Innovation in Electric Engineering Education through the Introduction of the Hybrid Integration in the Experimental Lessons

Edita Hejátková[1], **Ivan Szendiuch**[2]

[1] *BUT, FEEC, Department of Microelectronics, CZ- 616 00 Brno, hejatka@feec.vutbr.cz*
[2] *BUT, FEEC, Department of Microelectronics, CZ- 616 00 Brno, szend@feec.vutbr.cz*

Abstract

This paper describes not only the basic principle of the technology of hybrid integrated circuits, but also how such technology can be utilized at the high school in the education process with the necessary focus to introduce basic principles of integration. The estimated costs for simple configuration are also demonstrated. The curriculum for Bachelor and Master Study programs are presented at the Faculty of Electric Engineering and Communication (FEEC) of the Technical University in Brno. The contents of the contribution can be useful and helpful to all who are thinking about improving of quality in the teaching process in this area by means of laboratory assignments. Based on previous experience, the aim of this would be to increase student motivation and also improve their access to this field of study through practical skills. Because this experimental learning process brought a very positive response from students in addition with new ideas in technical solutions, the intention is to use these labs also for the research activities of the Central European Institute of Technology (CEITEC), which is built as part BUT the financial support of the European Union. [1]

Keywords: *Experimental lessons, Hybrid Integrated Circuit (HIC), Electric engineering education.*

1. Introduction

Experimental teaching in the laboratory is the most effective form of education. This statement is the result of a long time survey students' opinions on Brno University of Technology (BUT). It allows instantly transforming theoretical knowledge into practical skills and developing students ‘abilities for the application in practice. One of the main areas for all branches of education in electrical engineering is the electronic hardware, which is created on the basis of the microelectronic technologies. The problem of experimental teaching in the field of Microelectronic technologies is currently expensive electronic equipment and appliances, whose workload is not sufficient, as in the normal production process. It is easy to work with PC or measuring instruments, but much more difficult is to implement the technological processes with concrete outputs, such as integrated circuits. One of the ways to implement the active participation of students on the realization of integrated circuits with low cost is the acquisition of hybrid thick film technology (HIC). This technology allows realize integrated circuits through non-vacuum processes without the requirement for clean rooms and other additional costs, which are necessary for the semiconductor technology. In this way, students can practically verify the basic principles and laws of modern microelectronics and take home the integrated circuit, which themselves have designed and made.

Hybrid integrated circuit (HIC) is miniaturized electronic circuit composed from individual devices, which are realized by various technologies as heterogeneous system. The basic and most utilized configuration of HIC is the passive network realized through thick film technology by screen printing, which is combined with semiconductor devices and other chip components [2]. Generally HIC´s offer to build through non vacuum processes various configurations, from simple circuits to high level integration structures like multichip module (MCM), Chip Scale Package (CSP), System on Package (SoP) etc. This involves knowledge from many technical areas, as materials, electronic components, electronic processes, semiconductors and also designs of electronic circuits etc. Curriculum for the Master study subject “Modern microelectronic technologies” is shown in Figure 1.

The most important fact is that this technology allows for tactile and visual access to the individual parts. So it is possible to perform various measurements directly inside an integrated circuit on the individual components such as resistors, capacitors, transistors and integrated circuits including semiconductor chips.

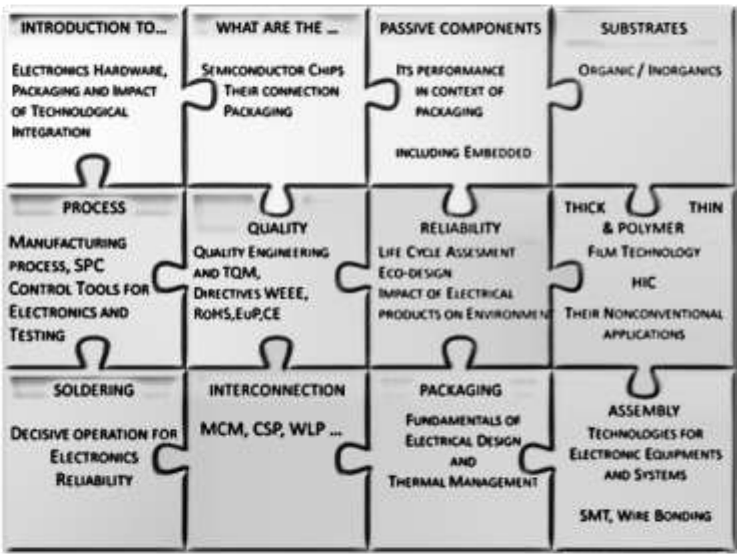


Figure 1. Modern Microelectronic Technology Curriculum.

