# Investiture Lecture for Honoris Causa Dr. of Craiova University

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First, I wish to thank Professor Mangra, the Faculty of Engineering and Technological System Managing, the Senat of the University of Craiova, chaired by his Rector, Professor Dr. Ion Vladimirescu my nomination for Honoris Causa Dr. This nomination honors me and makes me feel honored and identify me with the University of Craiova, which gave the award to me as well as the doctor's senat, which I belong to from now on. To this country, Romania, where I have so many friends, and where I have spent a lot of time working, discussing, and enjoying the friendship and landscape.

I want to thank also my family, my wife Ana, and my children Mario and Rocío, for their permanent support; and to my research group, the Powder Technology Group of the University Carlos III of Madrid, and its former members, now at other universities, I want to show my thanks for their support and help during years. Without their assistance, it couldn't be possible to progress in a field such as Materials Science and Engineering in which it is only possible to work in a team in order to achieve any improvement. For this reason, this recognition is for all of them too.

In this investiture lecture, I would like to make some comments regarding the knowledge field in which I have developed my teaching and research activity, Materials Science and Engineering (MSE), and its possible implications in the Engineering studies as well as what we can hope from it in the future.

I have always been a defender of Materials Science and Engineering as an Engineering field. When I arrived at the University Carlos III, as a full Professor in 1996, I drove the formation of the Materials Department (I was its first department head), the formation of the Alonso Barba Research Institute, devoted to Materials and Chemistry, and the PhD program in Materials. Today, the knowledge field is a consolidated area with a certain robustness that will allow one, under the frame of the new Bologna declaration, to maintain a degree in Materials Engineering in our University.

This knowledge area, which always I have defended with high faith, has not always has had so many successes. From the creation of the first Materials Departments in the USA and UK, the field has been open space between others with a higher social reputation (like Business Administration), more fashion (like Telecommunications or Computer Science), or antiquity in the engineering field (like Mechanics or Electronics).

The fact that in both the USA and Japan have, over the last decades, considered the research on Materials to be fully prioritized in their National Research Plans, along with the fact that competitiveness in the product markets forces the optimization of properties through material design (which is something that is also highly related with the cost), forced us to consider MSE as an important subject in the education of engineers with more interest. Materials, with Information and Communications technologies and Biotechnology, are the three main research areas in most advanced countries. From those three, Materials is the most horizontal, being fully necessary for the development of the other two.

Another important milestone was the fact of the birth of the discipline. According to Professor Cahn[1], it was at the late 50's with the appearance of the first Materials Science and Engineering Department in Northwestern University, in Chicago, and a little bit later in the Massachusetts Institute of Technology (MIT). With it was born the need of interaction between knowledge from physics, chemistry and metallurgists, that from different way were analyzing the behaviour of the materials and, from those interactions, the concept of the tetrahedron over which our discipline is based started to appear. The vortex of this tetraedron is structure and composition, synthesis and processing, properties and performance[2]. The appearance of materials departments in highly prestigous universities, was the driving force for its spreading through USA, UK, Japan, afterwards in South America, and lastly in Europe. Unfortunately, Spain was one of the latest countries in assuming this opportunity, and the degree of Materials Engineer was developed, as a masters degree, in the late 90's.

Our discipline, today, is strong, and this strength came from its origin: based in several disciplines (physics, chemistry, metallurgy), it is one of the most multidisciplinary subjects in science and technology. Many different kinds of departments including solid state physics, organic or inorganic chemistry, and physical metallurgy, can be transformed into MSE departments thanks to this multidisciplinariety, welding professionals from very wide and different, but fully complementary, origins. This is why our discipline is known as 'science and engineering'. There is no other discipline in which the frontier, the boundary between science and engineering, is more diffuse.

Why should an engineer be proficient in materials? To answer to this question, first we should discuss what kind of things should be included in the knowledge of an engineer. Different studies done in USA make clear the fact that most engineers and managers end up working in small and medium enterprises (SME). So, is not unappropriate to suggest, as Professor German did in the investiture lecture for his Honoris Causa doctorate awarded in our University[3], that an engineer should have, mainly, three skills: communication skills, people management skills, and SME management skills. It is clear that the new Bologna diplomas should include in their curriculums this disciplines, in any engineering degree. The teachings for the development of these skills are fully horizontal and transversal for any kind of engineer. Obviously, any engineer should develop the technical skills related to his discipline. In this sense, Materials Engineering has enough content to be an independent engineering discipline, different than other engineering degree. But, moreover, the knowledge of materials by the engineer, any kind of engineer, is compulsory. Functional or structural materials, the knowledge of materials is fundamental for the best praxis in any kind of engineer.

My experience as a professor under the umbrella of this field is that, most of the consultations that I received from my former engineering students, came from those students that followed the materials subjects without intensity. After working in industries which are so different (like the automotive or telecommunications industries), they have problems related to materials behaviour that they should be capable to solve,

[1] R.W. Cahn, "The coming of Materials Science", Pergamon, 2001.

[2] The paradigm which links "processing-structure-properties" was introduced before by Albert Sauveur, in 1912, in " Metallography and Heat Treatment of Iron and Steel".

[3] Investiture Lecture of Profesor Randall German, in "Autonomía universitaria y libertad académica II", Universidad Carlos III de Madrid, 2006.

but they can't. This is due to their lack in the fundamental knowledge of materials, which is usually promoted by engineering programs at their universities highly specialized in their own engineering technical skills. Materials science is a horizontal skill which is needed in all engineering branches.

