The New Degree in Materials Engineering at the Technical University of Madrid (UPM)

J.M. Atienza, G. V. Guinea, M. Elices
Department of Materials Science
Technical University of Madrid (UPM)
Madrid, Spain
jmatienza@mater.upm.es

Abstract — **The Technical University of Madrid (UPM) is pioneering the introduction in Spain of a new Degree in Materials Engineering, with a four-year duration, accessed directly from the baccalaureate-level studies. The materials engineers from the UPM will be prepared to meet the challenges not only in the field of structural materials, but also in functional materials and biomaterials. With the objective of enhancing student exchange programmes, the third year of studies will be taught entirely in English.**

Keywords: Materials Engineering, Degree Programmes

I. INTRODUCTION

The ability to manipulate, understand and use innovatively materials is an important measure of the sophistication of a civilisation. Our lives are enhanced and restricted by our relationship and ability to use materials effectively.

Materials engineering is an interdisciplinary field that studies the relationship among the structure of materials at atomic or molecular scales, their macroscopic properties, their processing and their applications. Materials scientists and engineers help to develop the materials required for new products, find better lower-cost manufacturing routes, and enhance the performance of existing materials. They consider the environmental impact and sustainability of their products. They discover how to optimise the selection of materials and create sophisticated databases from which properties and service behaviour can be predicted.

The study of materials engineering has for many decades been established across the economically-developed world. The academic study of materials encompasses aspects of the physical sciences and of engineering, with two central themes: the link between structure and chemical, physical and mechanical properties; and how control of microstructure through processing can be used to optimise engineering performance. The range of programmes to which this benchmark statement applies is diverse and extends from science-based to engineering-based programmes.

In this paper, the new Degree in Materials Engineering that the Technical University of Madrid (UPM) has started in 2009 is described. First, the scientific and engineering related knowledge and skills of Materials Engineering discipline are analysed. After that, characteristics of the Materials Engineering programmes at present in Spain and the rest of the world are revised, and finally the main features of the new Degree at the UPM are exposed.

II. THE MATERIALS ENGINEERING DISCIPLINE

Historians have categorised the early ages of humankind in accordance with the materials utilised, with the emergence of the terms Stone, Bronze and Iron Age. In more contemporary times both concrete and steel have arrived, with the latter material being at the base of the industrial revolution.

The field of materials engineering began to be considered as a discipline in itself around the mid-1960s. At first, many materials science departments were named metallurgy departments and focussed their research and teaching on metals.

Yet if there were a material that could be said to have characterised the second half of the twentieth century, such a material would be silicon. Silicon is the *steel* of the semiconductor industry [1]. As steel allowed the industrial revolution to transform the more advanced countries of the time, silicon has provided the support that has enabled information technology to transform the contemporary world.

Developments in silicon have shown that materials engineering was not merely the legacy of metallurgy or even that of structural materials. There is no doubt that the field of structural materials engineering has a significant part to play in the aerospace, automotive and energy sectors. But, in addition, the area functional materials, those without a resistance function, cannot be overlooked, in particular those linked with the area of electronics (the next revolution in information technology will use light to transport and amplify information through photonic materials), as well as in the production of *clean* energy (materials for solar cells and fuel cells will be essential for the development of such *clean* energies) [1].

However, equally important is the development of biomaterials in the assessment, cure and replacement of organs and tissue. The dawn of a new age has been reached, one which has been termed the age of biomimetic materials. Materials will be developed that are able to "mimic" the properties and processing of biological materials. Previously little known nouns such as hierarchical microstructure and self-assembly will serve as basic terminology for the materials of the future. Furthermore, nanotechnology – applied to the field of

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biomaterials – is providing new approaches in the design of materials that will permit diagnostic and therapy techniques which will revolutionise healthcare.

In the 21st century, the field of materials engineering has been broadened to include every type of materials, including ceramics, polymers, semiconductors, magnetic materials, medical implant and biological materials.

III. Materials Engineering Programmes at Present

With significant media attention focussed on biotechnology and nanotechnology, in recent years materials engineering has been propelled to the forefront at many universities.

The study of materials engineering has for many decades been established across the economically-developed world, in particular in the member states of the European Union, in the United States and Japan [2]. In these countries, the degree in materials engineering – undertaken by students who have completed baccalaureate studies – provides graduates with a high level of professional competence throughout its four-year duration.