The main part of the contribution is contained in chapters 2 and 3. Chapter 2 describes basic principle of thick film technology, which enables to realize integrated circuits through non-vacuum process. The cost for simple line producing HIC is about one tenth of cost for equipment producing semiconductor integrated circuits (approximately less than 40 k€). In chapter 3 is described experimental curriculum compiled for an experimental lessons.

2. Thick Film Technology and Process

Microelectronics is composed of several different technologies, which can be classified as semiconductors, thick/thin layer, polymers and discrete parts. Semiconductors are very small (µm, nm) and discrete to large (mm, cm). Between these two groups are the film technologies, which consists of thick and thin layers. An important segment in microelectronics is thick film technology in combination with semiconductor and discrete components. It is a low-cost technology, which uses the non-vacuum processes. This process allows both large and small volumes realization of integrated circuits with very favorable competitive economic results. This means that it gives the possibility to implement a single integrated electronic circuits with low cost.

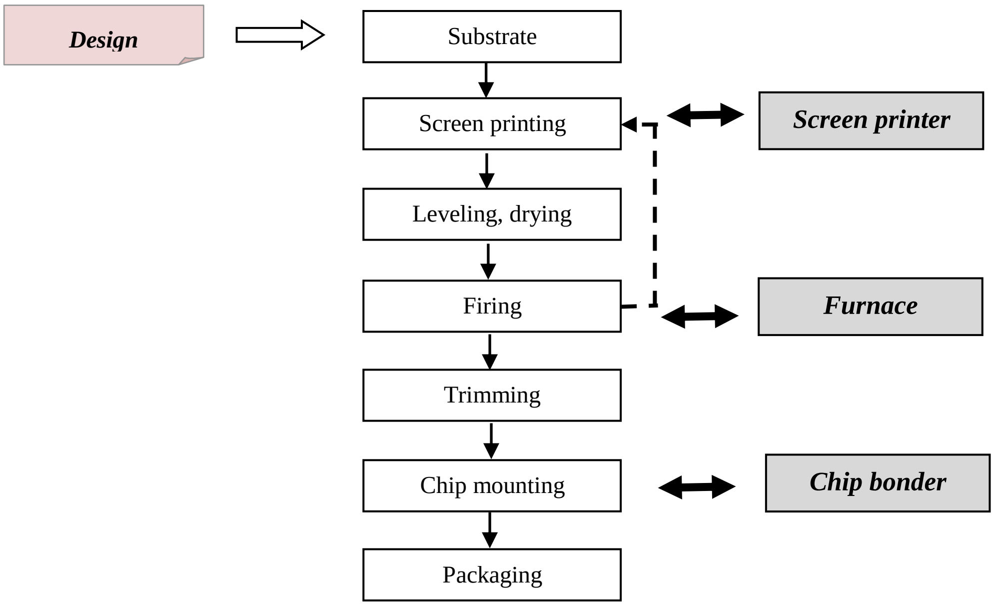


Figure 2. Technology process for realization of HIC.

Thick film technology was developed during World War II for military applications [2] and conventional HIC´s comprised the first generation of this technology. Second generation is born some decades later in the form of non-conventional applications, as sensors, actuators, antennas etc. In this paper is presented the next new possibility for utilizing, which is the experimental educational process for high schools and technical universities. Thick film process consists of a number of simple steps which are repeated several times. These main steps, which need special equipment, are only three. Deposition of thick film pastes through the screen printing, burning of deposited thick film paste in the oven at 850 ºC (firing) and mounting chips through using ultrasonic wire bonder. The complete thick film process is shown in Figure 2. More detailed thick film process is described in [2]. As indicated in the figure, the process of creating thick layers structure in electronics consists of a series of operations that may be repeated multiple times.

