Theme-based objectives and endpoints

Objective: Design and create increasingly high-performance power converters and supply devices targeting :
Compactness - Performance - Compatibility with the environment

Through decisive actions involving :

- New semiconductor devices (GaN, diamond, SiC) : gate driver and characterization
- Power integration : packaging concepts, EMI, cooling...
- Converter design : topologies, modular converters, system level converters networks...
- Innovative design methods and tools : electroMagnetic modeling, optimization-oriented models

Keywords : modelling, integrated power electronics, EMC, gate drivers, packaging, power converters design and optimization, cooling.

EP Team
POWER ELECTRONICS

Scientific activities

Power devices and integration

Semiconductor devices
- 2D and 3D integration including wafer level packaging,
- Gate drivers,
- Thermal and electrical characterization

Passive devices
- Integration,
- Characterization

Converter integration
- Integrated modular converter from elementary cells

Power converter Design

Topologies, control, design

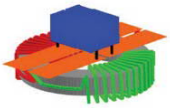
Targets
- Multisource converters,
- Modular converters,
- Applications with high constraints

Modelling, methodologies and design tools

Devices and EMC modelling
- Converters, Systems (network, plane...),
- Evolution of standards (PLC, EMC, ...),
- Semiconductor devices,
- Passive devices

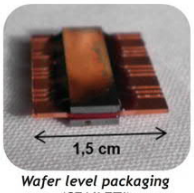
Methodologies for converter design

Tools for rapid prototyping



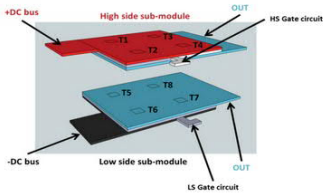
EMC filter model

Achievements

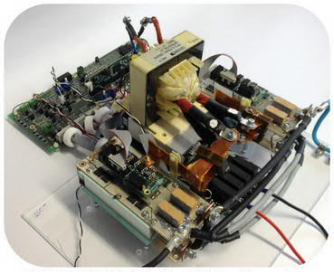


Wafer level packaging (CEA/LETI)

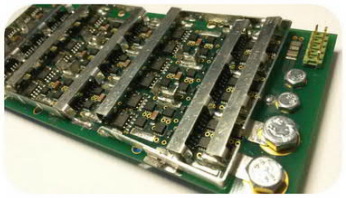
DC-DC converter (15V-5W) with insulation voltage capabilities up to 40kV (Schneider)



PCoC power module with embedded dies



4kW DC-DC Triple Active Bridge Converter for Aircraft Application (Thales)



DC/DC converter from elementary conversion cells

Experimental facilities

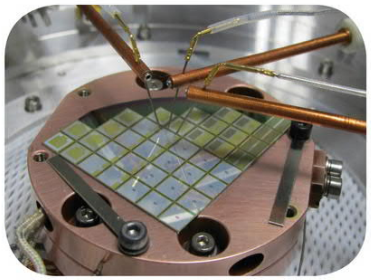
Semiconductor Characterization

Electrical characterization (Temp. 77K-675K)
Thermal impedance measurement.

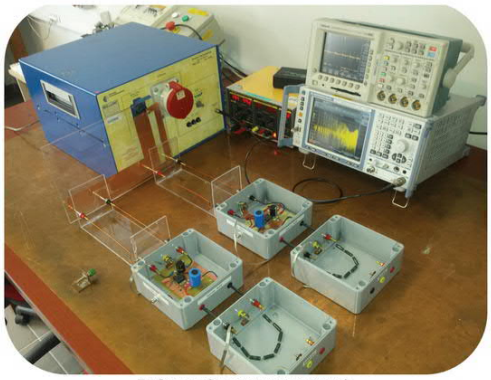
EMC test bench

Technology platforms

CIME Nanotech Clean Rooms and packaging facilities acces



Component testing facility CARAPACE



EMC test of a converter network

Collaborative projects

Industrial projects
Alstom, Altair, Eaton, Ecoways, Freemens, Hager, Luxol, Microspire, Mitsubishi, Renault Truck, Schneider-Electric, Siemens, Thalès, ST Microelectronics, Safran

European project
Green-diamond

Start-up
Freemens (Battery Management Systems)
Sirepe (Power converters design)

National Projects
National research agency, OSEO, FUI, Région Rhone-Alpes, Institut Carnot Energies du Futur, Laboratoires d'Excellence: LANEF, GaNEX, IEED Supergrid

Academic partners
Research group with CEA/LETI, and SAFRAN
Others in Grenoble: CIME Natotech/PTA, LEGI, Néel Institute, IMEP, SIMAP...
National : Ampère (Lyon), LAPLACE and LAAS (Toulouse), SATIE and IFSTTAR (Paris), INES (Le Bourget du Lac).
International: Algérie, Allemagne, Brésil, Bulgarie, Canada, GB, Iran, Japon, Mexique , Pérou, USA

Theme-based objectives and endpoints

Conception and design of innovative electromagnetic devices going beyond the limits of existing systems: energy efficiency, environment, compactness, new functionalities ...

