Report on the First Moroccan Spring School On Advanced Materials (MoSSAM'1)

Marrakesh, Morocco – April 15-17, 2018

1. OVERVIEW

Further to the demand of Ph.D. students in physical science of some Moroccan and foreign universities, and the will of several professors and researchers to bring theirs areas of expertise within students' and colleagues' reach, the project of an international spring school focused on advanced materials took concrete form, spurred on by Prof. Amane OUERIAGLI and Prof. Mohammed Essaid ACHOUR in particular. Thus, the first edition of this school, so called *Moroccan Spring School On Advanced Materials (MoSSAM'1)*, was held in Marrakesh (Morocco) between the 15th and the 17th of April 2018 at the Faculty of Sciences Semlalia of Marrakesh (FSSM) of the Cadi Ayyad University.

A brief opening ceremony introduced the scope, the variety of areas of interest, the contributors, a brief outlook of the forecasted program, and the expected objectives of the school. Afterwards, the first courses took place in the same day (April 15) within a single session. The official opening ceremony took place in the day after and the following tutorials and courses had taken place within single or double sessions depending on contents and specialization levels. The closing ceremony of the 17th April allowed organizers to take stock of the overall sequence of MoSSAM'1, to draw up some learned lessons and to make contributors and participants express their comments about the held school and theirs proposals regarding the future editions.

The First Moroccan Spring School On Advanced Materials was organized by Cadi Ayyad University, Faculty of Sciences Semlalia Marrakech, Moroccan Society of Applied Physics and Moroccan Association of Advanced Materials (A2MA).

2. OBJECTIVES

As introduced above, the key objectives of the First Moroccan Spring School On Advanced Materials (MoSSAM'1) rely on providing an academic learning about advanced materials involved in a wide variety of areas as well as the different characterization techniques used to probe theirs properties. In addition, the First Moroccan Spring School on Advanced Materials was supposed to be an international forum for reporting the recent developments in advanced materials and theirs applications in the following themes:

- Materials for Solar Energy Applications and Energy Storage Systems.
- Synthesis techniques of advanced materials and Nanomaterials.
- Advanced structural materials, ceramics and composites.
- Biomaterials.
- Polymeric materials and polymer nanocomposites.
- Inorganic and hybrid materials.
- Nanostructured materials for functional applications.
- Nanomaterials single crystals, nanomaterials, multifunctional for diverse applications.
- Nanofluids for heat transfer.
- Thin film coatings.

International contributors were asked to provide courses and tutorials including either basic and advanced knowledge since the targeted audience was composed of heterogeneous students and researchers; in addition, the courses were expected to provide precise insights about the applications of materials of interest, and ideally to be documented by the contributors own research work or that of the scientific community.

The students were strongly encouraged to interact with the international contributors during the discussions following the courses and the breaks. Besides, this event was an occasion for researchers to discuss their works and to consider opportunities of making theirs students use characterization techniques or even contribute in colleagues' work.

3. SOME NUMBERS

Since the call for registration in February 2018, the organizing committee of the MoSSAM'1 had received applications from different countries. At the close deadline, 67 students had completed the registration process: 61 from Morocco, 4 from Algeria and 2 from Portugal.

Regarding the allotted time to the First Moroccan Spring School On Advanced Materials, the dozen of professors and researchers (5 from Morocco, 2 from each of Portugal, Bulgaria and France, and 1 from each of Jordan, Germany and Tunisia) having been invited to give courses had kindly accepted to be involved. The organizers of MoSSAM'1 were engaged in collecting, evaluating and advising about the material and the content of courses submitted by contributors.

4. CONTENTS

The courses sequence was designed within single or doubles sessions with regards to areas of interest and specialization levels of different contributions. The chart below summarizes the adopted program.