In summary, thick film process is complementary to semiconductor integrated circuits technology. HIC with using semiconductor chips, which are mounted on a ceramic substrate must be protected to environment. Packaging becomes special part of the modern microelectronics that comprises besides knowledge of production processes, other electrical engineering subjects, as signal and power interconnections, and principles of thermal management, requires acquaintance with a quantity of data related to materials, processes, electronic circuits and testing. [3] Students must understand the connection between these areas. They must be familiar with all phases of the life cycle of each product, so that they can assess the quality of the questions and also the impact on the environment. The advantage of this technology is very good availability and visibility of individual components, which enables user-friendly measurement and testing.

3. Experimental curriculum

HIC is a miniature integrated electronic circuit composed of the individual components, which are implemented through a variety of technologies in a heterogeneous arrangement. There is a good possibility to organize a demonstration in visible configurations, where you can monitor electrical effects. The basic and most utilized configuration is thick film passive network combined with semiconductor devices and other chip components that are assembled on the ceramic substrate as shown in the Figure 3. There are also documented thematic areas, which relate to the implementation of the HIC.

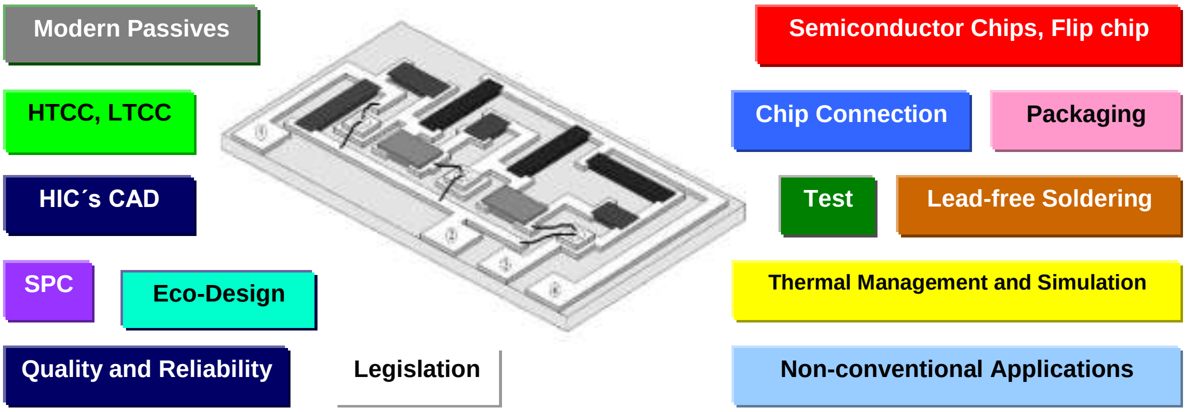


Figure 3. View on HIC and technical areas closed to its design and realization.

In general usage, offers the HIC when you need some special integrated configuration lead to the maximum possible miniaturization, such as multichip module (MCM) or system on package (SoP), etc. [3] Other possibility that offers hybrid thick film technology are non-conventional applications, where is large field of use for various applications.

The most important of course is the availability of all the areas in the available conditions and the ability to handle and measure the actual components such as semiconductor chips, SMD with integrated passives, etc. There is a possibility to prepare samples for measurement and experiments for the following practical and experimental topics relating to the process of integration:

- Substrates for integration process (comparison of organic PCB with inorganic alumina – insulating resistance, thermal conductivity, coefficient of expansion)
- Conductive network design and realization (screen printing and firing of thick films, gauge of conductivity and resistivity, cross-talk, parasitic features)
- Integrated (embedded) resistor realization (nominal value and tolerance, sheet resistance, temperature coefficient, power rating)
- Integrated (embedded) capacitors (monolithic ceramic, nominal value and tolerance, temperature coefficient, maximum voltage, quality factor)
- Integrated (embedded) inductors (inductance range and performance of layer configuration)
- Trimming of passives by laser (adjustment of resistivity values and influence on features)
- Semiconductor chip connection (mounting and wire bonding (thermo-compression, ultrasonic and thermo-sonic wire bonding, mounting of surface mount devices – SMD)
- Packaging (mounting of leads by lead free soldering, protection of integrated circuit by various techniques – fluidization, dispensing and molding, insulating resistance and parasitic parameters)
- Solder and soldering process (solder alloys, fluxes, soldering methods, solder joint assessment – quality and life cycle).

