

Group D  
Evaluation campaign 2017 – 2018  
Research unit  
Application

Unit name: Soft Matter Sciences and Engineering

Acronym: SIMM

Research department (if any):

Director's name (current contract): Christian Fréigny

Director's name (next contract): Etienne Barthel

Application type:

Renewal (without important modification)

Restructuring

Creation

Supervising institutions and bodies:

List of supervising institutions and bodies of the research unit:

Current contract:

- ESPCI

- CNRS

- UPMC

| Next contract:

| - ESPCI

| - CNRS

| - UPMC

Inter-disciplinary evaluation for the research unit:

Yes

No

# I APPLICATION

## 1. Presentation of the unit

### Introduction

The lab was created when the two ESPCI historical polymer teams (respectively lead by L. Monnerie and R. Audebert-F. Lafuma) merged into a single research unit, and it has since then substantially broadened its research fields by including many aspects of Soft Matter. In order to better reflect these new themes, the name of the lab was changed to its current name in 2014. In addition to polymeric systems that remain a field of expertise of the lab, a large variety of systems are now dealt with, involving for instance organic and inorganic colloids, emulsions, foams, etc...

The phenomena we are interested in include wetting, fracture, adhesion... More generally, we are interested in situations associated with or resulting from a broadened dynamics and a structural disorder within complex soft systems: glass transition, polymer toughness, interfacial dynamics... The related systems range from simple ones such as liquids, bulk polymers or gels to more complex systems such as self-assembled ones, complex elastomer networks, nanocomposites, emulsions, foams etc...

The wide field of the activities that are encompassed is made possible by the large range of skills of the researchers in SIMM lab, from chemistry and physical chemistry to physics and mechanics. Researchers with complementary expertise thus work together on projects involving several of these scientific domains, which constitute a major strength of the lab.

### Workforce and resources of the unit

At the time of writing, twenty scientists and a pool of 11 technical persons from CNRS, ESPCI and UPMC hold a permanent position in the lab. The lab is fairly attractive for students as evidenced by the recruitment of eight to ten PhD students a year, together with an average of five postdocs. A large number of students are also taking internships at different levels of their university or engineering school education. Part of this attractiveness results from the implication of most members of the lab in teaching activities either at ESPCI or at UPMC.

The main part of the lab funding (75-80 %, permanent staff salaries not included) comes from joint projects with both academic institutions (Europe, ANR: 25-30 %) and private firms (45-60 %). Since the different facets of our research activities are susceptible to have a high societal impact, the lab is naturally involved in a large number of industrial collaborations, most of which involve international companies (Saint-Gobain, Michelin, Solvay...). Along that line, a noteworthy event is the creation in 2015 of a "Laboratoire Commun", Physicochimie des Interfaces Complexes (PIC), a joint CNRS-ESPCI-UPMC structure with Total-Lacq. This "Laboratoire Commun" associates members of the lab with engineers of the Total center of Lacq. SIMM lab is also involved in a joint "chaire" with Hutchinson and Ecole des Mines de Paris. In both cases, the salaries of several PhD or Post-doc students as well as the accompanying budget are secured for several years. In addition, one lab member was awarded in 2016 an advanced grant from the European Research Council, from which the lab funding will also benefit.

## Scientific policy

In framing the description of the macroscopic properties of complex systems, Soft Matter research often relies on modelling the processes at stake at the microscopic scale, which is either the molecular or a mesoscopic scale. However, coupling the different scales is generally a challenging task. As a result, oversimplified descriptions of local phenomena are often adopted by e.g. linearising equations, neglecting non-stationary phenomena or using mean field approximations... An example can be found in fracture mechanics, where an assumed linear behaviour at the crack tip (near field) is coupled with a large scale deformation (far field). In a similar fashion, subtle dissipation mechanisms that are responsible for wetting dynamics are generally accounted for by simply using effective contact angles... However, recently developed theoretical and experimental tools have proven to be efficient enough to tackle more realistic situations or to engineer matter at small scales. The interplay between different scales is at the center of our activity. Along that line, material molecular design for improved properties, the analysis of the role played by the interfaces and by the molecular transport on macroscopical characteristics of matter as well as fine analysis of the non-linear local phenomena controlling plasticity and fracture are some of the research directions which will be briefly described in this report.

According to a long standing practice in the lab, many of our subjects involve complex and profound scientific interrogations, which are often related to industrial questions about processes, formulation and mechanical properties. In this respect, a large fraction of our research is performed with industrial partners. It is one of our priorities that the publications originating from those collaborations meet the same high scientific standards as these issued from purely academic collaborations.

## 2. Scientific production and activities (for the unit, and next for each team and/or theme of the unit)

### Scientific output

Since January 2012, lab members published more than 200 papers in high impact factor journals (210), among which prestigious journals such as Nature, Science (2), Report on Progress in Physics, Advanced Materials, Advanced Functional Materials (2), ACS journals (8), Angewandte Chemie (3), Nature Communications (3) or Physical Review Letters (7). It is noteworthy that the lab publications are published in the best journals in our community (31 Soft Matter, 17 Macromolecules, 17 Langmuir, 8 Physical Review E...).

Several patents (7) have also been filled in the same period. This may appear a small figure considering the large number of industrial collaborations we are involved in. The reasons for that are twofold: first, we mainly work on industrial processes which are less prone to be patented than industrial products, and secondly we rather choose to publish in academic journals. For instance, 35 of our publications are co-authored with at least one member of an industrial research center. As reflected by their publication in good quality journals (1 Science, 1 ACS Macro Lett., 3 PRL, 4 Macromol., 3 Langmuir, 10 Soft Matter...), the scientific level of these papers is as good as those with a purely academic authorship.

International joint projects represent 25% of our published works. They are facilitated by a large number of invited scientist visits (22 renowned personalities visited the lab) and by the large attendance of the lab members to international conferences. Invited professor positions were funded either by industrial (Saint Gobain, Michelin, Total) or academic chairs (ESPCI, UPMC, Hokkaido University).

Another measurement of the quality of our scientific production is provided by the number of invitations of members of the lab to international conferences: 102 invitations in the reference period. It

is noteworthy that the field of the corresponding conferences covers all of the domains of expertise of the lab.

### Quantitative data

See Excel file "Données du contrat en cours", Table 5, "Scientific production and activities".

### Selected production and research activities

(see appendix 4, page 4).

### Highlights

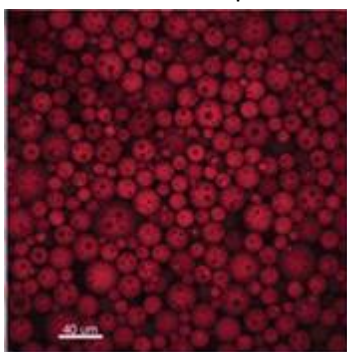
Three thematic highlights are described below.

#### I/ Science and engineering of interfaces

When considering fluid soft matter systems, flows are set by hydrodynamic boundary conditions at their interfaces: how can we determine the behavior of an interface and is it possible to tune it? The question is challenging as boundary conditions that are set by molecular or microscopic length scales have consequences at the macroscopic scale, making it difficult to observe both the macroscopic behavior and its origin at small scales. At SIMM, we are able to either observe the specific behavior of interfaces at local scale, or to control it by mastering the physical-chemistry of the liquids and their interfaces. Some examples are detailed below.

