CENTRE OF EXCELLENCE OF MULTIFUNCTIONAL ARCHITECTURED MATERIALS
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CEMAM
Laboratoire d'excellence

IRP 1: HIGHER-PERFORMANCE MATERIALS FOR EXTREME ENVIRONMENTS

Efficiency of energy production and transformation requires often increasing temperatures and pressure in hostile environment : this is true for instance for airplane engines, as well as for thermal or nuclear power plants. At the same time, increase the reliability, in particular by the control and understanding of early failures is one the key point for the future materials. Beyond societal impact should also be improved by increasing material lifetimes in service and the extension of recycling time.

SCIENTIFIC STRATEGIES

More and more, the limits of standard materials are reached and the challenge can be met only via a "system approach" associating materials and geometry. For instance, the increase of operating temperature in propulsion engines, impossible to reach either because metals and alloys have a limiting operating temperature, or because of the poor damage tolerance of ceramics, has led to the development of cooling devices and thermal barriers. The aim of this project is to investigate a "materials by design" approach in situations where temperature, or chemical environment, or radiation damage is an issue.

Fig.1 Cladding (Zirconium alloy) typically used as the primary safety barrier in nuclear power plants.

The fundamental issues raised in the above programs are:
* interface mechanics in relation with chemical degradation,
* irradiation damage in multiphase materials, and specifically the role of interfaces, * multiscale modeling strategies, and especially in the case of competing time scales,
* mechanics of architectured materials with sliding internal interfaces,
* damage and healing kinetics for different processes,
* microphysics approach to chemical degradation.

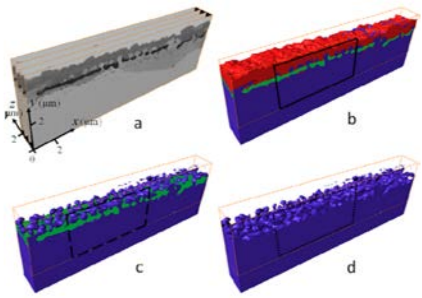

Fig.2 Example of advanced characterisation of materials at CEMAM: 3D tomography obtained by FIB/SEM on an oxide layer grown at high temperature.

The consortium gathers a variety of competences in physical metallurgy (phase transformation and plasticity), in corrosion and oxidation of materials, and in mechanics of materials. Multiscale modelling is a well developed competence (Molecular dynamics, Monte Carlo simulation, dislocation dynamics, polyphase plasticity, discrete element models, micromechanics of fracture) and the implication of some teams in the LABEX in nuclear materials is well recognized at the national and international level.




Combining long term competence with short notice reactivity

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STAFF AND INDUSTRIAL PARTNERSHIP

More than 25 permanent researchers (not including PhD students) are involved at CEMAM in the Interdisciplinary Research Projects 1 (IRP1) at the frontier of the physic, mechanic and chemistry.
All the projects include a training component, particularly through PhD grants and postdoc positions offered by CEMAM (regular request for proposal). connected with partners in nuclear industry: CEA, AREVA, as well as producers of steels: ArcelorMittal, Aperam, Manoir Industries, producer of gas turbines: SAFRAN, petrochemistry: Total…

ZOOM ON CURRENT ACTIVITIES

Design Tools for Achitectured Bio-Mimetic Actuators (Coll. Lehigh University / USA)

Actuators, controllable work-producing devices, serve many natural and man-made or artificial engineering applications. These devices often exploit phase changes or differences in properties (thermal expansion, magnetostriction) in order to elicit forces and/or displacements. The objective is to lead collaborative fundamental studies of this conflict between man-made bi-layer actuator efficiency and lifetime in order to provide guidelines for improved actuators.

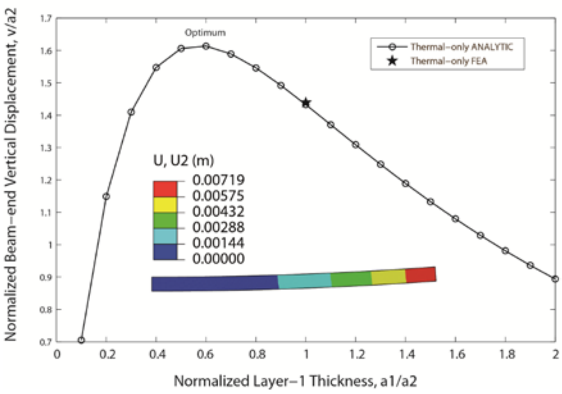

Fig.3: Simplified analysis to demonstrate the proposed approach. A displacement profile of a sample FEA model at a1/a2=1 is superimposed.

Behaviour of Nanostructured PVD coatings under extreme environments (Coll. Nanyang Technical University / Singapore)

Nanocomposite coatings are of a great interest due to their enhanced properties such as mechanical properties, tribological performance, thermal stability and oxidation resistance. Their structures are divided into two categories: nano-multilayered coatings and monolayered bulk nanocomposites.
The main goal is here to lead new studies on composite materials where structuration is controlled at the nanometer range and produces high mechanical and oxidation resistances in extreme environments (high temp. irradiation, etc.)

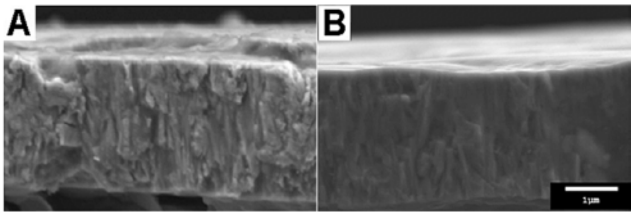

Fig.4 SEM cross-section micrograph of different nanocomposite coatings: (A) single-TiN and (B) $Ti_{1-X}Si_XN$ with x = ≈ 10 at. %.

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