SCIENCES SORBONNE UNIVERSITÉ

2021-2022

Master thesis proposal

Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie

Campus Pierre et Marie Curie
Tower 23 - 4th floor -23-22
Director: A. Marco Saitta

Title: Synthesis and characterization of new nitrides at extreme conditions

Keywords: materials sciences, high pressure, reactivity, phase diagram, diamond anvil cell, laser heating

Scientific description:

History shows that the successful synthesis of new materials under pressure has always been correlated to technological developments. Nowadays, the technology of the diamond anvil cell (DAC) allows to generate static pressures of several million bars (1Mbar = 100 GPa). The energy brought by such compressions becomes comparable to those of strong chemical bonds (~eV) and thus allows to access a whole new chemistry of elements. The emblematic examples are that of dihydrogen, an insulating solid at low T, which becomes a metallic solid when compressed to P≈ 500 GPa [1] and the ammonia and water ices which become ionic and superprotonic conductors at high P and high temperature [2,3,4]. The reactivity of the elements under extreme conditions is also radically different from that under ambient P : for example, it has been shown that compounds considered as the most stable under ambient conditions (N_2, Pt,…), become strongly reactive under extreme conditions (45 GPa-2000 K) and allowed the synthesis of new strategic nitrides.

Up to now, high pressure nitrides have been synthesized by direct reaction of metals with N_2. In this master internship, we will exploit the strong reactivity of NH_3 to induce the diffusion of elements within the metal to synthesize new nitrides. We will follow the reactivity of selected metals (Fe, Pt, Ir,…) with ammonia at extreme conditions (1-100 GPa) and HT (T> 1000 K) by Raman scattering. These studies are not only crucial for materials science but are also important for planetary sciences to understand the formation and properties of giant icy planets, such as Neptune and Uranus. Current models of these planets consider that molecular ices (NH_3, H_2O,..) are the major internal constituents and exist under extreme P,T (20-600 GPa; 2000-5000 K). The inner layer made up of hot ice would be in contact with a core mainly composed of rocks and metals. The experimental data on ice/metal mixtures under HP-HT (non existent up to now) are thus required for interpreting astrophysical data.

[1] P. Loubeyre et al., Nature, 577, 631 (2020) ; [2] S. Ninet et al., Phys. Rev. B, 89,174103 (2014) ; [3] S. Ninet et al., Phys. Rev. Lett., 108,165702 (2012) ; [4] J.A. Queyroux et al., Phys. Rev. Lett., 125, 195501 (2020)

Techniques/methods in use: Diamond anvil cell, laser heating, Raman spectroscopy
Applicant skills: Motivation for experimental physics; good background in condensed-matter physics.
Internship supervisors : Sandra Ninet, sandra.ninet@sorbonne-universite.fr, 01-44-27-44-22
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Internship location: SU, Campus Pierre et Marie Curie, IMPMC, Tower 23 – 3rd floor – 13-23
Possibility for a Doctoral thesis: yes