- By investigating the spontaneous thermal fluctuations at the free surface of nanometric liquid films, we probed the hydrodynamic boundary condition at a solid wall under vanishing applied shear. For two different pure liquids on glass, contrasted slip lengths were interestingly found: For silicone oil films as thin as 20 nm, a zero slip length was measured, whereas a 4 nm negative slip length was obtained with hexadecane. This demonstrates that at vanishing flow a nanometric solid-like layer close to the wall may exist depending on the nature of the liquid [1].
- We also explored the effect of roughness on wetting dynamics: When a solid plate is withdrawn from a liquid, the liquid meniscus adopts a dynamic shape which elongates as the plate velocity increases. Above a critical velocity, a liquid film is entrained on the plate. Although used in dip-coating processes, this forced wetting transition is poorly understood. By exploring this transition on rough surfaces and within cylindrical tubes, we showed that the pinning of the triple line by surface heterogeneities considerably anticipates and widens the transition. We shed light on the role played by the transient states that set the film thickness (Prix l'Oréal, brevet).
- On the other hand, we controlled interfacial properties by tailoring liquid/gas or liquid/liquid interfaces. First, we focused on bubble surfaces within aqueous foams. Aqueous foams are unstable, due, among others, to the gravity-driven drainage of water between bubbles. By formulating aqueous foams with amphiphilic polymers that adsorb to the liquid/air interface, we were able to increase the interfacial viscosity by crosslinking the polymer at the bubble interface. Indeed, upon addition of a crosslinker, a reversible polymer gel was formed in the bulk and at the air/liquid interface. With enhanced viscous dissipation in the films and at the interface, the gravity drainage was reduced by several orders of magnitude depending on the crosslinker concentration, and foams were stabilized over weeks (coll. Saint-Gobain, [2]).

- Besides, we tailored liquid/liquid interfaces in emulsion-based systems. We were able to form membranes at drops surfaces such that they could be used to encapsulate and release active principles on demand. First, polymers multilayers were assembled at the interface of oil-in-water emulsions drops: two different polymers, either proton acceptor or donor, were successfully adsorbed and assembled by hydrogen bonds to provide remarkably stable capsules. By adjusting the pH, the hydrogen bond strength was modulated and both the thickness and the mechanical properties of the membranes could be varied over several order of magnitude. This provides an efficient tool to trigger the release of the encapsulated active principle within a short time (coll. Stanford, Givaudan, [3,4]).

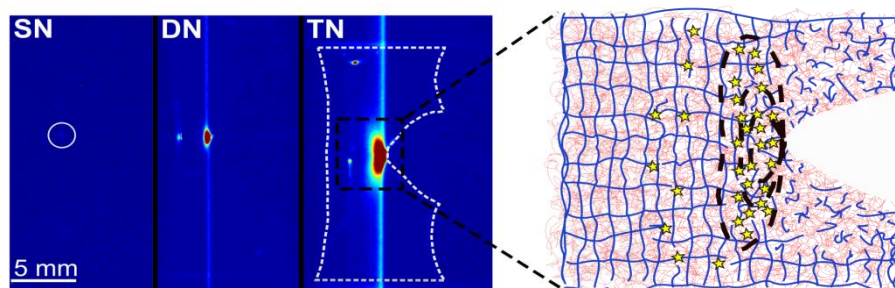


- Finally, a multi-responsive encapsulation method was developed, based on multiple emulsions (water-in-oil-in water) stabilized by a single tailored-made polymer as surface active agent (see image). Remarkably stable multiple emulsions were obtained with a one-step easy-to-implement process providing droplets with good encapsulation properties. Moreover, several stimuli could be used (temperature, pH or ionic strength) to trigger the release of the encapsulated species at will [5].

## II/ Mechanics up-scaling in complex soft matter systems

Understanding the relation between the macroscopic mechanical behavior of soft matter systems and the small scale arrangement is key in many situations – academic as well as industrial. However, with soft matter systems this task encounters many specific difficulties: large deformation, large dissipation and strong heterogeneities. Recently, we have had some success in understanding the relation between microscopic and macroscopic mechanics, overcoming several of these difficulties. Some of them are described below.

Elastomers are generally brittle when they are unfilled. Inspired by the work of prof. Gong at the University of Hokkaido we have developed novel elastomers that are both stiff at low strains and tough in large strains. They are made of interpenetrated networks with a stiff and brittle network embedded into a soft extensible network. The key mechanism responsible for this increase in toughness while retaining elasticity, is the presence of sacrificial prestretched strands that break in the bulk and delay crack propagation, a mechanisms that we were able to demonstrate directly by using mechanoluminescent molecules that emit light when the bond breaks (coll. TU, DSM, [6]).



Crack propagation in single (SN), double (DN) and triple (TN) networks elastomers, probed by mechanoluminescence.

Associative materials, with elaborated structure, are promising candidates for improved toughness. We have studied a dual crosslink gel with permanent and transient crosslinks. We control the macroscopic dynamical response by adjusting the molecular dynamics of the transient crosslinks, as

shown by a combination of micro- and macroscopic rheometries [7]. We have evaluated fracture toughness in this non-linear elastic material despite the predominance of dissipation, which is taken into account by an accurate constitutive relation allowing the proper evaluation of the stored mechanical energy [8].

Another method to toughen swollen gels that we developed is based on the use of graft copolymers that can microphase separate at high temperature while maintaining the same total volume. If the dense poorly soluble phase is the backbone of the chain, these gels have dramatically improved mechanical toughness and are able to deflect cracks [9].

Simple system geometries may already involve elaborate multiscale response: in our recent study of adhesive tapes, we have found that the fibrillated adhesive response can be incorporated into an intermediate scale adhesive zone to predict measured adhesion through a quasi-analytical model [10].

Laminated glass sandwiching a soft elastomer (polyvinylbutyral or PVB) - or SECURIT® glass - is known to have astonishing impact resistance. In this case, the specific dissipation characteristics of PVB, a non-linear elastic, viscoplastic polymer with an associative sub-phase, is mobilized by the overall architecture of the laminated glass sandwich: the macroscopic rupture experiments have revealed how the coupling between crack tip dissipation and macroscopic polymer stretch enhances dissipation, for maximum impact resistance (coll. Saint-Gobain, [11]).

Glassy polymers are also the object of interest in our lab. Recently, while studying the small scale rupture mechanisms of epoxies (Y. Nziakou's PhD), we found that the non-linearities induced by plastic flow permeated all length-scales. Moreover, glasses are intrinsically disordered dynamically — the so called “dynamic heterogeneities”. We have proposed a simple model that couples these dynamic heterogeneities elastically. We find that the macroscopic apparent time distribution is quite different from the microscopic one [12]. Application to thin films provides a simple understanding of confinement effects on the glass transition [13].

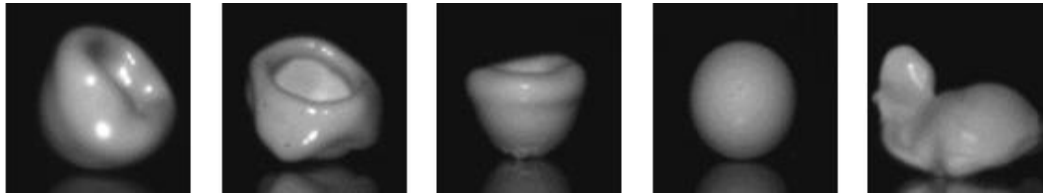
### III/ Processing Grains and Powders

Mixing, flowing and more generally handling of solid dispersions are important processes encountered in industry in many domains (food, ceramics, concrete, polymers, coating, etc...). However it is a challenge to deduce from the microscopic properties (surfaces interactions, but also transfers at small scale) the macroscopic properties such as rheology, drying, setting, dissolution.

We describe below some of our research area in this domain.

