Syllabus for The International Summer School

(Please fill in the form. Thank you very much.)		
課程名稱 **Course name_** at least in English, additionally in Chinese preferred	（中）： 奈米材料(S)TEM 電鏡分析原理與技術	
	（Eng）： Nano-material characterization with a (S)TEM	
授課老師所屬單位 **Offering dept. and university**	Laboratoire de Physique des Solides UMR8502 CNRS / Université Paris-Sud, France.	
授課教師資料 **Offering teacher's information**	Name: GLOTER Alexandre Tel. / mobile phone number: +33682867054 Email: gloter@lps.u-psud.fr	☑ 6 days /3 hours a day ☐ 3 days /6 hours a day
學經歷 **Curriculum vitae**	Education: Solid state physic, PhD.	☐ Morning (9:00~12:00) ☑Afternoon (14:00~17:00)
課程開辦系所 **Hosting Department**	Professional appointment: Senior researcher in Solid State Laboratory, CNRS University Paris Sud 11, 91405 Orsay, France.	
授課教師資料 **Offering teacher's information**	Other qualification:	
學分數 **Credit(s)**	1	
課程目標 **Goal of this course** description within 150 words	The goal of this course is to teach to the students about the transmission electron microscopy (TEM) for the characterization of materials, including some recent developments. The student should acquire the basic of elastic interaction of the electron beam with atoms and solid. They then should acquire the image formation process in a TEM and notably the case of "Phase contrast" and the case of "Amplitude contrast". From these, the students should be able to retrieve some structural parameter of nanomaterials from TEM images and diffraction such as some crystal structure or thickness. I will also detail recent developments that has lead TEM to be a unique tool for nano-characterisation and in particular some elements of correction of the aberration of electron lens. At the end, the students should also be aware of the existence of a diversity of technique available in a TEM.	
課程簡述 **Course description** description within 350 words	The course will first describe the physic of elastic interaction of an electron beam with a solid in order to induce the important key-parameters (electron wavelength, Bragg angle, ..) and functions (atomic scattering factors, ..) to understand the formation of image and diffraction. The basic elements of a transmission electron microscopy (TEM) are then described. It will be done with an emphasis on technical issues and will give the opportunity to discuss points such as resolution or signal to noise ratio. We will then described the main principle of contrast formation in a TEM notably the phase contrast and the amplitude-diffraction contrast. We will see how high resolution atomic image can be interpreted by phase contrast and how it can be used to measure atomic distance. Examples of amplitude-diffraction contrast will also be reported and we will see how thickness of sample or geometry of dislocation can be interpreted. The case of scanning transmission electron microscope (STEM) will then be	

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<tr><td></td><td colspan="3">introduced since it is the TEM technique that shows actually the faster development. This is notably due to the development of aberration correctors and some of these elements will be reported in the course. Example on how STEM can be used for characterization of devices or semiconductors will be reported.
The course will be finish by the description of the spectroscopy associated to the TEM. Such spectroscopy either based on X-ray or electron are rich of information and can be used to quantify the local stoichiometry of the samples.</td></tr>
<tr><td>課程內容 / 授課大綱
Course content / outline</td><td>The course will be divided in 6 session of 3 hours each.

1- The electron beam interacting with the materials.
2- The transmission electron microscope (TEM)
3- Image formation in a TEM. The case of weak phase object.
4- Image formation in a TEM. The case of diffraction contrast.
5- The Scanning transmission electron microscope, id est, the STEM approach.
6- Spectral characterization in a material using a transmission electron microscopy.

I will first describe the electron beam interaction with materials. It includes the presentations or reminder of concept of crystal, scattering and Bragg angle, then the presentation of elastic scattering by individual atoms and crystal with and without finite size. Atomic scattering factor for electron and</td><td>授課對象
Target audience</td><td>Postgraduate</td></tr>
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	for X-ray are presented and discuss. At this point the student should have the building brick for understanding diffraction and images (in principle whatever the microscope or involved particles). In a second session, I will give a general description of what a transmission electron microscope (TEM) is. This will be described in technical, engineering oriented way with a description of how work an electron gun, an electron round lens and electron detectors. The notion of limit of a TEM will be discuss in term of resolution (with respect to electron lens aberration) and of sensitivity or signal to noise ratio (depending on detectors). Examples of microscope, microscopes companies, range of price, obtained images, business applications, etc, will be presented and discussed. In a third session, we will describe the formation of phase contrasted images in a TEM. The sample is described as a “pure phase object” (it means that the atoms		

	of the sample only change the phase of the incoming electron, which actually is only valid for thin sample, but make an easy description). The microscope is then described as a filter in spatial frequencies and the role of microscope focus and resolution can be describe and discuss easily. It is then possible to discuss real high resolution TEM experimental images and for example the nature of contrast. 3 examples will be described 1) are the atoms the white or black spots in high resolution TEM ? 2) how to measure the diameter of a nanotube by high resolution TEM, 3) the best choice of defocus for a low resolution biological sample where contrast is more important than resolution. In the section 4, we will continue to address the formation of image in a TEM. We will describe the case of image formation in case of diffraction contrasted where amplitude of the scattered beam play the major role. We will discuss the evolution of such contrast with thickness, orientation		

	or defect (dislocation) in the materials. This section will conclude on the general case where Amplitude and Phase both play a role on the image formation. The section 5 will be devoted to the case of the Scanning transmission electron microscope (STEM). While STEM has been for a long time considered a Scanning module attachment to a TEM it is now seen as the most developed TEM techniques. I will discuss these aspect and the reason for (Cs corrector). I will then describe the image formation in STEM mode that can be primary discuss by correcting the Atomic scattering factor with a Debye Waller term. Example of use of STEM for characterization of material will be given. We will see how STEM can be used to measure atomic position of atoms or differentiate between different elements. Examples will concern devices, dopant, etc.. In a last section, I will describe how non-elastically scattered electron can be used to characterize materials. It includes		

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	spectroscopy techniques related to TEM techniques. I will described two of them the EDS (X-ray spectroscopy, as emitted by the sample) and the EELS (electron energy loss spectroscopy) and their application to study material characterization.		
學習評量方式 **Assessment / grading policy**	(1) Report: 50% (2) Presentation: 50%		
課程目標之教學方法 **Teaching methods for this course**	Power point presentation and blackboard.		
教科書＆參考書目 **Textbook & other reference**	Introduction of conventional transmission electron microscope by M. de Graef (Cambridge Univ Press). High Resolution Transmission electron microscopy and associated techniques, Editors P. Buseck, J. Cowley and L. Eyring (Oxford Press).		

Thank you for your help!