



Laboratoire de Mécanique des Solides  
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Parrainé par la Chaire André Citroën et la Chaire Arkema



**DESIGN AND MODELING  
OF INNOVATIVE MATERIALS**

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# *Symposium*

# *Jean Mandel*

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***Multiphysics problems in mechanics***  
*Problèmes en mécanique multiphysique*

**Thursday, June 18<sup>th</sup> & Friday June 19<sup>th</sup> 2020**

Zoom webinar  
École Polytechnique

Inscription pour un zoom webinar sur invitation avant le 18 juin 2020  
Registration for a zoom webinar by June, 18<sup>th</sup> 2020  
Contact : [manas.upadhyay@polytechnique.edu](mailto:manas.upadhyay@polytechnique.edu)

***The Jean Mandel Symposium, organized annually in memory of the founder of the LMS, is open to all students, researchers and scientists interested in mechanics. It combines a keynote presentation by an internationally renowned scientist in a topic of current interest, followed by talks from young researchers of the LMS working on a related topic and time dedicated to discussions.***

# Plenary Lecture

by Alexander B. Freidin

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## Chemical affinity tensor in mechanochemistry

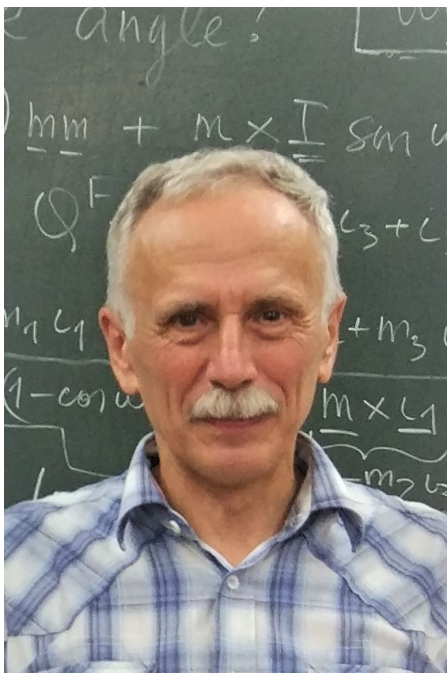
Chemomechanics or mechanochemistry – i.e. coupling between chemical reactions and mechanical stresses – problems have been studied intensively during last decades. Among the examples one could mention are: the oxidation of silicon in integrated-circuit technology with reaction retardation produced by stresses in silicon microspheres and nano-wires, the oxidation and accompanying damage in microscale parts of MEMS, the formation of intermetallic phases in solders and lithiation in lithium-ion batteries. It should be emphasized that stresses may arise in mechanochemistry due to strains produced by chemical reactions in the absence of external mechanical loading. Furthermore, accurate formulations and solutions of mechanochemistry problems are motivated by applications involving miniaturization in electronics and mechatronics.

In this talk the interaction between solid and movable diffusive constituents is discussed within the framework of mechanics of configurational forces. At first, the fundamental notions of chemical kinetics are recalled, including the notion of chemical affinity which controls the chemical reaction rate in classical physical chemistry. We subsequently show from balance laws and the second law of thermodynamics that in the case of chemical reactions in deformable solids the chemical affinity is a tensor. The normal component of the affinity tensor acts as a configurational force driving the reaction front propagation, while stresses affect the reaction rate through the affinity tensor. A kinetic equation in the form of the dependence of the reaction front velocity on the affinity tensor together with constitutive equations for the solid reactants, mechanical equilibrium equations and diffusion equation form the system of governing equations for the coupled problem “diffusion – chemistry – mechanics”. In the last part of the talk are presented solutions of coupled problems for elastic and inelastic solid reactants, showing how mechanical stresses can accelerate, retard or block the propagation front. Finally, the reaction front instabilities and arising damage problems are also discussed and applications are presented.