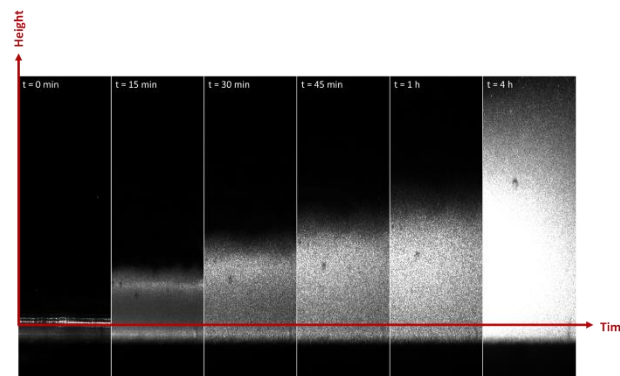
- The rheology of non-Brownian – but micrometric - suspensions is a good example of this type of problem. This problem is original because the local interactions between particles cannot be described nor by a simple Coulomb law (in contrast to granular matter), neither by purely hydrodynamics and Brownian interactions (in contrast to classical suspensions). Some examples are detailed below.
- Non Brownian suspensions of PVC particles in their solvent – but below the glass transition temperature behave as solid particles covered by polymer brushes. These suspensions are shear thickening. We have proved experimentally for the first time that the friction between particles controls the shear thickening of suspensions: under a sufficient stress, the brush covering the particles are squeezed enough such that the contact friction increases significantly. This results in a jump of stress for increasing shear stress. (coll.Tarkett / ENS, [14]).
- Drying suspensions is also challenging. In the literature, it has been shown that various parameters were governing the shape of granules formed by spray-drying suspensions. We have studied the

precise transfer at stake in the spray drying process. We have shown that an elastic shell of coagulated nanoparticles may form during drying and that the shell further undergoes a buckling instability. We have established that suppression of the instability can be achieved by decreasing the Darcy pressure, which is responsible for shell formation. On that basis, we have deduced for the first time the precise DLVO interactions needed to allow formation of spherical granules of spray dried ceramics (coll. Saint-Gobain, [15]).



*Shapes of spray-dried ceramics suspensions for increasing ionic strength*

- Geopolymers, binders based on clay particles dispersions, are currently examined as environmentally friendly substitutes to traditional concretes. Its rheology however is not well understood. We have shown that the rheology of geopolymers - during their setting - is not ruled by solid/solid interactions, but by a complex chemistry leading to the formation of a transient aluminosilicate gels (coll. Ec. des Ponts, ETH Zurich, [16]).
- Dissolution of powders in liquid often leads to the formation of lumps. We have shown, that contrary to the common belief, the dissolution of high molecular mass polymer, is not governed by reptation, but simply by the coupling between osmotic swelling and flow. We were also able to give a quantitative prediction of the rate of dissolution under stirring. (Coll. Schlumberger, [17]).



*Time series of a polymer layer swelling in brine: light scattering intensity allows for polymer concentration measurement in the swelling gel. Swelling is driven by osmotic pressure and gel disappears when the dilute concentration limit is reached everywhere in the gel.*

### 3. Organisation and life of the unit (or of the team if relevant)

#### Management, organisation and scientific animation

Researchers have various backgrounds – physical chemistry, physics, material science and chemistry. However, scientists with different cultures are associated in most of the research projects. As a result, lab's members consider themselves as belonging to a unique team – the lab's itself. For practical reasons such as the organisation of scientific animation (meetings, information diffusion...), three teams are however defined. In addition to those teams, the lab includes a mechanical/rheological platform and a shared workshop.

The mechanical platform is equipped with a variety of conventional equipment which allows to characterize a very wide range of materials going from very fluid formulations to stiffer materials such as suspensions, granular materials, soft gels, yield stress pastes and elastomers... Moreover, non-conventional tools, specifically developed in the lab, are available in order to probe viscoelastic properties at mesoscopic and nanoscopic scales: the Surface Fluctuation by Specular Reflexion (SFSR) and Diffusing Wave Spectroscopy (DWS). Approximately 40 % of the activity of the platform is devoted to the internal research of the laboratory. It is largely open to the socio-economic and to the academic (local and national) communities.

A workshop is also hosted by the lab with, in particular, two dedicated CNC (computer numerical control) milling machines. Two engineers are in charge of the workshop which offers an open access to the researchers of three different labs.

Along the same line, a large part of the equipment (such as chromatographs, calorimeters, thermogravimetry, infra-red cameras, fast cameras, microscopes...) is not devoted to specific studies but is shared in different contexts between lab members. The financial support for the different projects is also partially mutualized and it is made available to every lab member, irrespective to their actual contribution to the externally funded research. This shared part of the budget primarily serves to the acquisition of small devices and consumables. Decisions for investments in large equipments are taken each year at the first "Conseil de l'Unité".

Questions related to everyday life of the lab (decisions on new equipments, choice of the applicants for permanent positions, welcome procedures for students, safety issues etc..) are debated during lab meetings ("conseils de l'unité") that are convened three times a year. An executive board ("comité de direction") constituted by permanent researchers is in charge of preparing the decisions.

The scientific animation consists first in periodic meetings of the lab members directly collaborating with each other; once a year a "journée de l'unité" (lab day) is organised. During this day, all lab members attend to scientific presentations given by all 2<sup>nd</sup> year PhD and postdoc students. In addition half days are periodically organised for the researchers to discuss selected topics and projects. Students have also periodical scientific meetings. Seminars by invited scientists are also regularly organised (2.3 seminars per month on the average). Lastly, PhD and post-doc regularly organised "non-permanent meetings" where they invite one permanent staff member of the lab to describe his activities, and share together their own scientific projects.

#### Parity

Among the permanent members of the lab, the gender ratio F/M is 10/19. Restricted to the researchers population, it becomes more balanced (8/11), however it should be noticed that considering only the highest positions (Professors, directeurs de recherche), it is only 2/8. This confirms the general tendencies that decision-makers positions are more often attributed to males than to females by the academic community. Student gender is nearly equilibrated.



### Health and safety

In order to ensure the compliance of the lab with safety standards and to maintain them at a good operational level, we collaborate fruitfully with the ESPCI technical staff dedicated to maintenance of the common services of the laboratory, especially when safety regulation are updated. During these last five years, several actions were undertaken:

- Formation of all the newly hired students (PhD, master, postdocs) to chemical or fire risks (organised by CNRS, ESPCI or UPMC) and, locally, presentation of the safety rules of the lab.
- Writing of safety notices for many experimental devices.
- Definition of a safety procedure for experiments which are automatically performed overnight.
- Registration of all the maintenance procedures.
- Every month, safety regulations are discussed and possibly reminded to lab members during security meetings (“visite de sécurité”). These meetings consist in a thorough visit of two lab rooms. It is an opportunity to make the lab members aware of lab safety and possibly to improve the procedures.
- A general meeting of all the lab members, dedicated to safety issues, was organised, following a chemical leak during an overnight experiment, in order to discuss and improve safety procedures.

Data safety issues were also addressed by the installation of a local NAS server which allows secured back-up of data and files and access to common computer tools. During their initial visit of the lab, students are made aware of the data safety issues, as well as of the use of a lab book for raw data consignment.

## 4. SWOT analysis of the unit or the team/theme

### Strength

The scientific activity of the laboratory has a very positive dynamics. Subjects are renewed, and the average number of students, the number and the quality of publications keep increasing. Despite a decrease in the number of ANR grants, the total external funding of the laboratory grows thanks to the ERC and to multiannual contracts with companies.

Second, a major strength is the very good employment rate of the PhD students after their thesis – most of them being hired even before their defence, in general by international companies. It contributes greatly to the attractiveness of the laboratory.

A third strength is the ability of the lab to develop both applied and fundamental subjects in the same time, a good measurement of which is provided by the large numbers of both industrial collaborations and academic international collaborations.

### Weakness

The pluridisciplinary approach we have in the field of soft matter (physics /physical chemistry /mechanics) leads to a scattered lobbying power among the concerned academic communities. As a consequence, it leads to difficulties in recruitments and promotions of permanents researchers, as well as in the hiring of PhD students which are not specifically attracted by industrial collaborations.

As a result, the communication and the image of the lab – which is very good in the industrial community - should be improved in our natural national academic communities.