SUNDAY 15 APRIL 2018		
14:00-16:00	***Registration***	
16:00- 17:30	**Cyril POPOV** *Kassel University, Germany* Characterization of basic and application relevant properties of thin diamond films: Principles and examples	
17:45- 19:15	**Mustapha AIT ALI** *Cadi Ayyad University, Marrakesh, Morocco* Chemistry of 2D-nanomaterials: Silicene and phosphorene	
MONDAY 16 APRIL 2018		
8:30-9:00	***Opening ceremony***	
9:00-10:30	**Christian BROSSEAU** *University of Brest, France* Matériaux composites: Ingénierie et Propriétés de Transport Électromagnétique	
10 :30-11 :00	***Welcome reception***	
11:00-12:30	**Manuel Pedro Fernandes GRAÇA** *I3N, Physics Department, University of Aveiro, Portugal* Glasses and glass-ceramics, preparation methods versus applications	
13:30-15:00	***Lunch***	
	Session A: **Structural characterization**	**Session B:** **Photovoltaic materials**

<table>
<tr><td>16:00- 17:30</td><td><u>Mustapha MABROUKI</u>
Faculté des Sciences et Techniques Béni Mellal, Morocco
La microscopie à force atomique du principe de fonctionnement à l'exploitation des images</td><td><u>Abdelkader OUTZOURHIT</u>
Cadi Ayyad University, Marrakesh, Morocco
Advanced Materials for Energy Conversion, Harvesting, and Storage</td></tr>
<tr><td>17:45- 19:15</td><td><u>Mahmoud AL-HUSSEIN</u>
Physics Department, University of Jordan, Amman, Jordan
Revealing the Structure and Morphology of Nanostructured Materials Using Advanced X-ray Scattering Techniques</td><td><u>Ahmed IHLAL</u>
Sciences Faculty, Ibn Zohr University, Agadir, Morocco
Conversion photovoltaïque: de l'atome au système PV</td></tr>
<tr><td colspan="3">TUESDAY 17 APRIL 2018</td></tr>
<tr><td></td><td>Session C:
Impedance spectroscopy</td><td>Session D:
Materials</td></tr>
<tr><td>8:30- 10:00</td><td><u>Luis Cadillon COSTA</u>
I3N, Physics Department, University of Aveiro, Portugal
Impedance spectroscopy: physical concepts and applications</td><td><u>Mustafa BENYOUCEF</u>
FST, Cadi Ayyad University, Marrakesh, Morocco
Single Crystal Ni-base Superalloys From the Microstructure to the Outstanding Properties</td></tr>
<tr><td>10:15-11:45</td><td><u>Asma TRIKI</u>
LaMaCoP, Département de Physique, Faculté des Sciences de Sfax, Université de Sfax, Tunisia
Apport des analyses diélectriques dans la science des matériaux</td><td><u>Zineb GUENNOUNI</u>
ECE PARIS & Université Pierre et Marie Curie, France
Matériaux polymères : Structures et propriétés en solution et aux interfaces</td></tr>
<tr><td>11:45-12:00</td><td colspan="2">Coffee break</td></tr>
<tr><td>12:00-13:30</td><td colspan="2"><u>Tamara PETKOVA</u>
Bulgarian Academy of Sciences, Sofia, Bulgaria
&
<u>Plamen PETKOV</u>
University of Chemical Technology and Metallurgy, Sofia, Bulgaria
Advanced chalcogenide and oxide materials for multifunctional applications</td></tr>
<tr><td>13:30-14:00</td><td colspan="2">Closing</td></tr>
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14:00-15:30	***Lunch***

Abstracts of courses provided in the framework of the First Moroccan Spring School On Advanced Materials are as following:

- ✓ **Characterization of basic and application relevant properties of thin diamond films: Principles and examples (Cyril POPOV):**

  The comprehensive characterization of the basic and application relevant properties of bulk materials and thin films requires the application of a number of complementary analytical techniques. The lecture course will present an overview of techniques for characterization of the topography, morphology, structure, crystallinity, composition and chemical bonding structure of materials, including Atomic Force Microscopy (AFM), White Light Interferometry (WLI), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Electron Energy Loss Spectroscopy (EELS), X-ray Diffraction (XRD), X-ray Reflectivity (XRR)Auger Electron Spectroscopy (AES), X-ray Photoelectron Spectroscopy (XPS), Secondary Ion Mass Spectrometry (SIMS), Fourier Transform Infrared Spectroscopy (FTIR), Raman Spectroscopy Nuclear Reaction Analysis (NRA). The basic principle of each technique will be presented together with examples for characterization of diamond and different diamond films. The analysis of some application relevant properties, such as mechanical (hardness, adhesion, friction), optical (transmission, optical constants), and biological will be also presented and discussed.

