CENTRE OF EXCELLENCE OF MULTIFUNCTIONAL ARCHITECTURED MATERIALS
46 avenue Félix Viallet 38031 Grenoble Cedex 01 FRANCE
cemam@grenoble-inp.fr **www.cemam.fr**

CEMAM Laboratoire d'excellence

IRP 6 : BIOMATERIALS DESIGN FOR BIOMEDICAL ENGINEERING

Many biomedical applications require the design of multifunctional architectured materials. Advances in material science, surface functionalization and biology allow to design materials that are not only biocompatible but also bioactive, *i.e.* able to help tissue engineering, regenerative medicine and medical device design.

SCIENTIFIC STRATEGIES

Biological tissues are intrinsically organized at multiple scales. They also perform multiple structural and physiological functions. Biomaterials used to substitute the biological tissues and to design medical devices should therefore be designed in the same way. The CEMAM teams provide knowledge and know-how in the many scientific facets of these complex materials and applications: biology, mechanics, numerical simulation, physical chemistry, physiology,... Both close relationships with clinical research and an easy access to many characterization and visualization techniques are essential in our partnership.

TISSUE ENGINEERING, REGENERATIVE MEDICINE

Reciprocal interactions between materials and biological matter are at the core of our research activity. We are thus involved in the design of bioactive materials.

Thanks to specific and controlled functionalization, the material surfaces have an effect on cell adherence, motility, proliferation and differentiation. It therefore influences the tissue organization at the interfaces. In addition to biochemical signals, cells and tissues are also very sensitive to mechanical constraints and fluid mechanics. This aspect is addressed in several teams. Reciprocally, materials can be modified by the presence of living cells. We are thus also involved in the development of bioresorbable materials and are studying the changes in the biomaterials with time. Finally, the interaction with other CEMAM IRPs provides additional expertise in materials design, elaboration and characterization as well as multi-scale modeling.

Biomimetic materials surface are developed using polyelectrolyte multilayer films with controlled mechanical and biochemical properties. These thin films (20 nm-2 µm) can be applied on almost any material surfaces, and functional patterns can be created at the 10-100 µm scale or using porous textured materials. The adherence, motility, proliferation and differentiation of progenitor stem cells are studied. We are well equipped to study biological processes, both with characterization and visualization techniques. Key applications are the development of osteo-conductive materials and materials surfaces to study muscle cell differentiation and cancer cell motility.

Figure 1.

Bone biosynthesis (red) in contact to an titanium implant (black) coated with a functionalized PLL-HA polyelectrolyte film

Flexible transparent devices are developed to analyze the muscle tissue formation and study their physiological function and reaction to drugs.

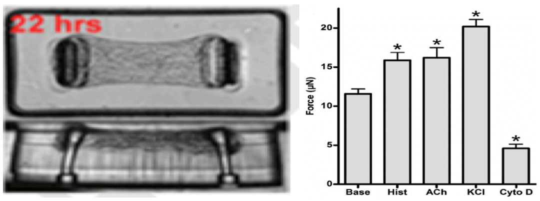


Figure 2 : Left : micromuscle platform, top and side views. Right : micro-muscle developed force as a reaction to different drugs.

Combining long term competence with short notice reactivity

Microscopy and biophysical methods are developed to study and model the organization of biological cells and tissues, as well as some physio-pathological processes, especially in blood vessels, muscles and cancer cells.
More fundamental studies are conducted on interactions between materials surfaces, macromolecules, and cells. We work in particular on the design of substrates based on polymer-brush coatings allowing controlling cell adhesion in space and time, in order to gain insights into the dynamics of cell/surface adhesive interactions, at the single cell level. We focus on the use of stimuli-responsive polymers to design such "smart" culture substrates.
As the development of supported cells is strongly coupled to the mechanical properties of their substrate, we develop fine non-contact mechanical metrology on soft surfaces of biological interest (elastomers, hydrogels, etc...) so as to disentangle the respective role of surface interactions and bulk mechanics.

IMPLANTS AND MEDICAL DEVICES

Medical devices are used during surgery and new materials are inserted to reconstruct the resected biological parts. These materials usually consist in flaps directly extracted from the patient body and/or biocompatible materials. Such materials, referred as implants, intend to interface with the biological systems in order to treat, improve or replace the damaged body function.
Innovations in medical devices contribute to the patient safety improvement. A key point for the design of new medical devices is their mechanical properties. Mechanical characterization of biomaterials was thus developed; especially on shape memory materials, silicone and bioresorbable elastomers. A key aspect of this work is the coupling between experimental and numerical studies. The mechanical properties of prostheses and orthesis can thus be optimized by designing the materials structure at several levels. An example of such materials is a vascular implant made of NiTi knitted fabric inserted in a silicon elastomer.

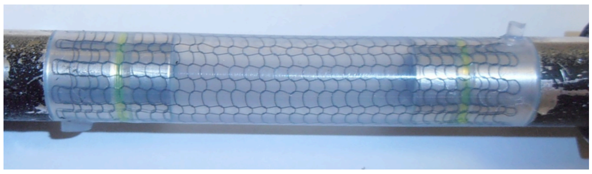


Figure 3 : Vascular implant made of NiTi knitted fabric inserted in a silicone elastomer.

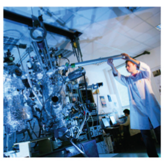
Activities on bioresorbable metallic implants are also carried out with the aim to study the effect of microstructure on bioresorbabiliy kinetics of magnesium alloys. Due to additive manufacturing facilities in the AMEP elaboration platform of CEMAM, titanium alloys with controlled architectures promoting bone integration in implants can also be produced.
Surgical glues are also studied in order to enhance adhesive property on tissue. This requires a better knowledge of the glue/tissue interaction as well as a reliable way to measure its adhesion on tissue.
Finding new ways to assess the biocompatibility and *in vivo* functionality of any given biomaterial is a necessary step to validate its commercial use. An extensive knowhow is available in CEMAM around a wide range of advanced characterization tools. This is favored by the access to a number of high level instrumental platforms. Of particular interest, is the local synergy around the analysis of bone quality and bone/implants interfaces from the macroscopic level down to the nanoscale. This multiscale characterization is achieved through original combinations of sophisticated techniques, e.g. non-linear optics, electron microscopy, spectroscopy and synchrotron X-ray radiation at the ESRF, for which a unique expertise at the international level has been developed within CEMAM.

STAFF

Full time equivalent staff of about 20 people with close to 10 PHD students and post docs.

CONTACTS

Denis Favier: Denis.Favier@imag.fr
Lionel Bureau: Lionel.Bureau@ujf-grenoble.fr




Combining long term competence with short notice reactivity