### Opportunities

The ERC advanced grant, as well as the establishment of long term industrial collaborations provide financial security, ITN, and GiCore programs will help attracting foreign students. Those favourable conditions will allow the lab to focus on new long term projects, with an excellent efficiency. The durability of the lab activities is thus ensured for the next five years. In addition, the building of a new laboratory on ESPCI site will solve the long-lasting problem of the geographical implantation of the lab which is currently split between two non-adjacent staircases.

### Threats

One of the greatest difficulties we have concerns the UPMC permanent members of the lab. As a consequence of the tortuous national scientific policy in the last decade, they have no prospect of promotion in the future – except if they leave the lab. In addition, no hiring of assistant professor from UPMC can be expected. As a result, the multi-disciplinary richness of the laboratory is seriously threatened on the mid-term, which endangers the future of the lab.

Second, works on the ESPCI site will result in a dispersion of the laboratory members into five non-adjacent sites – although fortunately all on the ESPCI site - for about 3 years. During this period, special care will have to be taken regarding the unity of the laboratory.

## 5. Scientific strategy and projects of the unit or team/theme

### Overview

Capitalizing on our areas of recognized expertise, emphasis for the coming years will be laid on three major, intimately connected, research directions:

- **Functional assemblies:** understanding molecular or mesoscopic scale associative processes for the elaboration of architected soft, porous or liquid systems.
- **Soft solid mechanics:** the dynamics of mechanical deformation in soft solids
- **Dynamics of complex liquid interfaces:** Interfacial dynamics of fluids and their interactions with solids

As shown in more detail in the following section, these research directions span the full **spectrum of the present lab competencies** and offer **multiple points of intersection** between themselves. They also happen to be significantly transverse to the team structure of the lab. Moreover, through their obvious relevance to **science** on the one hand, and to **engineering** on the other hand, they integrate naturally with the national research strategy (**SNR**), with the evolving landscape of **undergraduate and graduate studies** in both of our COMUEs, *Paris Science et Lettres* and *Sorbonne Université*, and with a number of significant **technological issues** in industrial R&D.

As detailed in the *Report* section of this document, a number of long term contractual projects, strong ties with industrial partners, and also some renown in the field of soft matter all provide a sound basis for the development of this scientific policy. Simultaneously, a number of difficulties can be foreseen.

The shortest term difficulty is the **multi-year ESPCI building renovation** starting in 2018. During this period, SIMM, a ca 60-people strong lab (all included) will be scattered over no less than 5 areas within the premises, and all in close proximity to... the typically noisy/dusty building works. In order to keep a decent standard of working environment for the agents and maintain attractivity for visitors and students, we need to encourage in-lab daily interactions and especially:

- maintain **inviting social areas** and activities,
- promote proactive, fast and easy **information exchange** by not only providing ad hoc technology but also fostering human interactions at the adequate level of granularity (e.g. team structure).

In parallel, **health and safety** conditions will require special scrutiny since some of the experimental set-ups will be moved into temporary facilities where the safety of the operating conditions will have to be secured as stringently as in their previous location.

A longer term difficulty relates to an apparently rising antagonism between our **two COMUEs** *Paris Science et Lettres* and *Sorbonne Université*. Their individual policies are way beyond our means of action and we can only reiterate our adhesion to the open-minded spirit which has long prevailed in the UMR status at the time of ESPCI/CNRS/*Université Pierre et Marie Curie* and which is an integral part of our identity. Let us hope the best will emerge from the inevitable clarification to come.

At an even longer term, the research directions detailed below should provide a basis for a long term **communication policy** around the SIMM identity, relying on the communication cells provided by CNRS and ESPCI. The objective is to ensure a wider projection of our activities and results, in line with both the expectations of a rapidly evolving society and age-proofed scientific practice, as well as facilitating **recruitment of new researchers**.

**Project****I/ Functional assembly**

We will capitalize on our experience with controlled assembly in solvent media to propose new building blocks for soft matter, more specifically gels, elastomers and liquid-liquid interfaces. We will control their assembly through interactions and kinetics, to improve their architectures, tune their dynamics and activate responses through stimuli.

I.1/ Designing the architecture of soft matter

(CC, GD, J-BdE, DH, AM, TN, NP, PP, NS, YT)

Beyond molecular scale interactions, **phase separation** in copolymer solutions is now well understood. It can be harnessed for a better design of **gels** and especially the control of their **mesoscale structure**. The characteristic sizes of the self-assembled phase can be adjusted but also its morphology. In particular, percolation of the secondary phase is of primary significance for gel functionality. Beyond direct impact on mechanical response, the mesoscale structure drives fluid/solute transport in the bulk, with strong impact in applications where gels are used as host matrix for growth such as organic/inorganic hybrids [Niederberger 2006] or biological tissues for example [Costa 2015]. (coll. IPCM-UPMC, UMET, ENSMP)

Parallel strategies underlie the **assembly of inorganic solids** where interface control strongly affects final structure and properties. We are interested in how the **mesoscale structure** [Ioannidou 2016] can be directed during assembly. Two major inorganic binders are of interest to us: 1) **geopolymers** (alkali alumino silicates) and **cements** (hydrated calcium silicates), for which it is now well known that the mesostructure is of paramount significance for long term durability both chemical (destabilization by ingress of an external solution within the pore structure, crystallization pressure) and mechanical (creep and crack propagation). Cements and geopolymers are interesting cases because they form by very different routes: nucleation-growth-physical gel mechanism for cement and sol-gel chemical transition for geopolymers. Beyond the possible control of heterogeneous nucleation and growth by organomineral interactions, gelation can be **directed through interaction with hydrophobic organic additives**. (with BASF – coll. ETH, CEA)

Along the same line but at a slightly larger scale, we are interested in the control of **inorganic particle assemblies** [Glotzer 2007], which are of interest as solid porous materials (e.g. thermal insulators) but also as a model for fundamental understanding of the collective behavior of interacting particles. Based on our previous experience where silica particles assembly was carried out in water with tuned surface hydrophobicity, we propose to investigate how more advanced **surface modifications** could help overcome the capillary stresses induced by the drying front. Good candidates for that purpose are **copolymers** and **gel layers**. Finally, the **interface between solids and gels** is of more general interest in other areas as well, for example in the elaboration of active gels/gold multilayers (§ I.3). (coll. PHENIX)

Interface modification similarly drives liquid/liquid structures i.e. emulsions and foams. **One-step processes for multiple emulsions** are highly desirable [Clegg 2016]: based on our recent progress with a **single polymeric emulsifier**, we aim at making a fully biocompatible, stable, tunable, easy-to-process w/o/w multiple emulsions. A possible application is **encapsulation and delivery** of bioactive compounds. To achieve this goal, we also need to understand the molecular mechanisms leading to the formation of the polymer stabilized multiple emulsions. Combining surface control and bulk material assembly, this research also paves the way to **solid architectures through segregation of the solvent phase**. Building up on our ability to control emulsions, we propose to develop new methods for the structuration of elastomeric materials into **solid foams** or **gels** for tunable mechanical properties. Similarly, emulsion templating has been used for decades. However, for very soft solid, the technique runs into the danger of

pore collapse during drying. We will use novel strategies to overcome this problem. (coll. CRPP, CEA, Pharm. Fac. Paris)

### 1.2/ Tuning the dissipation: damping and fracture

(CC, GD, DH, AM, TN, NS, YT)

**Dissipative mechanisms** are a major contribution to mechanical response, both for energy absorption and **fracture resistance**. Tuning dissipation is therefore an integral component of the design of soft matter [Johnson 2010]. Based on different elaboration strategies, various principles are currently being investigated at SIMM : 1) molecular associativity in **dual cross-link gels** ; 2) **chain-filler adsorption**, through inclusion of nanoparticles with **tuned interactions** ; 3) **secondary phase** from phase separation (section I.1). Another strategy to tune the out-of-phase response is to adjust compliance: novel building blocks will be tested, in particular **semi-flexible polymers** for very soft gels (sacran). (with Solvay – coll. LPMA, UMET, LCMCP, Un. Hokkaido)

For dissipation processes, gels are a source of inspiration for **elastomers**. We have started to investigate the application of the **double network strategy**, originally developed for toughening gels [Gong 2003], to elastomers through elaboration strategies pertinent to elastomers. It is expected that the secondary network provides additional, « plastic like », dissipation channels which result in strongly enhanced toughness. Especially interesting in the case of elastomers is the competition between chain scission vs intermolecular dissipation mechanisms. (with DSM)

Finally, our aim is to combine elementary dissipation mechanisms with mesoscale structures under developments (for example structured gels or solid foams - section II.1.a) for the investigation of scale bridging in mechanical response (§ II.1).