- ✓ **Chemistry of 2D-nanomaterials: Silicene and phosphorene (Mustapha AIT ALI):**

  2D materials are atomically thin sheets that exhibit unique electronic, optical and mechanical properties with remarkable potential for technological applications and a plethora of unexplored fundamental science. For example, graphene is the prototypical 2D material, exhibiting high charge carrier mobilities, chemical inertness and high mechanical strength. Although many bulk materials exhibit layered structures with quasi 2D characteristics, 2D materials are defined here as those composed of one to several (generally, 10 or less) discrete, atomically thin layers that are weakly interacting, often through van der Waals forces. The superlative physical properties of 2D materials arise from the intrinsic chemical properties of their constituent elements, which are incorporated into covalently bonded structures of particular symmetry and low (that is, 2D) dimensionality. The chemically simplest cases exist in elemental 2D materials, of which two are known to also occur in bulk layered form: graphene and recently: silicene and phosphorene. Since facile fabrication processes of large area nanosheets are required for practical applications, a development of soft chemical synthesis route without using conventional vacuum processes is a challenging issue. Techniques for the exfoliation of layered compounds are widely used to fabricate nanometer-thick materials, such as oxides, niobates, chalcogenides, phosphates, and graphene. Although a variety of nanosheets have been synthesized, there have been few reports of silicon and phosphor nanosheets. Mass production of silicon and phosphor nanosheets without conventional vacuum processes and vapor deposition can be achieved using low cost top-down approach starting from materials that comprise a 2D sheet structure as a fundamental unit. Chemical processes provide an alternative route to large-scale synthesis of 2D nanomaterials under production conditions. In this perspective, this work focuses on recent progress in chemistry of 2D-nanomaterials: Silicene and Phosphorene.

- ✓ **Matériaux composites: Ingénierie et Propriétés de Transport Électromagnétique (Christian BROSSEAU):**

  La complexité des matériaux composites requiert généralement une analyse multi-échelle des propriétés physiques, physicochimiques, et structurales. Deux aspects sont évoqués: (i) Quel peut être l'apport des simulations numériques d'hétérostructures pour la prédiction des propriétés diélectriques effectives ? (ii) Est-ce que les relations micro/macro sont adaptées à la modélisation et à la caractérisation des propriétés électromagnétiques de nanostructures ?

- ✓ **Glasses and glass-ceramics, preparation methods versus applications (Manuel Pedro Fernandes GRAÇA):**

  Glasses, glass-ceramics, and ceramics are essential materials for the humanity, having a constant presence in day-to-day and contributing to a better way of life for many people. Those materials are used on a wide range of applications, from everyday objects, art, decoration, among many others, expanding to scientific and technological areas like microelectronics, power electronics, physics, including nuclear physics, optical telecommunications, etc. All of this is possible due to the different physical and chemical properties that can be tune in these materials, particularly in glasses. Besides the control of the chemical composition, the preparation method is crucial. Although glasses and ceramics can be presented as different materials, they are strongly correlated. The key to their success is mainly the production methods applied during its manufacture. So, it is essential to know and study the techniques implemented in their production, as well as their relation to the properties presented by the material as a final product. In this course, a description of the glass preparation processes, namely melt-quenching and sol-gel, will be presented. Techniques for the promotion of crystal particles grow on such glasses, like thermal, thermoelectric and thermomagnetic treatments will be presented.

- ✓ **La microscopie à force atomique du principe de fonctionnement à l'exploitation des images (Mustapha MABROUKI):**

  La microscopie à force atomique (AFM) est une technique d'imagerie à balayage de sonde qui permet de cartographier les interactions entre une pointe fine et une surface ou des objets supportés. Beaucoup de paramètres (forme et nature de pointe, portée des forces d'interaction, etc…) influencent la résolution. Bien que l'on puisse voir des défauts atomiques ponctuels, la technique est très largement utilisée à résolution moindre ou basse. La palette de modes d'acquisition et d'échantillons observables est très riche. L'exploitation des résultats est d'une importance capitale pour les jeunes chercheurs et les doctorants. Le présent cours mettra l'accent sur les outils d'analyses et d'interprétation des images obtenue par AFM dans l'air et les liquides.

- ✓ **Advanced Materials for Energy Conversion, Harvesting, and Storage (ABDELKADER OUTZOURHIT):**

  In this course we will present an over view of energy conversion, harvesting and storage techniques as well as the materials used there in. These include solar energy (both PV and solar thermal), thermoelectric, piezoelectric, electrochemical, bioenergy conversion as well as fuel cells. In addition, various energy storage techniques will also be presented. The state of the art as well as research path ways will be discussed. A special focus will be put on semiconductor materials and hybrid materials for solar cells and photo-thermal conversion, thermoelectric materials, piezoelectric materials, electrodes for advanced batteries and super-capacitors.