## Alexander B. Freidin

Institute for Problems in Mechanical Engineering of Russian Academy of Sciences  
Peter the Great S. Petersburg Polytechnic University & S. Petersburg University, RU

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Prof. Alexander Freidin obtained his Diploma in Mechanical Engineering from Leningrad Polytechnic Institute in 1976. He continued as a graduate student in fracture mechanics at the Novosibirsk Electrical Engineering Institute studying under A.I. Chudnovsky and I.A. Kunin. In 1979 he came back to Leningrad (St. Petersburg) to work for the polymer industry at Plastpolymer Research Institute until 1992. He obtained his PhD in Physics and Mechanics at Moscow Physical and Technical Institute in 1987. In 1993 he joined the Institute for Problems in Mechanical Engineering of the Russian Academy of Sciences where, in 1997, he was awarded a Doctoral Habilitation in Physics and Mechanics. He also holds the position of Professor at Peter the Great St. Petersburg Polytechnic University (Institute of Applied Mathematics and Mechanics) and St. Petersburg University (Faculty of Mathematics and Mechanics). His research interests are in nonlinear mechanics and thermodynamics of materials including multidisciplinary problems of stress-induced phase transitions and stress-affected chemical reactions.

# Thursday, June 18<sup>th</sup>, 2020 Program

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14:00 – 14:10 Introduction by **Andrei Constantinescu**, Director LMS

14:10 – 15:10 **Alexander Freidin** *Chemical affinity tensor in mechanochemistry*

## **SESSION 1. CHEMISTRY & CREEP, Chair: Michel Jabbour**

15:10 – 15:30 **Svetlana Petrenko** *Evolving chemical reaction front in plasticity*

15:30 – 15:50 **Ludovic Gil** *Chemo-mechanics of subcutaneous injections.*

15:50 – 16:10 **Bertrand Leturcq** *Model reduction following the integration of complex creep in a multiscale mechanical model.*

# Friday, June 19<sup>th</sup>, 2020 Program

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## **SESSION 2. MAGNETOMECHANICS, Chair: Laurence Bodelot**

14:00 – 14:20 **Dipayan Mukherjee** *Microstructurally-guided dissipative continuum models for hard magnetorheological elastomers*

14:20 – 14:40 **Matthias Rambašek** *Bifurcation of magnetorheological film-substrate elastomers subjected to biaxial pre-compression and transverse magnetic fields*

14:40 – 15:00 **Nicolas Hanappier** *A coupled electromagnetic-thermomechanical approach for the modeling of electric motors*

## **SESSION 3. EVOLVING MICROSTRUCTURES, Chair: Alexandre Dimanov**

15:15 – 15:35 **Lucas Benoit-Marechal** *Evolution laws for the step-bunching problem in crystal growth*

15:35 – 15:55 **Raphaël Bayle (PCM lab')** *Crystallization of a ternary alloy for phase change memory applications*

15:55 – 16:15 **Sofia Sakout** *Fast mesoscopic grain growth model based on dissipation*

16:15 – 16:35 **Cecile Patte** *Patient-specific pulmonary mechanics: modelling, estimation and application to pulmonary fibrosis*

16:50 – 17:00 Closing remarks by **Andrei Constantinescu**, Director LMS

# Jean Mandel

Founder of the Laboratoire de Mécanique des Solides

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After brilliant secondary studies, Jean Mandel went on to École Polytechnique in 1927 and later to École des Mines. In 1932 he became a professor at École des Mines de Saint-Étienne and in 1948 at École des Mines de Paris. From 1951 to 1973 he was professor of mechanics at École Polytechnique.

Jean Mandel's research career was devoted mainly to the mechanics of solids and the strength of materials. In 1961 he created the Laboratoire de Mécanique des Solides, a laboratory common to École Polytechnique, École des Mines de Paris, École des Ponts et Chaussées and associated to the Centre National de la Recherche Scientifique. In October 1964 he founded and became the first president of the Groupe Français de Rhéologie. In 1980 he became "honorary member" of this group.

The scientific work of Jean Mandel covers a very wide field with a bibliography listing more than 150 articles and 5 books. He presented original ideas on the buckling of beams and shells, the finite deformations of solids, laminar flow in porous media, the bearing capacity of shallow foundations, the punch resistance of a two-layer medium, the stability of underground cavities, the plastic flow of metals, and the effect of cyclic loading on structures, as well as contributions to the fields of thermodynamics, rolling friction and homogenization.

But Jean Mandel's influence extended far beyond the field of his personal research. A good many students were trained, under his direction, in the Laboratoire de Mécanique des Solides. A fine teacher and a constant stimulus to his research group, he gave his time generously to study the details of manuscripts that were sent to him and to suggest the minor modifications he deemed necessary. Those who had the privilege of working with him were left with an impression of palpable scientific passion and moral rigor that will continue to be an example for generations to come.

Jean Mandel passed away on the 19th of July 1982, the victim of a tragic accident at the very height of his intellectual prime.

Biography by Pierre Habib

(Former Director of the LMS)