### 1.3/ Driving the response

(CF, DH, AM, CM, TN, NP, PP, NS, YT)

Molecular interactions can be altered through medium changes, resulting in stimuli responsive binding [Cohen Stuart 2010]. Indeed many of the systems mentioned previously find a new dimension when combined with the ability to respond to stimuli.

For **liquid interfaces**, pH, ionic strength or temperature may trigger such a response. For that purpose, we plan to synthesize stimuli responsive stabilizing agents for several of the systems mentioned previously. For **multiple emulsions**, we primarily consider pH response for directed release in the relevant organ. For foam stabilization, we will synthesize polymers that can form **amphiphilic complexes with metal ions**, while remaining soluble in solution. Such macromolecules should yield liquid foams with metal scavenging properties where foam destabilization/metal release can be triggered by a stimulus (§ III.3). Finally, we also plan to design similar molecules for **gel structuration** by emulsions, resulting in **switchable** structure/response. (ANR, with Extractive – coll. CEA, BRGM, ENSCP)

Another strategy works in analogy with the Pickering principle for interface stabilization by particles. We propose to design smart **macro-surfactants** [Guennouni 2016] obtained from the coupling of **asymmetric gel particles**. This strategy opens up for the control of interface stability through the whole range of stimuli response of gels.

Active hydrogels are promising materials for **actuators or sensors** in aqueous media. They can become substitutes for either nuts and bolts components or droplet encapsulation presently used in the fields of microfluidics or microbiology. We plan to capitalize on our recent progress on thin film gel deposition and patterning by thiol-ene click chemistry to investigate the potential of **active gel structures** in a variety of areas. Another type of physic-chemical systems we are interested in is **active multilayers** driven by stimuli responsive hydrogels for **optical** and **thermal** control applications. Such systems require careful control of the gel/inorganic interfaces (§ I.1). (coll. ENSCP, LLB, LPEM, IPGG)

Finally **response** to a stimulus is also a method for **controlled kinetics of assembly**. An excellent example, which actually summarizes most of the challenges of functional assembly, is the problem of **injectable adhesives** [Sivashanmugam 2015], presently being studied at SIMM. The material is initially liquid and must set in (i.e. turn into a solid gel) upon temperature change as it is injected in the body. Simultaneously, it must both form an adhesive interface with the organ it contacts *and* display the correct structure and dissipative mechanical properties to actually perform as an adhesive! (*ITN Biosmart*)

The idea of using stimulus response for assembly has two other interesting sequels. It stresses the benefit which would result from the development of truly **orthogonal multiple stimuli** response for the efficient elaboration of smart active materials [Schattling 2014]. In this respect, we plan to add **light** (azobenzene) as a complementary stimulus to our present panel. It also opens the way to de-assembly of materials, which resonates with present environmental concerns.

## II/ Soft solid mechanics through scales

Understanding the mechanical response of soft solids is a question of considerable interest and difficulty because deformation mechanisms:

- depend upon geometry (fracture, filler particles, interfaces and confinement)
- are size dependent due to material heterogeneity, including the dynamical response
- involve material nonlinearities due to large deformations (stretch dependent dissipation is unavoidable) as well as geometric non-linearities due to structure
- involve surfaces, which play an increasingly more significant role as length scales decrease, with specific difficulties both for experiments and modeling

Our aim is to provide a better understanding of the interplay between these effects and investigate the relation between macroscopic and small scale mechanical response in some well chosen model systems. To bridge length scales, we will: 1) explore mechanical response at more local scales, and 2) model scale bridging, for which we propose two strategies, and numerical and the other experimental.

### II.1/ From the macroscopic into the smaller scales

(*EB, BB, AC, MC, CC, GD, CF, FL, AM, HM, CM, TN, LT*)

To explore the **macroscopic** end of the size scale, we rely on decades of experience and an **extensive range of measurement apparatus**, focusing on **rheology, traction, fracture and adhesion rupture**. More local scale methods have been recently developed at SIMM : 1) **image correlation** for soft polymer **friction** 2) image correlation of **AFM** image sequences for crack tip processes in **fracture**; 3) **fluctuation spectroscopy techniques** for local dynamic response, either particle or surface based. In addition to these techniques we propose to develop three other methods to access local scale information relevant for mechanical response.

Following our recent results [Ducrot 2014], **optical spectroscopy** will be harnessed for the **chemomechanical** investigation of molecular deformation or rupture within polymeric networks. These new tools, made possible by advanced organic synthesis, will provide **mappings of damage distributions** around crack tips, either *ex situ* or *in situ*. They should help unravel the respective contributions of **dissipation mechanisms** to fracture toughness. The principle will be applied to various systems under scrutiny at SIMM (§ I.2). (*ERC Chemech – coll. TU Eindhoven, Duke Un.*)

SIMM has a long experience in **single fiber traction** experiments. In parallel, other small scale measurement techniques have appeared in other fields, and especially metallurgy, where micropillar

compression and related techniques have proved fruitful in the last decade [Uchic 2004]. Similarly, with **micron scale stress-strain** investigations of soft solids, we can circumscribe or even eliminate problems resulting from inhomogeneous deformation, fracture, and also more easily reach the **large strains and strain rates** especially relevant for fracture processes. Preliminary tests have been carried out and we propose to develop small scale quasi static and dynamic mechanical experiments for soft matter mechanics, including small scale plasticity of vitreous polymers or single fibril traction measurements of soft acrylates. *(with Saint-Gobain)*

Finally, we have recently carried out **birefringence** measurements in viscoelastic-viscoplastic biphasic polymers designed for mechanical strengthening. The results clearly evidence rich data: the technique potentially allows for separation of the responses of different phases, which could be interpreted as the "direct" measurement of an **internal mechanical variable**. Moreover, the measurements can be carried out with a spatial resolution of the order of the micron, which is very promising for the present purpose.

## II.2/ Physics based modeling

*(EB, SC, MC, CC, CF, FL, HM)*

Various issues strongly limit our intuition of the relations between length scales, and most prominently **material heterogeneities**, disorder and elaborate geometries such as **inclusions, surfaces or crack tip**. For materials with complex mechanical responses, it becomes necessary to resort to numerical calculations. Following our recent practice, our strategy is to start from experimentally observed effects and imagine minimum models to simulate them, including the basic physical ingredients. This will typically mean simplified geometries and material constitutive relations trimmed down to the bare ingredients. Another specificity of our approach is the incorporation of statistical ingredients in the simulations in order to account for the disorder of the soft matter systems we are dealing with. The numerical resolution of the resulting differential equations is carried out using finite elements.