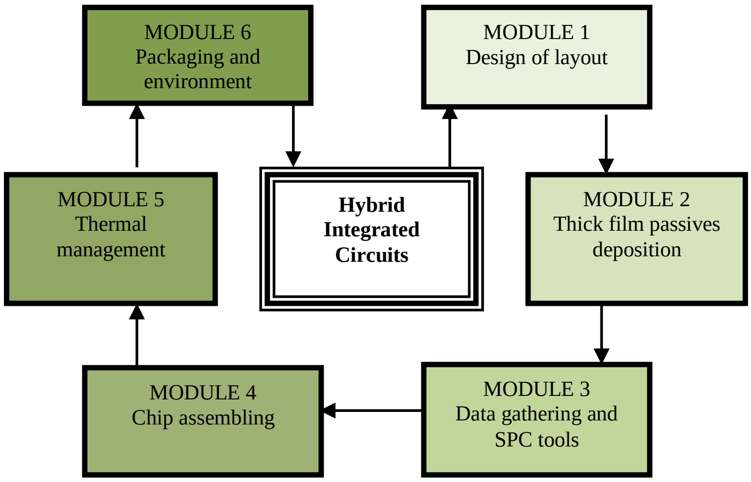


Figure 4. View on HIC and technical areas closed to its design and realization.

In the Microelectronics department at FEEC BUT was organized this laboratory exercise as part of subject "Modern Microelectronics Technologies", which is optional subject for Master study program for branch Microelectronics and for the branch Electrical Manufacturing and Management. Likewise this subject is open for other branches, and especially is recommended for Biomedical and Ecological Engineering, for branch Electronics and Communication, and for Power electrical and Electronic Engineering.

The organization of laboratory exercises contents during semester period altogether 26 hours, which are divided in six modules, each lasting 4 hours (Fig.4). Single modules are following:

- MODULE 1: Design of proposed HIC using Eagle and HYDE CAD, screen mesh selection, mask and screens preparation, emulsions for realization of printing pattern.
- MODULE 2: Thick film screen printing and the viscosity measurement. Importance of the drying process and the layer thickness measurement. Thick film firing and the effect of the firing cycle on conductor adhesion.
- MODULE 3: Statistical evaluation of the nominal values of resistors and resistors trimming. Measurement of the sheet resistance and the temperature coefficient. Evaluation of process errors which influence quality, quantification of errors and fixing acceptance standards.
- MODULE 4: Assembly of SMD and chip components, SMD capacitors and inductors, semiconductor chip mounting and connecting by ultrasonic, thermocompresion and thermosonic wire bonding.
- MODULE 5: Heat dissipation measurement using thermo vision system. Modeling and simulation of the thermal behavior in ANSYS. Case studies in cooling system design.
- MODULE 6: Packaging, soldering and leads connection, conformal coating by dispensing and fluidization, insulation resistance measurement. Material identification, analyze and ecological evaluation of e used materials.

Students work from each exercise short protocol, where collected data are processed and evaluated. The arrangement of the modules corresponding to the theme of the theoretical teaching of the subject of the lectures.

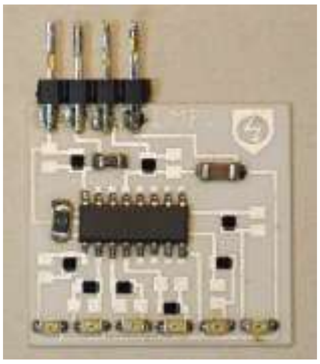
 a)  b)

Figure 5. Examples of HIC´s realized in lab a) passive resistor network b) functional HIC.

As the example are shown in Figure 5 two integrated circuit patterns realized for this experimental education process. In Fig.5a is the passive resistor network, which serves directly for demonstration and utilization in three modules. For the film resistor design process with sheet resistance calculation, for the explanation of screen printing process with adjustments of its parameters and for the statistical evaluation of processes with calculation of Gauss distribution. All of these procedures are commonly used in practice in the design and construction of new circuits. Fig.5b shows example of HIC, which was designed, realized and tested by students during their course in laboratory.

The lab exercises are in some cases supported with e-learning system and in some case also through virtual lab modules [4], especially where this process is some demanding one. The virtual lab module helps to understand microelectronic technologies in process. User is able to study these processes alive. Animations are supplied with description of appropriate technology process. As example Figure 6 shows frames of selected microelectronic technologies animations for connection of chip by ultrasonic wire bonding process.