The preparation of the syllabus of the new Degree in Materials Engineering at the UPM has involved consultation with more that 70 European institutions and more that 40 private and state universities in the United States [3]. In the latter, a country which boasts more than 20,000 qualified materials engineers, these professionals occupy a leading place in the annual salary ranking that spans the different fields of engineering [4].

In comparison with other developed countries, in Spain the materials engineering degree course is a relatively recent programme. The UPM was the first institution to introduce an upper-level degree in the field in 1995 [3]. To be accepted to the course a prerequisite of three years of studies in another area of engineering was set. The orientation of the course was to structural materials, evolving from metallurgical engineering. At present, this upper-level degree is taught in another 14 universities across Spain. Since the first students of engineering materials graduated in 1998, more than 10 years of running the course have allowed alumni to access excellent career opportunities in all fields of engineering.

IV. The New Degree at the UPM

With the arrival of the Bologna Process and reform and adaptation of higher education in Europe, in Spain the UPM is once again a pioneer institution in the introduction of a new post-baccalaureate, four-year degree course in materials engineering [5].

The degree programme is measured in accordance with the credits awarded by the new European Credit Transfer and Accumulation System (ECTS). Considering one ECTS credit to involve 25-30 hours of study, the new Degree in Materials Engineering will entail 240 such credits, structured over four academic years (eight semesters) of 60 credits each one (30 credits per semester). Under such a structure a final-year dissertation or end-of-degree project (equivalent to 12 credits) will be undertaken.

The objective of the new programme is to provide engineering graduates with an interdisciplinary technical preparation, seeing them equipped to work with any type of material (biological, ceramic, metallic and polymer), and primed with a high capacity to adapt, both in terms of research and in development and innovation. In a rapidly-evolving world, the materials engineer will have to know how to model (to extract the characteristic parameters of a given situation), design (both new material and structural elements) and possess multidisciplinary knowledge.

The course involves a forward-looking curriculum in which students acquire knowledge of the three main branches of the field of materials: traditional structural materials, but also functional materials (semi, dielectric, optical conducting and magnetic materials used to create integrated circuits, storage media, sensors and other devices) and biomaterials (materials that interact with biological systems; materials of biological origin; and biomimetics) [5].

Basic skills

On account of its content and orientation, the Degree in Materials Engineering will be attached to the area of knowledge of Engineering and Architecture, including a total of 60 ECTS credits of basic subjects of such an area (see, Table I). The primary topics include acquisition of knowledge and skills in mathematics, chemistry and physics, as well as biology in order to support aspects of biomaterials programmes. Economy and Industrial Process Management has also been included. These subjects will be studied in the first two years of the programme.

TABLE I. Basic Subjects

Subject	ECTS
MATHEMATIC	12
ELECTRICITY AND MAGNETISM	6
ESSENTIAL CHEMISTRY	6
MECHANICS	6
THERMODYNAMICS	6
BIOLOGY	6
QUANTUM PHYSICS	6
SURFACE CHEMISTRY	6
ECONOMICS AND INDUSTRIAL PROCESS MANAGEMENT	6

Clearly, skills in maths and physics are a requirement for filling the pipeline of future engineers. It may seem logical to teach the foundational concepts for an engineering problem first, and only then introduce the engineering task. In many ways, the traditional engineering curriculum follows this model. However, the "basic first" approach is a poor instructional strategy at present [6].

Several studies have shown that it is expected the number of students who enter engineering programmes in college is projected to drop. To address this problem, new motivators are urgently needed, and engineering design activities is one of them. Introducing engineering problems from the first courses could help to create a powerful motivation for learning relevant science, and improve the interest in engineering careers.

In the new degree programme efforts have been made – from the very first semester – to involve students in working with the nucleus of materials discipline: that is to say, in knowing how to associate the structure of materials with their properties (Table II). Property and structural synthesis is carried out as early as possible in the programme, which is something that has a bearing both on the design of the material and on that of the structural element.