Two problems are actually considered. The first one is **soft matter fracture** [Hui 2003], and especially energy flow and dissipation from the far field to the crack tip. Such models combine **large deformations** and a pertinent description of **material dissipation** with a crack geometry. The aim is not to establish a quantitative description of the rupture dynamics of these materials but more simply to qualitatively understand the relation between far field and crack tip field and how variations in material response will affect this relation. Two families of materials are presently considered for this study: **soft dissipative networks** on the one hand, and **vitreous polymers** on the other hand (epoxies). *(with Saint-Gobain, Renault)*

The second issue under investigation through numerical modeling is the **non-linear mechanics of polymers near their glass transition temperature**. If the nonlinear mechanics of elastomers is relatively well understood, the response below the glass transition temperature is known empirically but explanatory models are lacking, despite strong technical implications. The strategy here is to **explicitly take into account material heterogeneities** (covering in particular dynamic heterogeneities and composition heterogeneities) of bulk polymers and polymer blends through numerical modeling of their statistical effects and thus **derive homogenized mechanical responses** i.e. constitutive relations. We have already provided answers for the problem of the dynamic response near  $T_g$  and further efforts will deal with **plasticity** and **strain hardening**. Other systems of relevance are **filled elastomers** and **semi-crystalline polymers**. *(Chaire Hutchinson)*

### II.3/ Harnessing mesoscopic systems

(EB, BB, AC, MC, CF, AM, EV)

Another modeling strategy is to **fabricate systems at a larger length scale** (which we could call mesoscopic) to simulate, at an observable scale, microscopic phenomena. An interesting example recently proposed is the macroscopic "double gel network" based on Nylon fabric and which - to some extent - emulates the relevant stretch behaviour [Feng 2016]. This type of modelling is converse to the usual practice of geophysicists. Alternatively, the response of these mesoscopic systems is of interest by itself as demonstrated by the physical mechanics community.

**Friction** remains one of the most complex mechanical phenomena and is especially difficult to understand because of the **occurrence of non-stationary phenomenon at sliding interfaces**. Unfortunately, the contributions to friction of the related microscopic individual events (**pining/depining of molecules, micro-asperities interactions,..**) are efficiently averaged out within the interface and their signature is lost in macroscopic measurements. In order to mimic these events at a mesoscopic scale, we offer to use **elastomeric foam surfaces** (such as commercial polyurethane foams) or **model solid foams** designed at SIMM (§ I.3). Foam/foam friction exhibits remarkable frictional properties which rely on the entanglement of struts and cells across the interface according to a "Velcro" mechanism. The statistics of non-stationary individual events behind interface dynamics can thus be probed by **direct optical observation**. Moreover, these surfaces are easy to prepare, versatile, large scale, disordered at the mesoscopic scale, and should prove ideal for this purpose. *(coll. CRPP).*

Following a closely related strategy, designed interfaces using lithographic techniques can serve similar purposes and will be used to investigate the **impact of heterogeneity and disorder on adhesion of soft polymers** ("Scotch® tape") and friction. In relation with well-defined mechanical response, such mesoscopic systems should open towards a more quantitative understanding of the macroscopic response in the presence of disorder.

A 3D version of the same problem arises when considering **fibrous materials**. Beyond the problem of the individual response of a fiber, the mechanics of threaded wires, or disordered wools, for example, is still difficult to capture, especially due to the combination of **heterogeneities** and very strong **non-linearities** (buckling, intermittent contacts) found in this problem. It would therefore be highly interesting to investigate the mechanics of model 3D disordered fibrous systems which becomes possible through 3D elaboration methods such as polymer printing. *(with Saint-Gobain - coll. ENSMP)*

### III/ Surface and interface dynamics

The **dynamics** of out of equilibrium **liquid interfaces** is still a very open question. In many cases, static configurations are relatively well understood even though the **interface structure** itself is often still elusive. In fact, due to **long characteristic times**, some static states may actually not be equilibrium configurations, and are history dependent. In addition, typical problems involve a **large range of length scales** from the capillary length (meniscus, large drop) down to molecular scales. Moreover, for the various species present (solvent, solutes, surfactants), different **transport processes**, diffusion and convection, **compete** in the bulk, at the surface and between bulk and surface.

Given the complexity of the situation, our strategy is to set up **model systems** for which **interface chemistry** is well controlled and the **relevant physical parameters** can be tuned independently. For this purpose, we rely heavily on the systems developed by molecular assembly such as described in section II.1.



III.1/ Interface rheology*(CM, FL, LT, EV)*

In view of the multiple length scales involved, and the diversity of behaviours, it is desirable to measure liquid/liquid interface rheology in homogeneous systems with a **simple, well defined geometry**. Microfluidics has emerged as an adequate tool for that purpose [Huerre 2014]. We have recently shown how the time evolution of **microfluidic droplets** can provide valuable information on the viscoelastic response of interfaces decorated with adsorbed polyelectrolytes. We propose to develop the use of microfluidic systems for the measurement of interface rheology. Incidentally, an added value is also the better understanding of the **flow of heterogeneous liquids** in microfluidic devices. *(coll. IPGG, Gulliver)*

In addition to microfluidics device, other experiments allows to measure the interfacial rheology. The measure of a liquid film squeezed between another liquid and a solid surface, developed in the frame of the PIC project allows the **precise measurements of the interfacial extensional rheology** [Buteau 2017]. In addition, also in the PIC laboratory we develop a **condensation-induced Marangoni effect** device that will allows to detect interfacial rheology modification at the free surface of a liquid with a very high sensitivity. *(with TOTAL)*

III.2/ Films and transport*(AC, CF, FL, HM, LT, YT, EV)*

Transport properties in thin film geometry may also raise some complex issues. Two cases are of present interest at SIMM.

Very thin liquid films are frequent in the problem of pseudopartial wetting of a low molecular weight melts on solid substrates, where the formation of a **precursor film** with a typically nanometric thickness is observed. For such films, a standard **hydrodynamic description fails** and diffusive processes gain an increasing role [Mate 2012]. Adding to the complexity, the details of the **interaction with the substrate** (van der Waals or others) have to be taken into account in the driving forces. We have recently developed specific tools to quantify these phenomena based on **ellipsometric microscopy** and **surface fluctuation spectroscopy** measurements. Combined with our understanding of molecular interactions and rheology, these tools open to a thorough investigation of very **thin film dynamics** under spontaneous or forced wetting conditions. *(with Solvay)*

Stress-activated water transport phenomena in **thin hydrogel films** also control their surface properties. We will investigate the overlooked contribution of poroelastic flow to frictional response of hydrogel films confined within contacts by playing with gel network architecture (§ I.1) and using dedicated **contact and friction experiments** allowing to probe mechanical and frictional properties during the course of poroelastic drainage. We anticipate some strong connections between these contact-related poroelastic behavior and that involved in wetting dynamics (§ III.3). *(with Saint-Gobain)*

III.3/ Triple line and coupling with interface dynamics*(EB, FL, CM, TN, LT, YT, EV)*

Beyond the relatively simple film geometry addressed above, **wetting** front problems offer added complexity through the **local singularity at the triple line**. In close analogy to fracture problems (see section II.2), the fundamental question is therefore: how do **interface dynamics** and **species transport** couple to the singular fields associated with a moving line [Kovalchuk 2016]?

Systems of strong interest to us are **gels** for which the flow associated with the poroelastic response raises interesting issues. We plan to investigate how **geometry** (confinement in thin films) and the **material response** of both the **soft substrate** and the wetting **liquid** affect dynamics. Special attention will also be paid to the elastic contribution for novel gels with very low moduli (§ II.1.b). *(ANR Gelwet with Lab. MSC/Paris Diderot)*

Similarly, the dynamics of wetting for an **oil/water/solid** system in the presence of **surfactants** is a complex problem. In particular, evolution of the molecular conformation around the triple line may result in **highly non trivial dynamics** (superspreading) [Stoebe 1997]. Due to obvious technological implications, we will consider both well-defined chemicals and also natural species such as asphaltenes. For these studies, the edge dynamics of thin liquid films will be investigated in Sheludko-like film destabilization.  
(with TOTAL - Labo commun PIC)

Finally, very few studies have considered the problem of the **dispersion relation** of interface dynamics [Snoeijer 2007]. However, the characteristic times of the triple line depends upon **length scale**, which may be an efficient way to probe the key phenomena behind interface dynamics. In analogy to the strategy outlined in § II.2.c, it is of interest to set up interfaces with **well-defined heterogeneities** to experimentally explore the characteristic features of this wavelength dependent response and interrogate interfaces in this novel way.

