PhD Proposal 2017

School: Ecole Centrale de Lyon	
Laboratory: Laboratory of Tribology and System Dynamics	***Web site:*** http://ltds.ec-lyon.fr/spip/
Team: **Tribology, Physical Chemistry and Dynamics of Interface**	**Head of the team: Siegfried Fouvry**
Supervisor: Pr. Stéphane Benayoun	***Email:*** stephane.benayoun@ec-lyon.fr
Collaboration with other partner during this PhD: ***In France:*** 1. MATEIS – INSA of Lyon: Supervisor: Pr. Bernard Normand Co-supervisor : Dr. Sheng Yuan 2. LMI – Universty of Lyon 1: Supervisor: Dr. Bérangère Toury	**In China:**

Title: **Development of innovative multi-functionalized *CMC* composite coating via electrospinning deposited on metallic substrate**
Scientific field: Surface engineering, Corrosion, Tribology
Key words: CMC Coating, sol-gel, multi-functionalization, interface, anticorrosion, tribology properties, characterizations

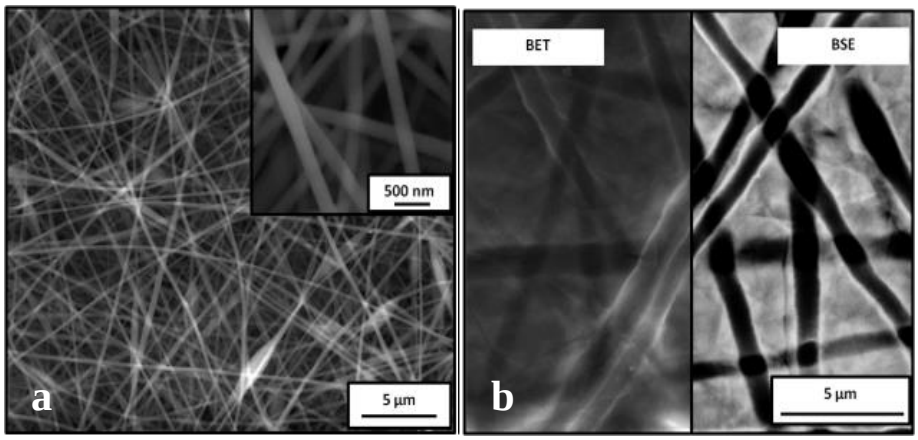
Details for the subject:

Background, Context:

Corrosion degradation of materials and structures remains one of the most important issues that leads to depreciation of investment goods in many key industry sector (automotive, aircraft, energy production, building and electro-devices). The deposition of barrier layer is an wildly used efficacious approach to reduce corrosion risk by preventing contact of susceptible materials to corrosive environment. However, the development of modern industry requires more powerful barrier coating providing, meanwhile, multi-functionalities such as: wear resistance, electrical/thermic conductivity, self-healing, biocompatibility as well as special superficial texture for specific applications.

Nanostructuring process is a powerful method allowing to enhance anticorrosion performance and/or impart novel functionality to conventional compounds.[1] The most used methods to form nanostructured protective coating consist usually in a direct mixture of nano sized fillers with liquid state precursor before the sharping process. Different natures of fillers have been applied. Metallic nanoparticle, carbon nanotube and graphene widespread interest for coating's electrical conductivity, corrosion inhibitor encapsulated in nanocontainers can improve resistance performance, for instance. However, by this strategy, it is rather difficult to obtain homogeneous coating for a larger area because of detrimental interactions between the matrix and the active species.

Previous work of colleagues in laboratory MATEIS of INSA of Lyon (http://mateis.insa-lyon.fr/node/285),[2] have proved the feasibility of an innovative multifunctional *CMC* composite coatings refilled with nanostructured carbon fiber deposited on metallic substrate. This strategy consists in a multiple steps process combining two advanced techniques: 1) the synthesis of inorganic carbon fibers by electrospinning and electrostatic deposition (see Fig. 1a);[3] 2) the preparation of the sol-gel barrier matrix[4] (SiO_x or ZrO_2) as shown in Fig.1b; 3) the thermal treatments (T & P). There are many advantages of this method. At first, the nanofiber's properties are tunable according to preselection of precursor molecule. Isotropic and anisotropic structure can be achieved by innovative spinning process. By insert nanoparticles and corrosion inhibitor can be inserted on the nanofibers and hold homogeneity in large area. Sol-gel, as a wet chemical method, is suitable for the preparation of organic/inorganic coating matrix combining the most important properties of their constituents.



a) b)

Fig.1: a) : carbon base nanofibers network. b) CMC composite with carbon based fibers fillers.

The objective of the PhD, in collaboration with INSA of Lyon (MATEIS) and the University Lyon 1 (LMI, http://lmi.cnrs.fr/), attempts to optimize the different key-parameters correlated to the elaboration process as well as the physicochemical characterization of so obtained coating. Aim to the development of multifunctional coating, the evaluation their performances especially in term of corrosion & wear resistance.

Research subject, work plan:

The work during the PhD is mainly experimental and will be organized in three successive steps:

Optimization of the coating: At first, the student will tend to well control the synthesis parameters along the different steps. Powerful physicochemical characterization techniques are available in the laboratories: **XRD**, **Raman**, **EDX**, XPS and **IR** completed with the microscopy (**SEM**, **TEM**, and **tomography**). This part of work will basically be performed in two laboratories of Lyon city LMI & MATEIS. Bérangère TOURY (LMI) and Sheng YUAN (MATEIS) will be involved in the chemical synthesis aspects. The student should be able to obtain stable, homogenous, recovering and adhesive coating on metallic substrate for the further characterization.

Selection of the coating candidate: So-obtained samples will be investigated in MATEIS, basically in the group CorrIS who has a huge expertise in electrochemical fields under direction of Pr. Bernard Normand and Dr. Sheng YUAN. The student, in this stage, will evaluate the corrosive resistance of the samples using electrochemical devices (**EIS**, **potential dynamic**, **impedance**…) in aggressive electrolytes. Besides, the conductivity of the coating surface will be estimated by a special EIS technique[5] and the coating's conductivity by ICR as well. This study will be used as critical parameters allowing to identify the most promising samples.

Tribological properties: The life-time of protective coating is usually very limited by the sharping process and their tribological properties. These abrasive / adhesive wear processes leading constantly to galling and seizure of the coating. Thus, to pass from a laboratory idea to functional products, it is important to understand their evolution mechanisms and their usage properties of the formed pieces. Pr. Stephane Benayoun will be more concerned in this tribology study and help the student to establish an appropriate tribosystem in order to assess coating's surface resistance against wear and other mechanical solicitations.

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1 G. Schottner, *Chem. Mater*, 2001, **13**, 3422

2 S. Yuan, X.J. Yang, B. Ter-Ovanessian, B. Toury, N. Mary, S. Bénayoun, A. Broioud, B. Normand, *Scripta Materialia*, (in preparation)

3 Z. M. Huang, Y. Z. Zhang, M. Kotaki and S. Ramakrishna, *Compos. Sci. Technol*, 2003, **63**, 2223–2253.

4 N. Le Bail, S. Benayoun and B. Toury, *J. sol-gl Tech*., 2015, **3**, 710

5 B. Normand, H. Takenouti, M. Keddam, H. Liao, G. Monteil and C. Coddet, *Electrochimica Acta*, 2004, **49**, 2981–2986