronics Elsevier Journal, Vol. 37, No. 3, March, pp. 943-947, ISSN 0026-2692

Ravariu[b], C. & Botan, R. (2008). The Electrical Transport Mechanisms Investigation In Adrenergic Synapses Using A Parallel BioOI Biodevice, Proceedings of IEEE 19th Conference, Biosignal, pp. 63.1-63.4, University of Technology Vutium Press, ISBN 978-80-214-3613-8, Czech Republic, June 2008, Brno

Ravariu[c], C.; Rusu, A.; Ravariu, F. & Babarada, F. (2005). Bio-electrical-engineering: a strategic course with an European opening, Proceedings of ICL - 8th International Conference Interactive Computer aided Learning, pp.7.1-7.4, Kassel University Press, ISBN 3-89958-136-9, Austria, September, 2005, Villach

Ravariu[d], C.; Rusu, A.; Profirescu, M. & Ravariu, F. (2005). A Nano-Transistor with a Cavity, Proceedings of IEEE 8-th International Conference Nanotech-MSM Modeling and Simulation of Microsystems, Vol. 1, Chap.4, pp. 111-114, IEEE Soc. Press, ISBN 1-58488-465-7, USA, May, 2005, Anaheim

Ravariu[e], C.; Rusu, Al. & Ravariu, F. (2006). From Silicon On Insulator to the electrical characterisation of some Bio-solution On Insulator, Proceedings of 9-th International Conference of Nanoscience and Technology ICNT, pp. 206, ISBN: 3-905084-71-6, Switzerland, July, 2006, Basel

Grundbacher, R.; Hoetzel, J.E. & Hierold, C. (2009). MEMSlab: A Practical MEMS Course for the Fabrication, Packaging, and Testing of a Single-Axis Accelerometer, IEEE Transactions on Education Journal, Vol.52, No.1, pp. 82-91, Feb 2009, doi: 10.1109/TE.2008.919807

Ravariu[f], C. & Ravariu, F. (2007). A test two-terminals biodevice with lipophylic and hidrophylic hormone solutions, ISI Journal of Optoelectroncs and Advanced Materials, JOAM, Vol.9, No. 8, pp. 2589-2592, ISSN 1454-4164

Gronemeyer, H.; Gustafsson, .JA. & Laudet, V. (2004). Principles for modulation of the nuclear receptor superfamily. Nature reviews. Drug discovery, Vol. 3,, No. 11, pp. 950–964, ISSN : 1474-1776

Ravariu[g], C. (2008). The Feed-Back from a Biodevices and Cellular Nano-Electronics Course Learned in an Electrical Engineering Faculty, Proceedings of, IEEE 8-th International Conference on Advanced Learning Technologies ICALT, pp. 882-884, Editors: Paloma Diaz, Kinshuk, Ignacio Aedo, Eduardo Mora by IEEE Computer Soc., ISBN 978-0-7695-3167-0, Spain, July, 2008, Santander

Ravariu[h], C.; Tuhari, P.; Branzila, M.C.; Ravariu, F. & Botan, R. (2008). Diagnosys in medicine using Virtual e-Healthcare, Proceedings of 5-th Edition of REV International Conference - Remote Engineering and Virtual, pp. ST.1-ST.4, Kassel University Press, ISBN 978-3-89958-352-6, Germany, June, 2008, Dusseldorf

Rusu, Al.; Golescu, N. & Ravariu, C. (2008). Manufacturing and tests of a mobile ecg platform, Proceedings of IEEE International Conference of Semiconductors CAS 2008, pp. 433-436, IEEE Computer Soc., ISBN 978-1-4244-2004-9, Romania, Oct, 2008, Sinaia

Ravariu[i], C.; Sevcenco, A.; Auer, M.; Ionescu-Tirgoviste, C.; Ravariu, F. &, Babarada, F. (2008). The BioNEC Platform, Proceedings of International Conf. on Internet Computer Learning ICL, pp. Pa-4C: 1-4, Kassel University Press, ISBN 978-3-89958-353-3, Austria, Sept., 2008, Villach

Ravariu[j], C.; Rusu, A.; Udrea, F. & Ravariu, F. (2006). Simulation results of some Diamond On Insulator nano-MISFETs, ISI Diamond and Related Materials Elsevier Journal, Vol.15, No. 2, pp. 777-782, ISSN 0925-9635

Babarada, F. & Ravariu, C. (2004). Technology of fabrication for microsensors and biosensors, Printech Press, Bucharest, pp.179-258, ISBN 973-718-119-0, Romania

Advanced Learning

Edited by Raquel Hijn-Neira

ISBN 978-953-307-010-0
Hard cover, 444 pages
Publisher InTech
Published online 01, October, 2009
Published in print edition October, 2009

The education industry has obviously been influenced by the Internet revolution. Teaching and learning methods have changed significantly since the coming of the Web and it is very likely they will keep evolving many years to come thanks to it. A good example of this changing reality is the spectacular development of e-Learning. In a more particular way, the Web 2.0 has offered to the teaching industry a set of tools and practices that are modifying the learning systems and knowledge transmission methods. Teachers and students can use these tools in a variety of ways aimed to the general purpose of promoting collaborative work. The editor would like to thank the authors, who have committed so much effort to the publication of this work. She is sure that this volume will certainly be of great help for students, teachers and researchers. This was, at least, the main aim of the authors.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821