As a conclusion, let us stress that real systems of practical relevance usually involve **combinations** of several of the **interfacial effects** which we have proposed to understand individually in § II.3.a-c. For example, in an incipient project, we propose to use innovative metal complexing, stimuli sensitive, stabilizing agents (§ II.1.c) for **metal scavenging through liquid foams** and subsequent controlled release. Such a complex sequence can be worked out only if dynamic wetting (with the substrate from which metal recovery is expected) and transport in the liquid films (of the foam) are well understood. (ANR, with Extracthive – coll. CEA, BRGM, ENSCP)

## Bibliography

Bluteau, 2017 "Water film squeezed between oil and solid: drainage towards stabilization by disjoining pressure." L. Bluteau, M. Bourrel, N. Passade-Boupat, L. Talini, E. Verneuil and F. Lequeux *Soft Matter* (2017) **13**, 1384.

Clegg 2016 "One-step production of multiple emulsions: microfluidic, polymer-stabilized and particle-stabilized approaches." Paul S. Clegg, Joe W. Tavaoli, Pete J. Wilde *Soft Matter* (2016) **12**, 998-1008.

Cohen Stuart 2010 "Emerging applications of stimuli-responsive polymer materials." M. Cohen Stuart et al., *Nature Materials* (2010) **9**, 101-113.

Costa 2015 "Extremely strong and tough hydrogels as prospective candidates for tissue repair—a review." Costa, Ana MS, and João F. Mano, *European Polymer Journal* (2015) **72**, 344-364.

Ducrot 2014 "Toughening elastomers with sacrificial bonds and watching them break." Ducrot, Etienne, et al. *Science* 344.6180 (2014): 186-189.

Feng 2016 "A highly stretchable double-network composite." Feng, Xiangchao, et al. *Soft matter* 12.44 (2016): 8999-9006.

Glotzer 2007 "Anisotropy of building blocks and their assembly into complex structures." Glotzer, Sharon C., and Michael J. Solomon. *Nature materials* 6.8 (2007): 557.

Gong 2003 "Double-network hydrogels with extremely high mechanical strength." Gong, Jian Ping, et al. *Advanced Materials* 15.14 (2003): 1155-1158.

Guennouni 2016 "Self-organization of polystyrene-b-polyacrylic acid (PS-b-PAA) monolayer at the air/water interface: a process driven by the release of the solvent spreading." Guennouni, Zineb, et al. *Langmuir* 32.8 (2016): 1971-1980.

Huerre 2014 "Bubbles and foams in microfluidics." Huerre, Axel, Vincent Miralles, and Marie-Caroline Jullien. *Soft Matter* 10.36 (2014): 6888-6902.

- Hui 2003 "Crack blunting and the strength of soft elastic solids." Hui, C-Y., et al. *Proceedings of the Royal Society of London A: Mathematical, Physical and Engineering Science* (2003) **459**
- Ioannidou 2016 "Mesoscale texture of cement hydrates." Ioannidou, K. et al. *Proc. Natl. Acad. Sci.* (2016) **113**, 2029–2034.
- Johnson 2010 "Some hydrogels having novel molecular structures." Johnson, J. A., et al. *Progress in Polymer Science* 35.3 (2010): 332-337.
- Kovalchuk 2016 "Kinetics of spreading of synergetic surfactant mixtures in the case of partial wetting." Kovalchuk, Nina, et al. *Colloids and Surfaces A: Physicochemical and Engineering Aspects* 505 (2016): 23-28.
- Mate 2012 "Anomalous diffusion kinetics of the precursor film that spreads from polymer droplets." Mate, C. Mathew. *Langmuir* 28.49 (2012): 16821-16827.
- Niederberger 2006 "Oriented attachment and mesocrystals: Non-classical crystallization mechanisms based on nanoparticle assembly." Niederberger, M. & Cölfen, H. *Phys. Chem. Chem. Phys.* (2006) **8**, 3271.
- Schattling 2014 "Multi-stimuli responsive polymers—the all-in-one talents." Schattling, Philipp, Florian D. Jochum, and Patrick Theato. *Polymer Chemistry* 5.1 (2014): 25-36.
- Sivashanmugam 2015 "An overview of injectable polymeric hydrogels for tissue engineering." Sivashanmugam, A., et al. *European Polymer Journal* (2015) **72**, 543-565.
- Snoeijer 2007 "Relaxation of a dewetting contact line. Part 1. A full-scale hydrodynamic calculation." Snoeijer, Jacco H., et al. *Journal of Fluid Mechanics* (2007) **579**, 63-83.
- Stoebe 1997 "Enhanced spreading of aqueous films containing ethoxylated alcohol surfactants on solid substrates." Stoebe, T., et al. *Langmuir* 13.26 (1997): 7270-7275.
- Uchic 2004 "Sample dimensions influence strength and crystal plasticity." Uchic, Michael D., et al. *Science* 305.5686 (2004): 986-989.

## II APPENDICES

### Appendix 1: Contractual mission statement



Paris, le 25/09/14  
Monsieur Christian FRETIGNY  
Directeur de l'UMR7615-SIMM

Affaire suivie par : Jean-François TASSIN  
Nos réf. : CHIMIE-D-2014-

Monsieur le Directeur, Cher Christian

Vous avez assuré durant le précédent contrat la responsabilité de la direction de l'UMR CNRS/ESPCI/UMPC « PhysicoChimie des Polymères et des Milieux Dispersés ». Cette UMR historique à l'ESPCI a su, sous votre impulsion, faire évoluer ses thématiques, touchant de plus en plus des systèmes variés de la matière molle. La mise en place d'une instrumentation dédiée, l'utilisation de systèmes modèles reposant sur des compétences de chimistes vous ont permis d'obtenir des résultats remarquables dans de nombreux sujets. Leur inspiration industrielle n'est nullement pénalisante dans votre approche mais s'avère au contraire d'une grande richesse. La compréhension des propriétés macroscopiques de l'échelle moléculaire aux échelles mésoscopiques le cas échéant constitue un savoir-faire et une thématique qui distinguent votre unité au niveau national. Votre attractivité est forte et la qualité des recrutements de personnels permanents comme non permanents en atteste. Nous tenons à vous féliciter et vous remercier pour le travail accompli.

Vous avez accepté de prolonger votre mandat de Directeur pour le contrat qui vient de débuter au 1<sup>er</sup> janvier 2014. Nous vous en remercions et souhaitons vivement un succès équivalent à la période précédente. Vous avez choisi de faire évoluer la dénomination de l'UMR ce qui traduira effectivement mieux votre positionnement dans le champ de la matière molle et votre évolution vers les procédés. Nous vous invitons à maintenir des objectifs ambitieux dans vos challenges théoriques ou expérimentaux et vous encourageons à maintenir la qualité et la densité de vos relations industrielles. La structuration de l'UMR en équipes projets permet de mobiliser des compétences de façon souple. Il faudra toutefois veiller à ce que ces dernières ne s'étiolent pas et développer en conséquence des projets davantage disciplinaires permettant une forme de ressourcement et de prise de risque. La qualité de certains de vos travaux nous semble digne de publications dans les meilleurs journaux internationaux, nous vous invitons à aller dans cette direction, ce qui ne pourra qu'être bénéfique pour les auteurs et l'ensemble de l'Unité. Une stratégie vis-à-vis de l'ERC pourrait également être mise en œuvre parallèlement.

.../...

