INSTITUT JEAN LAMOUR

# PhD contract offer

## Hydrogen plasma reduction of low-grade iron ores: exploitation of gangue elements as self-forming slag agents

### General information

Workplace : NANCY
Type of Contract : PhD Student contract / Thesis offer
Contract Period : 36 months
Start date of the thesis : 1 September 2025
Proportion of work : Full time
Remuneration : 2 200,00 € gross monthly
Section(s) CN : Section 15 : Chimie des matériaux, nanomatériaux et procédés

### Missions / Activities

The major obstacle to render steelmaking more sustainable is undoubtedly the decarbonization of its process chains. Currently, the production of 1 ton of steel is linked to the staggering emission of **2.1 tons of $CO_2$**, a fact that makes iron- and steelmaking responsible for **8% of the total $CO_2$ emissions on the planet**. This is because we have been extracting iron from its ores through chemical reactions that employ C-carrier substances, leading $CO_2$ as the by-product [1]. Accompanied by this challenge, the scarcity of high-grade iron ores to be exploited as feedstock is a near reality. This creates an absolute dilemma that will force steelmakers to produce **green steel from low-grade iron ores** [2].

The hydrogen plasma smelting reduction of iron ores (HPSR) emerges as an attractive $CO_2$-lean pathway to produce iron, where the ore is exposed to a reducing lean hydrogen plasma (10%$H_2$) – in an electric arc furnace (EAF) – to get simultaneously melted and reduced, Fig. 1 [1,3]. When using hydrogen plasma species (H, $H^+$) as a reducing agent for iron ores, the by-product is **water** rather than $CO_2$ ($FeO + 2\ H \rightarrow Fe + H_2O$) [4].

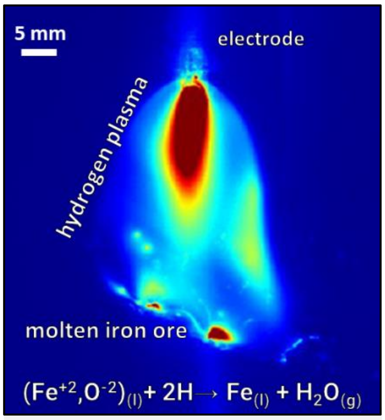


**Figure 1.** HPSR of iron ores, conducted in an EAF filed with Ar-10%$H_2$ gas mixture. Thermal gradients were captured by special set of lenses [5].

This doctoral work aims to investigate the **fundamentals** of HPSR to **transform** low-grade iron ores into sustainable and clean iron. The project will target low-grade iron ores containing less than < 59% Fe and substantially containing high quantities (~15%) of gangue-related oxides (i.e., less valuable constituents than iron oxides: $Al_2O_3$, $SiO_2$, $P_2O_5$ etc.). Partially and fully reduced ores will be chemically and microstructurally **characterized**. The results will reveal important details about the **reaction mechanisms** and the **efficiency of the process** in terms of hydrogen consumption and iron formation. The composition of the slag (self-formed by the gangue oxides) will also be fully characterized, and it will be destined to cement industry. The hydrodynamic aspects resulting from the **plasma/liquid** interaction and **temperature** distribution will be monitored via high-speed and infrared cameras. Hydrogen plasma will be characterized via optical emission spectroscopy.

**References**


[1] Souza Filho, I.R. et al. **Acta Materialia** 213, 116971 (2021)
[2] Jovičević-Klug, M., Souza Filho, I.R., et al. **Nature** 625, 703–709 (2024)
[3] Souza Filho, I.R. et al. **Journal of Cleaner Production**, 340, 130805 (2022)
[4] Souza Filho, I.R. et al. **JOM**, 1-13 (2023).
[5] H. Pauna et al., **6th European Steel Technology and Applications Days** (2023)


### Work context

This doctoral work is part of the 4-years European project entitled **"Decarbonized Steel Production with Novel Decarbonized Processes"** whose acronym is **ZEROSTEEL**. It is a project fully funded by the European Union (550 k€ for 4 years) and pertaining to the recently launched **Chair of Sustainable Metallurgy** at IJL. Dr. **Isnaldi R. Souza Filho** and **Dr. Thierry Belmonte** are the main contact persons and responsible for the project. For more information, please, contact also isnaldi.rodrigues-de-souza-filho@univ-lorraine.fr or thierry.belmonte@univ-lorraine.fr. The work language will be mostly in English and French.

## Skills

We seek candidates with strong knowledge in **physical and/or extractive metallurgy**, **materials science** and **engineering** or **physics** and **plasma characterization,** good experience in **metallography** practices and **thermodynamic** calculations. Good command of spoken and written **English** is necessary. The selection of applications will be carried out in compliance with the principles of **transparency** and **equal treatment** of candidates after examination of the applications received. We are highly engaged with the **gender and diversity equality** and encourage and welcome applications from all backgrounds.

## Constraints and risks

The project will be conducted under all **safety rules** of IJL aiming to preserve the integrity of all employees, incl. students, technicians and scientists, as well as the facilities and infra-structure of the laboratory. The concentrations of hydrogen to be employed in the experiments lie **below** any inflammability risk. The manipulation of the plasma reactor is a **safe procedure** as it contains all safety measurements against overpressure and displays adequately electric insulation. The reactor is customized for this purpose, also being produced by a specialized company with wide experience in the market.

## About Institut Jean Lamour

The Institute Jean Lamour (IJL) is a joint research unit of CNRS and Université de Lorraine.
Focused on materials and processes science and engineering, it covers: materials, metallurgy, plasmas, surfaces, nanomaterials and electronics.
The IJL has 263 permanent staff (30 researchers, 134 teacher-researchers, 99 IT-BIATSS) and 394 non-permanent staff (182 doctoral students, 62 post-doctoral students / contractual researchers and more than 150 trainees), of 45 different nationalities.
Partnerships exist with 150 companies and our research groups collaborate with more than 30 countries throughout the world.
Its exceptional instrumental platforms are spread over 4 sites; the main one is located on Artem campus in Nancy.