- ✓ **Revealing the Structure and Morphology of Nanostructured Materials Using Advanced X-ray Scattering Techniques (Mahmoud AL-HUSSEIN):**

  New materials with controlled structure ranging from nanometer to macroscopic scales are essential for advanced technological applications. Many organic materials self-assemble spontaneously into ordered structures with well-defined symmetry and dominant characteristic lengths. However, controlling length scale and precise positioning of the molecular components are critical for advanced technological applications. Therefore, scientists are currently attempting to mimic the precision and complexity of many biological materials into synthetic organic materials. On the other hand, a proper characterization of the structure and morphology of such nanostructured materials on the nanoscale is the key for a better understanding of the structure forming mechanisms and in turn more control of their properties. To this end, grazing incidence X-ray scattering is employed to obtain information on both the lateral and vertical order in nanostructured thin films. Specular X-ray reflectivity (XR) measurements are used to probe the electron density profile along the surface normal direction. Lateral ordering is studied using grazing incidence small and wide angle X-ray scattering (GISAXS and GIWAXS). Within this context, the following topics will be addressed in my lectures: –An introduction to the principles of advanced X-ray scattering techniques used to characterize order in thin films, and representative examples will be discussed using organic nanostructured materials having nanotechnological applications.

- ✓ **Conversion photovoltaïque: de l'atome au système PV (Ahmed IHLAL):**

  L'électricité photovoltaïque constitue aujourd'hui une alternative économiquement viable pour lutter contre le réchauffement climatique. En effet, la parité réseau est atteinte dans plusieurs régions du monde. Il existe aujourd'hui plusieurs générations de cellules solaires. Le but de ce cours est de passer en revue ces quatre générations. Un accent particulier sera mis sur la première et la deuxième génération de cellules PV. On y abordera l'état de l'art des différentes filières. Puis on s'intéressera aux systèmes PV. On s'intéressera plus particulièrement à l'évaluation des facteurs qui limitent les performances des installations PV. Un bref aperçu des aspects économiques sera également abordé.

- ✓ **Impedance spectroscopy: physical concepts and applications (Luis Cadillon COSTA):**

  Impedance spectroscopy is a powerful technique that permits to understand the polarization mechanisms in materials, that is, the charge migration and that one due to the orientation of permanent dipoles. To obtain a complete characterization of the dielectric response, a large range of frequencies and temperatures must be used. The different regimes of the dielectric function can be observed, and the dynamics of the relaxations can be found. In this talk, different examples of using impedance spectroscopy to characterize materials are presented, showing the capability of this technique. It offers performances that permit to investigate the fundamental aspects of the electrical properties, yielding a wealth of information about the molecular motions and relaxation processes present in the materials.

- ✓ **Single Crystal Ni-base Superalloys From the Microstructure to the Outstanding Properties (Mustafa BENYOUCEF):**

  The evolution of the chemical composition and the progress made in the manufacturing processes of superalloys enabled the development of the aeronautics industry. The increase in the content of refractory elements such as W, Ta and Mo, gave birth to the first generation of superalloys. Progressive introduction of Re, up to 6 %, by General Electric, Pratt & Whitney and Cannon Muskengon was a major step in the improvement of creep resistance at high temperature of second and third generation. In this course we present the different generations of single crystal superalloys with an emphasis on the developments made in the conception and design of these alloys in order to fulfill the need of the aeronautics industry. We will focus on the high temperature mechanical behavior of these industrial alloys which is directly related to their microstructure. Hence the importance of understanding the formation and aging of the microstructure. Particularly for aeronautical superalloys used in the manufacturing of the hottest parts of turbo-engines. The optimization of the microstructure of superalloys allows the development of alloys with high thermo-mechanical resistance (temperatures reaching 1100°C and loads of 150MPa). The use of high temperatures at the entry of the turbine slows the decrease of oil consumption. The outstanding mechanical properties of these alloys are mainly due to their particular microstructure, formed by γ' precipitates (L12 ordered structure) impeded in a γ matrix (FCC disordered structure). The γ' precipitates act as a barriers to the dislocation propagation. These dislocations are the origin of the irreversible deformation of metallic materials. Initially, the γ' precipitates have a cuboidal shape, and sizes of hundreds of nanometers with a volume fraction between 60 and 70%. During service, the microstructure of superalloys is subject to morphology changes leading to an oriented coalescence, called rafting, driven by an important plastic activity with dense interfacial dislocations at the γ/γ' interface. When the rafted structure becomes unstable, it leads to the rupture of the material. Therefore, it is important to understand and control the formation and evolution of this rafted structure in superalloys. These topics will be treated in this course I order to understand the exceptional mechanical behavior of superalloys at high temperature.