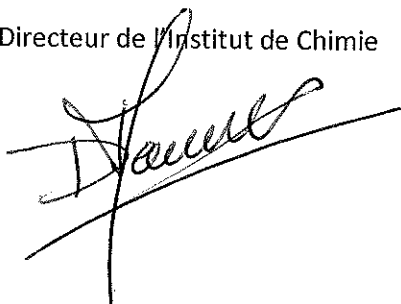
D'un point de vue administratif, vous connaissez déjà les missions quotidiennes qui vous incombent, en particulier en tant que responsable du suivi et de l'affectation interne des personnels et du budget. Nous vous rappelons que le Vade-mecum du DU contient les réponses à un certain nombre de questions standard auxquelles vous n'auriez pas été confronté jusque-là. Nous vous invitons également à suivre les offres de formation d'actualisation à la direction d'unité qui vous seront adressées dans le cadre du Parcours professionnel du DU mis en place par le CNRS et les formations complémentaires qui pourraient être mises en place par l'UPMC. Nous attirons en particulier votre attention sur l'importance de la gestion des ressources humaines, et en particulier des agents en CDD.

Il existe, au sein de l'enceinte de l'ESPCI, une communauté de grande qualité dans le domaine des polymères et de la matière molle, tant d'un point de vue théorique qu'expérimental, qui aurait tout à gagner à coordonner une animation scientifique inter-équipes. Votre Unité se doit d'y participer.

Nous vous assurons de notre soutien et vous prions de croire, Monsieur le Directeur, à l'expression de nos sentiments les meilleurs.

Dominique MASSIOT

Directeur de l'Institut de Chimie



Paul INDELICATO

Vice-Président  
Recherche et Innovation



Jean-François JOANNY

Directeur de l'ESPCI



**Appendix 2: Equipment, platforms**

**Plateforme rhéologie/mécanique :**

- Viscosimètre capillaire à dilution automatique Schott AVS360

- Rhéomètres déformation ou contrainte imposée :

Low-Shear 30 et 400

RHEOMAT RM 200

Haake RS600

TA Instruments DHR3

TA Instruments AR-G2

TA Instruments ARES

Anton Paar MCR501

- Machines de traction :

Zwick HC25

Instron 5565

Instron 3343

MTS 810

MTS 831

- Analyseurs Mécaniques Dynamiques (DMA) :

TA Instruments Q800

MTS 831

- Outils non conventionnels :

Fluctuations de surface

Diffusion multiple de la lumière

**Analyse thermique :**

DSC Q200 TA Instrument

DSC Discovery TA instrument

mDSC CEVO Setaram (microcalorimétrie)

ATG SDT Q600 TA instrument

**Mise en forme :**

Presse chauffante (200Bar, 100kN) DARRAGON

Mélangeur XPlore DSM

**Matériel pour la chimie :**

- 3 Chromatographes par perméation de gel (GPC/SEC)
- 3 Centrifugeuses
- 2 lyophilisateurs
- 1 analyseur de carbone (TOC)
- 3 tensiomètres (dont un à goutte tournante)

**Matériel pour les surfaces :**

- Hotte à flux laminaire Oxygen
- Insolateur UV Chloé UV-KUB2
- Spin-coater SPS SPIN150
- Plasma à oxygène
- Profilomètre interférométrique Fogale M3D
- ellipsomètres (dont un pour l'imagerie)

**Atelier mécanique**

SIMM abrite un atelier de fabrication mécanique, doté de deux centres d'usinage multi-axes, d'une imprimante 3D et d'un parc de machines traditionnelles. Cet atelier, géré par deux ITA, est commun à trois UMR du site ESPCI ; les chercheurs convenablement formés aux techniques d'usinage peuvent y accéder en libre-service.

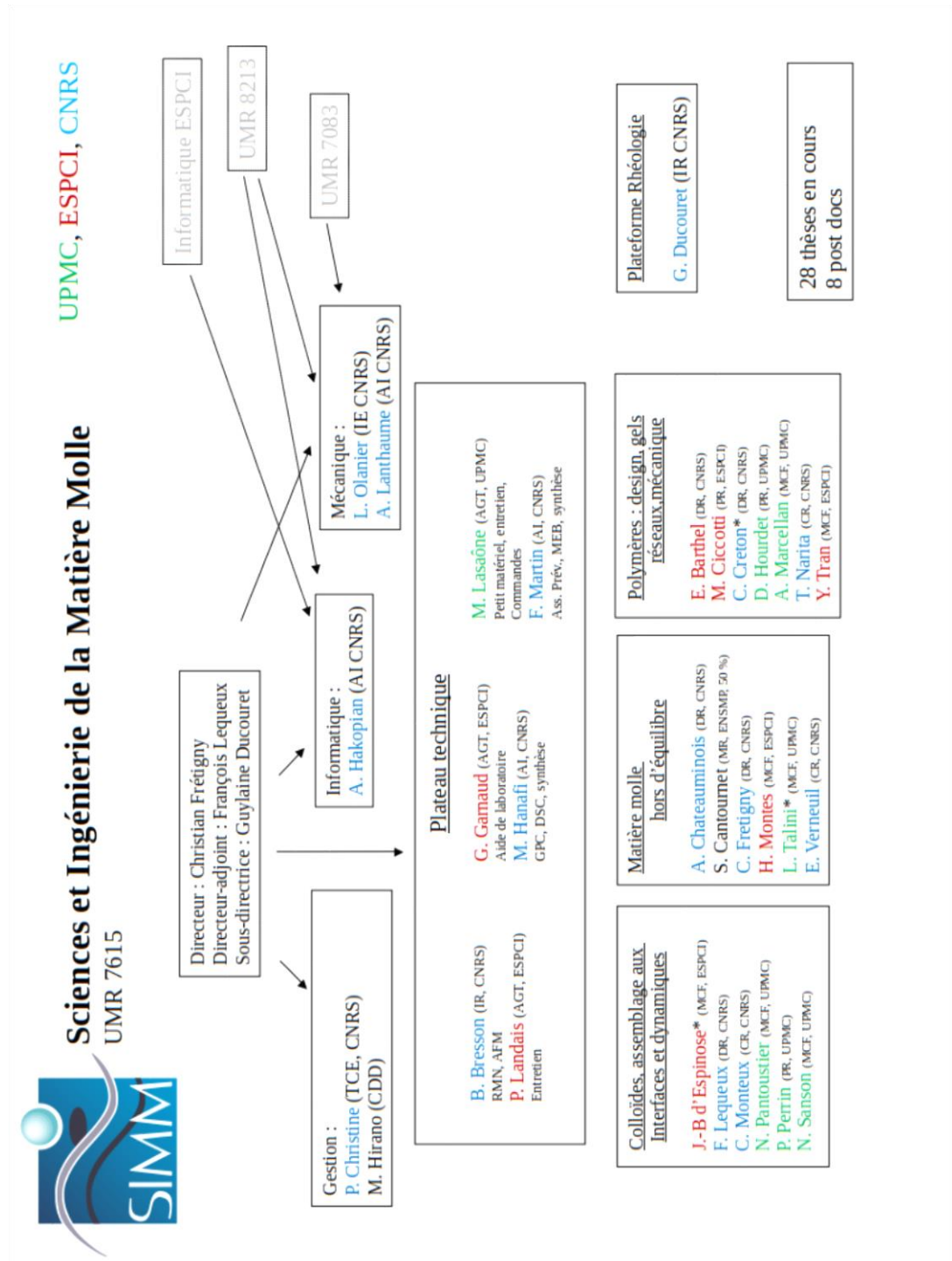
**Autres**

- 3 microscopes à force atomique (AFM)
- 1 microscope confocal
- 1 caméra IR...

De nombreux instruments sont fabriqués au laboratoire à partir d'éléments optiques et mécaniques pour la mécanique du contact, l'étude des interfaces liquides, la méchanofluorescence...



Appendix 3: Organisational chart



**Appendix 4: Selected scientific production and activities**