TABLE II. SUBJECTS INTRODUCING PROPERTIES-STRUCTURE DESIGN ACTIVITIES

Subject	Semester Schedule
STRUCTURE OF MATERIALS I	1st
STRUCTURE OF MATERIALS II	2nd
METALLIC MATERIALS	2nd
CERAMIC MATERIALS	3rd
POLYMER MATERIALS	3rd
SOFT MATERIALS	3rd

General and transversal skills

General (or transversal) skills identify shared attributes (in any degree course) which are considered to be of importance, whether by graduates or employers. Such general skills are distributed among three large groups:

- IT skills (use of information and communication technology)
- Communication and interpersonal skills (oral and written communication, organisational capacity, ability to work in a team, leadership skills, capacity to work in an interdisciplinary manner, ability to take on responsibility, and professional ethics).
- English language skills

All such skill sets, including the English language, will be taught and graded (as there will not be a specific module to cover them) in a horizontal manner, shared between all the subjects. Specifically, teaching in the English language will be deemed a priority, given its lingua franca position not only in science and technology but also in business and economic development. Consequently, the third year of teaching will take place entirely in English.

Itinerary: Specialties

Training in materials engineering requires a multidisciplinary and polyvalent approach, in the sense that the graduate will learn the foundations and applications of materials in three extensive fields: material structures, functional materials and life-science materials. Consequently, the subjects of the syllabus have been structured in a way that these three areas appear in obligatory study, both in their most fundamental aspects and in their applications, covering the necessary study needs of all graduates.

However, in order to address the complexity and specialisation of the three above mentioned areas, the syllabus will involve a specific approach, through three blocks of optional subjects taken mainly in the fourth year. Each such block marks a well-defined itinerary under which students will have to choose five subjects of a total of 24 ECTS credits. The three blocks are described in Tables III, IV and V:

TABLE III. ITINERARY: STRUCTURAL MATERIALS

Subject	ECTS
OBTAINING MATERIALS	6
SAPHE PROCESSING	5
MATERIALS ANALYSIS AND TESTING	5
JOINING TECHNIQUES	4
METALLIC MATERIALS III	4
BUILDING MATERIALS	4

TABLE IV. ITINERARY: FUNCTIONAL MATERIALS

Subject	ECTS
WORKSHOP ON FUNCTIONAL MATERIALS: STRUCTURAL	6
ADVANCED MATERIALS FOR OPTOELECTRONICS	5
ADVANCED MATERIALS FOR MICROELECTRONICS	5
WORKSHOP ON FUNCTIONAL MATERIALS: ELECTRONICS	4
WORKSHOP ON FUNCTIONAL MATERIALS: OPTICS	4

TABLE V. ITINERARY: MATERIALS FOR LIFE SCIENCES

Subject	ECTS
BIOMIMETICS	6
BIOMECHANICS	5
BIOSENSORS	5
ENGINEERING OF CELL MATERIAL	4
TISSUE ENGINEERING	4
WORKSHOP ON BIOLOGICAL MATERIALS AND BIOMATERIALS	4

Exchange programmes with other institutions

One of the primary objectives of the European Higher Education Area (EHEA) is to open education systems to free movement of students. In this sense, a primary objective considered for the new degree has been that of enhancing student exchange programmes with other European higher education institutions.

The third and fourth years of the new Degree have been open to exchange programmes, and specially important is that the third year will be taught entirely in English (Tables VI and VII).

TABLE VI. SUBJECTS TAUGHT IN ENGLISH IN THE FIRST SEMESTER (SEPTEMBER-JANUARY)

Subject	ECTS
MECHANICAL BEHAVIOUR OF MATERIALS III	6
PROPERTIES OF MATERIALS	6
COMPOSITE MATERIALS	6
NUMERICAL SIMULATION	6
OBTAINING MATERIALS	6
WORKSHOP ON FUNCTIONAL MATERIALS: STRUCTURE	6
BIOMIMETICS	6

TABLE VII. SUBJECTS TAUGHT IN ENGLISH IN THE SECOND SEMESTER (FEBRUARY-JUNE)

Subject	ECTS
QUALITY AND QUALITY MANAGEMENT	6
MECHANICAL BEHAVIOUR OF MATERIALS	6
NANOTECHNOLOGY	6
SURFACE ENGINERRING	6
RECYCLING OF MATERIALS	6

V. CONCLUSIONS

New materials have played an essential part in providing technology needed for scientific development, which has in turn brought great benefits to society. For this reason, empowering students in materials science and engineering is one of the paramount long-term investments that can be made in the technological future of a nation.

The first lectures of the new Degree in Materials Engineering at the UPM commenced in September of the academic year 2009-10, with the course being 100% subscribed.

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