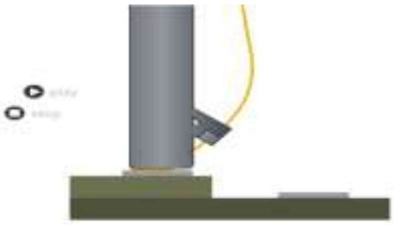
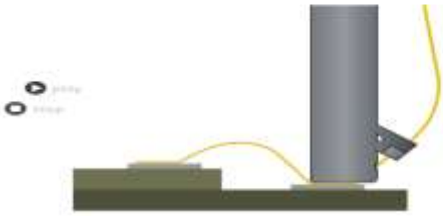
 a)  b)

Figure 6. Ultrasonic wire bonding a) frame A b) frame B [6].

4. Conclusion

Interconnection and Packaging, where thick film technology plays the important role, is one of fundamental areas of actual research and development in microelectronics. [5] That is reason to push this also in education of electrical engineering. The approach presented in this paper is a possible innovative way. It shows how graduates in Microelectronics should be provided with the general skills, which are needed to design, produce and use of integrated circuits, systems and devices for different sectors of electronics. Besides of the knowledge in circuit theory it is necessary for graduate students to have good knowledge also in materials and manufacturing processes Described experimental curriculum, which makes the part of subject “Modern microelectronics technologies” in Master study program, has a strong impact on the learning practical skills in microelectronics technology. This area of rapid development of integration technologies still occupies multiple disciplines, and this is the reason why it must be constantly updated. The innovation process requires to create ever more creative and comprehensive course content So this helps to graduates to improve the ability adapt the needs and priorities of their future employers in various sectors of electronics, as specialists for various positions in microelectronics and technology, design and manufacturing of integrated circuits, electric devices, service and

maintenance of sophisticated electronic and electric systems etc. Deeper skills can help graduates to apply on top of technical, operational and managerial positions.
The main benefit from innovation is the fact that students have opportunity to transform immediately their theoretical knowledge in practical skills. Laboratory exercises are organized in four-hour blocks, which provide sufficient time for the adoption of their own skills.

5. Acknowledgements

Funding for this research work was supported through project of EU EUREKA Euripides no. EUR-10-101 "Board on Board Technology" signed LF13007/OE 1830 1001 and grant project of the Czech Ministry of Education for Brno University of Technology FEKT-S-14-2168 "Research of modern innovative technologies for microelectronics packaging and interconnection".

References

[1] R. Vrba, CEITEC - Centre of Excellence in Life Sciences, Advanced Materials and Technologies to Improve the Quality of Life and Human Health, Proc. EMPC-2011, 18th European Microelectronics and Packaging Conf., pp. 12-17 September, Brighton, 2011

[2] M. Haskard and K.Pitt, Thick Film Technology and Applications, Electrochemical Publications Ltd., Isle of Man, 1997

[3] R. Tummala, Fundamentals of Microsystems Packaging, McGraw-Hill, New York, London, Sydney, Madrid, Lisbon, Milan, San Juan, Seoul, Mexico City, Toronto, 2001

[4] C. Vasko, I. Szendiuch, M. Novotny, Virtual Laboratory of Microelectronic Mounting and Packaging, Proc. IECC International Conference on Engineering Education, 3 – 7 September, 2007, Coimbra

[5] CH. A. Harper, Electronic Packaging and Interconnection Handbook, McGraw-Hill New York, London, Sydney, Madrid, Lisbon, Milan, San Juan, Seoul, Singapore, Sydney, Toronto, 2005

Authors

Principal Author: Ivan Szendiuch holds a Master degree in Electrical Engineering from the Brno University of Technology and PhD degree the same. He joint Tesla Company 1n 1969 and in period 1992-2008 he was managing director in Vemer Ceska Group Company. In 1990 he became Assoc. Professor and in 2007 received in San Jose Fellow IMAPS. Actually is Associate professor on Microelectronics department at FEEC BUT.

Co-author: Edita Hejátková holds Master degree in Electrical Engineering from the Brno University of Technology. She is presently an assistant at the Faculty of Electrical Engineering and Communication. She is specialized of electrotechnology branch and at the same time she works as a student's adviser at FEEC BUT.