- ✓ **Apport des analyses diélectriques dans la science des matériaux (Asma TRIKI):**

La caractérisation diélectrique de divers types de matériaux diélectriques à l'aide d'un pont d'impédance peut s'avérer d'une importance certaine dans la science des matériaux. Ceci contribue à l'amélioration de leurs conceptions. La caractérisation diélectrique est basée sur la polarisation du matériau de l'étude soumis à un champ électrique alternatif dans la gamme de fréquence 0,1 Hz-1 MHz. Des relaxations diélectriques d'origines différentes peuvent alors être observées sur les variations isothermes du facteur de perte ou de la partie imaginaire du module électrique dans des gammes de températures bien déterminées. Les conditions expérimentales de cette caractérisation diélectrique dépendent de la nature du matériau analysé. Dans ce cours, nous analyserons les propriétés diélectriques obtenues pour des bio-composites, des céramiques de types pérovskites et des céramiques poreuses saturées en eau pour des divers objectifs. Dans ces analyses, nous avons eu recours au modèle empirique de Havriliak-Négami.

- ✓ **Matériaux polymères : Structures et propriétés en solution et aux interfaces (Zineb GUENNOUNI):**

  Les polymères sont des matériaux omniprésents, qui s'imposent à nous dans tous les domaines de nos activités quotidiennes. D'origine naturelle ou d'origine synthétique, ces macromolécules ont des propriétés remarquables du point de vue microscopique et/ou macroscopique. La multitude des degrés de liberté de leurs monomères leurs confère un grand nombre de conformations possibles et complexes qui dépendent des différents paramètres physicochimiques. Nous présenterons dans ce cours les différents types de polymères, certaines de leurs propriétés et leur comportement dans différents environnements. Nous passerons également en revue quelques avancées scientifiques, les applications actuelles et potentielles dans différents secteurs d'utilisations de ces matériaux novateurs.

- ✓ **Advanced chalcogenide and oxide materials for multifunctional applications (Tamara PETKOVA and Plamen PETKOV):**

  Materials play an important role in progress of science and engineering. Throughout the world there is a large need for new types of materials. Materials used today are not available anymore or become too expensive. New materials are necessary also because of the limiting of the physical properties of the present materials .Two type of materials are presented non-oxide (chalcogenide) and oxide materials. Bulk chalcogenide glasses are prepared with melt-quenched technique are studied with respect to their properties – density, microhardness, compactness as a function of the composition. The biggest changes in the structure (higher sensitivity) are expected in the less compact sample, i.e. having flexible structure. Thermal characteristics are obtained from the calorimetric investigations. The sorption properties of thin chalcogenide films are studied upon exposure to water, ethanol, acetone, and ammonia vapors. The phase transition in films has been investigated using the temperature dependent sheet resistance method. The dependence of the resistance from the composition and temperature has been discussed. A standard optical recording was demonstrated in thin films with diffraction efficiency strongly depending on the composition. Very often the use of composite materials results in lighter weight, better functionality and provides greater environmental resistance (against, e.g., corrosion) than their compound counterparts. Low-cost composites are therefore being considered as beneficial materials in many areas. The preparation of oxides using various techniques (melt-quenching, sol-gel, hydrothermal, precipitation) is presented. The synthesis conditions are of great importance for the materials properties and performances. The materials characterizations both physic chemical and electrochemical demonstrate the opportunities for materials application in the practice.

5. COMMITTEES

Chair Committee:

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6. PARTNERS & SPONSORS

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- Association of Advanced Materials (A2MA)
- Université Cadi Ayyad, Marrakesh, Morocco
- Faculty of Sciences Semlalia of Marrakesh, Morocco

Prof. Nabil ROCHDI

For the organizing committee of MoSSAM'1

N. Rochdi.

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