The relationship between materials and human being's development and civilization is well known (for example, the knowledge of materials is present in many of the most important achievements like the compass, printing, or the development of the powder). Materials knowledge is highly linked with the most important engineering inventions of the modern era: the steam machine, the car, the computer, aircrafts,… and all the so-call emerging technologies. The influence of materials in art, architecture, civil engineering,… is also relevant. Many engineering problems, and even big disasters, could be avoided or solved with qualified materials engineers. In most of these disasters (the Titanic sinking, the Challenger explosion, the bridges that collapse, the airplane that fails by fatigue,…) there is a chain of facts that finish with the accident, but what is true, is that we can always reach the conclusion that, in the design or manufacturing step, more knowledge about the materials employed could have avoided or minimized the problem. Materials Engineering today, though, is not only to avoid disasters. Materials Science and Engineering is, today, responsible for new methods to obtain cheap energy (and maybe someday fusion reactors) as well as new light and stiff materials (and, as a consequence, new efficient transport systems, ways to produce energy, improvements in production manufacturing, better sports devices,…). There is no doubt that the reason we see levitation trains, vital artificial organs inside our body,… is because of the enormous improvements made in Materials Science and Engineering. Our discipline has a big and recognized impact in so many different industries such as transport (ships, cars, trains), space, defense, electronics, environment, robotic, automatic, biomedicine, information, telecommunications,… Our discipline has broken borders that, some years ago, look completely impossible: superconductivity at industrial temperatures, metallic glasses, tough ceramics, conducting polymers, polymers that can be converted in ceramics, and shape memory materials. Materials Science and Engineering is the main character in the most fashionable technological and scientific field: nanoscience and nanotechonlogy. These fields are indivisible and can be represented as facets of nanomaterials.

A recent study from the National Science Foundation (USA) in the 2000 regarding the feasibility and future of Materials Science and Engineering, discussed some interesting approaches for the future of materials science. One is the theory that MSE is crucial in the development of quality of life, national defense, economic security and the competitiveness of the American society; nevertheless, government and public powers are not aware of the critical role of this discipline. The increasingly wide base of knowledge, as well as the research lines, would require changes in the education of these engineers (the departments of Materials Science and Engineering are loosing visibility against more basic sciences departments, sometimes are poorly consolidated and, in many of departments, polymers are not included, which is something that I consider to be a mistake). The multidisciplinarity of the field provides a chance for search for strengths because, despite the fact that funding to this field is today still acceptable, there is a tendency to move the money to basic sciences. One weakness of the area is the division in different professional associations (ceramics, metals, polymers, composites). Many of these reflections can be applied, directly, to the Spanish situation.

In the next few years, the European University and, at the same time the Rumanian and Spanish universities, will suffer many changes produced by the development of the so-called Bologna regulation. This agreement strongly modifies the teaching process, making the student the core of the process and the main character, and learning more important than teaching. It introduce drastic changes in the education of the high degree diplomas and, at least in Spain, the engineering studies will change a lot .The length of the studies will be reduced, the masters will be introduced as official teaching (in Spain it was unofficial until the introduction of the new Universities' laws) and mandatory to access to the PhD studies.

In Spain, in the engineering field, we are still discussing the model to be followed, from the 3+2, or 4+1 patterns, till the model of 5+0, where the study of engineering continues to be five years long and, at the end, the student receives a double diploma: an engineering and masters degree simultaneously, but only if the student successfully finishes the five years. All the discussions hinge on the existence of professional colleges, which are the owners of professional competences. That does not occur in Materials Engineering, which does not have recognized professional competences, and it does not have any group who defends their interests.

One special and relevant aspect of the engineering studies in Spain is the high rate of failure. Usually, five years of studies are completed, on average, in six or seven years (sometimes even more). This situation is completely unacceptable in the new system where the student is the axis of the educational process. The engineering professors (we, me) should make an effort to modify the teaching systems in order to improve the success rate in engineering to make it close to other disciplines, at least at the level of the other experimental degrees.

Another important aspect to modify is the practical weight of the teaching. Labs should have more protagonism, and will be one important part of the curriculum. And last, but not least, we should include development of communication skills, working in groups skills, as well as skills regarding the management of persons and companies. Of course, we also want to include technical skills; those related to any engineering field, as well as any skills that allow the engineer to solve, design, and decide about solving problems related to engineering materials.

In the middle of all this mess introduced by the Bologna developments, it is time to have a Materials Engineering degree in Spain. The Materials Science and Engineering field has reached enough maturity. It is considered important in all the programs of the development of research, at regional and national levels, as well as in the VII Framework Programme; and what is more important is that industry demands materials engineers; engineers with knowledge of how to solve materials problems and design with materials, why they break, when they could break, why they corrode, when they fail under fatigue stress, etc., etc. Now is the time for Materials and its definitive role in engineering education.

And, just to finish, I would like to say a few words related to Powder Metallurgy. Inside the MSE field, I am lucky to due to the fact that I have devoted most of my time in science and technology to Powder Metallurgy. In a recent poll on the most important milestones in history, with regard to Materials Science and Technology, made by The

Minerals, Metals & Materials Society in 2006[4], one hundred important milestones for the Human progress were delineated. From those, there are three which are highly related to Powder Metallurgy: first, the production of a 7.2 meter high forged iron pillar, made from small ingots of sponge iron powder, in year 400; the second, the development of W wires by D. Coolidge from a powder metallurgy route (which was the introduction of the modern PM) and, third, the invention of cemented carbides in 1923, by Karl Schroter leading a group of engineers in OSRAM. Today, Powder Metallurgy is in the middle of most of the processes aimed at developing the so called 'advanced materials' and, to me, it is satisfying to be involved in this discipline.

Thank you very much again.

Craiova, 1st June 2007

[4] http://www.materialmoments.org/