Master Thesis subjects 2015-2016 in Chemical and Materials Engineering

Materials Engineering, Characterization, Synthesis and Recycling (4MAT) - ULB

1. Preparation and assessment of Dimensionally Stable Anodes (DSAs)
Summary: Dimensionally Stable Anodes are used in non-ferrous extractive electrometallurgy (copper, zinc…) and in water electrolysis for the oxygen evolution. They substitute in electrometallurgy lead alloys electrodes subject in normal industrial operating conditions to creep.
The objective of this work is to continue what was performed in a previous study and consists in the preparation of composite electrodes based on titanium and lead alloys. While the previous study defined the preparation conditions of these electrodes, this study will test electrodes in industrial conditions for the oxygen production, will optimize the electrodes preparation and will compare their electrochemical behavior and their lifetime with industrial electrodes.
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2. Study of the electrochemical production of amalgams and their decomposition
Summary: There are two liquid metals at temperatures close to room temperature: mercury and gallium. These two metals are able to dissolve other metals sometimes in large amounts, including some very reactive metals like sodium. This property is in particular used to quantitatively measure the content of alkaline metal ions in a solution by polarography. Electrochemistry, thanks to the high hydrogen evolution over-potential on these liquid metals, allows producing liquid alloys between mercury or gallium and alkaline metals. The objective of this research is to study for the two liquid metals, the electrochemical conditions for the production of these alloys and their decomposition.
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3. Purification of industrial waste water by sequential precipitation: in-depth study of the precipitation of phosphates
Summary: Industrial wastewater from the production of hydrogen phosphate contains large quantities of fluoride and phosphate ions. The water needs to be treated prior to elimination in the sewage system. Up to now, the purification process has led to the formation of a cake of precipitates containing fluoride and phosphate salts that cannot be easily valorized or recycled. The size distribution of the final product, its purity and the purity of the treated waste water are critical for the industrial process. The aim of this project is to investigate in depth the mechanisms of precipitation of the phosphates by the addition of calcium hydroxide to control these key parameters. The kinetics of precipitation and transformations of the products will be studied as a function of the lime addition rate, pH, temperature, and delay between additions.
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Industrial partner: PRAYON
4. Preparation and Characterization of silica aerogel from rice husk

Summary: Silica aerogels are among the best insulating materials available today. Unfortunately, on one hand, the preparation of these aerogels from organic silicon based monomer, such as tetramethyorthosilicate (TMOS), tetraethylorthosilicate (TEOX) or polyethocysiloxane (PEDS) is expensive and an industrial production of insulating panels for general applications is not economically viable.

On the other hand, rice husks are rich in silica and are a cheap raw material.

In this project, we will optimize the synthesis of aerogels from rice husks ash and their atmospheric drying procedure and characterize the influence of process parameters on thermal and acoustic properties.

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5. Additive manufacturing of Ti-6Al-4V parts : effects of heat treatments on microstructure and mechanical properties

Summary: Additive manufacturing (or 3D-printing) includes various promising technologies that build objects from a digital model, by laying down successive layers of material. The major advantage of additive manufacturing processes lies in their unique ability to create parts with very complex geometries. During Electron Beam Melting (EBM), each layer of metal powder is melted by a powerful electron beam to the exact geometry defined by a CAD model. The titanium alloy Ti-6Al-4V is widely used in EBM manufacturing, for two main applications: the medical implant market and the aerospace industry. Electron-beam melted Ti-6Al-4V parts undergo a complex process, characterized by a succession of melting, rapid cooling, and partial re-melting of each layer. A better understanding of the impact of this specific thermal history on the microstructure of the material is required in order to improve the mechanical properties of electron beam melted parts. Moreover, it is key in order to introduce such parts in critical aeronautic applications. In this Master’s Thesis, particular attention will be paid to the possible post-treatments that can be carried out in order to optimize the mechanical properties of the 3D-printed parts.

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Industrial partners: Techspace Aero, Sirris

6. Influence of quenching and partitioning conditions on the microstructures and mechanical properties of a 0.4C steel

Summary: Continuous weight reduction and increased safety requirements of vehicles have driven the automotive industry to design new steels that offer both a high strength and a good ductility. Steels produced by Quenching and Partitioning are promising candidates as the new generation of steels for automotive applications. The Q&P process consists of an interrupted quench between Ms and Mf, followed by a partitioning step in order to stabilize the austenite through carbon enrichment. The resulting microstructures are complex and multiphased. In the present Master’s Thesis, Q&P heat treatments will be carried out in a quench dilatometer and at the lab-scale on a 0.4 wt.%C steel. Microstructural characterization will be achieved using SEM, EBSD, TEM and XRD. The kinetics of the phase transformations, especially martensite transformation, carbon partitioning and austenite decomposition will have to be evaluated. The tensile properties of Q&P samples will also be investigated and the relationships between process parameters, microstructures development and mechanical properties will be analyzed.

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Industrial partners: ArcelorMittal, CRM Group
7. Effect of glass structure on diffusion processes

Summary: The need for ultra-resistant thin glass is increasing with the growing demand for touchscreens. Due to the amorphous nature of glass, it is quite complex to optimize its mechanical properties. One way to achieve a strengthening effect is to use ion exchange so as to induce compression of the surface of the glass. Although of considerable industrial interest, the fundamental interplay between the glass structure (which is in fact more complex than being just disordered) and the diffusion processes is not understood yet. In this Master’s Thesis, we will highlight the effect of glass formers and modifier on the interdiffusion process of smaller cations such as Na⁺ and K⁺. This project will be mainly experimental, consisting in casting glasses at the lab scale, producing chemically strengthened glasses, and studying the interdiffusion process and the structure of the glasses using various techniques such as local composition measurements by EDX or local mechanical characterization using nanoindentation.

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Industrial partners: AGC FlatGlass

8. Waste management of discarded cell phones and proposal of material recovery techniques

Summary: Is the discarded phone cell “mine” significant in Europe and/or Belgium? What is the lifetime of cell phones? Do they have a second life outside Belgium or Europe? Does the amount of metals contained in discarded cell phones match the future needs? Is the waste collection system efficient to valorise these metals and to what extent? Are these metals concentrated in components that can be easily identified? What is the best to separate these metals: manual dismantling or shredding? In this Master’s Thesis, the amounts of strategic metals will be assessed, based on a sample of cell phones. Separation techniques will be proposed and ecodesign principles will be used to propose improvements for future cell phones, so as to increase recycling rates.

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9. Ettringite-like materials for solar heat thermochemical storage applications (continuation of MA1 project)

Summary: A promising candidate for thermochemical storage is ettringite, a compound usually found in cements. Ettringite is able to crystallize with several water molecules like in following reversible reaction:

\[ \text{Ca}_6\text{Al}_2\text{(SO}_4\text{)}_3\text{(OH)}_{12} \cdot 30\text{H}_2\text{O} \rightarrow \text{Ca}_6\text{Al}_2\text{(SO}_4\text{)}_3\text{(OH)}_{12} \cdot 13\text{H}_2\text{O} + 17 \text{H}_2\text{O} \]

During summertime, this reaction would occur from left to right, to store energy from solar collectors. During wintertime, water would be put into contact with dehydrated form, to give energy back to the house.

In this work, it is proposed to: (i) synthesize ettringite, ettringite enriched in salts or compounds from the family of ettringite that were not tested yet; (ii) apply or improve a protocol to measure their energy density – a target may be ~500 kWh.m⁻³; (iii) verify the reversibility of the cycles and the durability of the materials; (iv) interpret the results in the light of chemical or structural transformations.

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