Multidisciplinary approach from materials to applications including physical analysis of phenomena, model building and experimentation at different scales

MADEA+

MATERIALS AND ADVANCED ELECTROMAGNETIC DEVICES

Scientific activities

Functional materials for Electrical Engineering

Magnetic materials, superconductors, magnetocalorics, coupled magnetic materials, etc.
In close cooperation with Grenoble-based physics laboratories

- Study and enhancement of properties and exploration of new functionalities
- Model building of static, dynamic and multi-physical behaviours
- Characterisations of giant EMC materials at atmospheric temperature
- Magnetic materials treated in intense fields

Conversion and processing of energy

Innovative converter devices

- Design and sizing considering actual operating conditions and the environment
- Analytical and semi-analytical modelisation for design and optimisation
- High critical temperature superconductor magnets (HTS)
- High performance actuators and machines
- Magneto and electro-caloric systems
- Fault current limiter

Information conversion and processing

Original information processing structures

- Implementation of materials and use of multiphysics couplings
- Instrumentation, signal processing and specific model building
- Giant magneto-impedance sensors (GMI)
- Innovative CEM filters for aeronautic systems
- Low field N.M.R systems

Design of immersed transformer-connector for sea turbines (collaboration DCNS and M PRIME Energie)

NMR and GMI sensors

Magnetic refrigeration devices

Experimental facilities

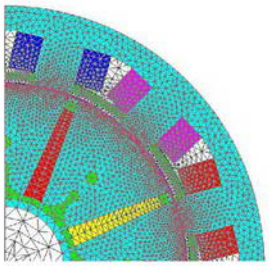
- Characterisation benches for magnetic materials: losses and hysteresis different wave shapes, high and low frequencies, mechanical stresses, etc.
- Electromagnets for fine characterisation of hard and soft materials
- Characterisation benches to determine critical parameters of superconductors
- Helmholtz coils, sensor calibration, magnet characterisation
- Low field NMR sources
- Magnetic refrigeration devices to study active regeneration thermal cycles (AMR)
- Automatic rotating machine test bench (50kW, 500Nm, 10000rpm)
- Furnace for magnetic annealing treatment under magnetic field (0.1 T, 900°C)

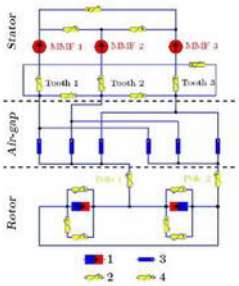
Studies

- Analytical calculation of interactions between permanent magnets
- Magneto-mechanical coupling at high frequency in ultra-soft materials

Achievements

- HTS superconductor magnets
- Magnetic refrigeration prototype
- Temperature sensor deposited on a YBaCuO ribbon
- NMR measurement probe working in low fields
- Superconducting current limiter
- Planar magnetic component integrated on to PCB with meander core geometry and ultra fine (20mm)FeNiCrCu magnetic ribbons

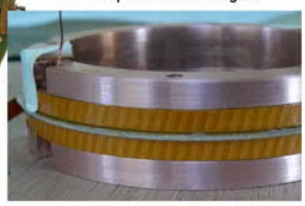




Design Optimization of Permanent Magnet Synchronous Machines for Electric Vehicle

Superconducting Fault Current Limiter

HTS superconductor magnet



Collaborative projects

Industry

Absolut System, Air Liquide, Aperam, ARaymond, ArcelorMittal, Alstom, Chauvin-Arnoud, Cooltech Applications, CIH, DCNS, Dymeo, EDF-DTG, Enerbee, IDEA, Mitsubishi, MPrime Energie, Nexans, Renault, Schneider Electric, Thalès, Valeo, ST Microelectronics, Zodiac Aerospace

National

AMPERE, CEA-LITEN, CEA-SACM, CRETA, CRISMAT, DGA, ICMCB, Institut Néel, ISL, Gipsa-lab, LAPLACE, LEPMI, GEEPS, LMGP, LMT, LNCMI , IMP-INSA LYON

International

LIA-LAS2M, CAPS, IZFP, HEIG-VD, Tech-Inst. of Bandung, Ecole Polytechnique Montréal, KIT, EPFL, Tohoku Univ.

Theme-based objectives and endpoints

- Extending the computing capabilities by focusing on methods of computational electromagnetics in continuous media, on models of materials for electrical engineering and on multi-physics and multi-methods coupling
- Helping the expertise and the design of devices addressing the themes of innovation, sizing and capitalization and management of knowledge.

MAGE Team

MODELS, METHODS AND METHODOLOGIES APPLIED TO ELECTRICAL ENGINEERING

Scientific activities

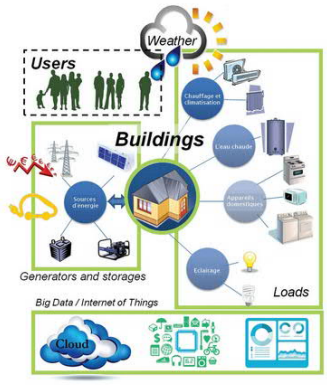
Computational Electromagnetics
- Innovative electromagnetic formulations (static, steady state and transiencircuit and mechanical couplings, rigid body motion)
- Numerical methods and techniques (finite elements method, integral methods, matrix compression, parallel computing)
- Materials modeling (dielectric, magnetic, superconductors,...)
- Meshing techniques

System Modeling
- Multiscale modeling (analytical, semi-analytical, numerical models)
- Multi-physics
- Multi-components
- Multi-methods
- Multi-materials

Design
- Innovation, pre-sizing, feasibility studies by taking into account processes and people

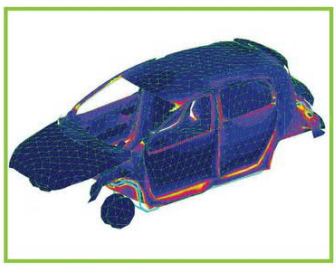
Optimisation and inverse problems
- Optimisation techniques adapted to simulation (screening, surface response methodology, genetic, conjugate gradient, simulated annealing,...)
- Eco design by optimisation to minimise ecological footprint
- Automatic differentiation

Engineering of knowledge and capitalisation of know-how
- Formalism of knowledge modeling, modeling languages (Modelica, VHDL-AMS)



Complex systems : Modeling, optimal design and control. Application to smart buildings

Modeling of a contactor with a volume integral method

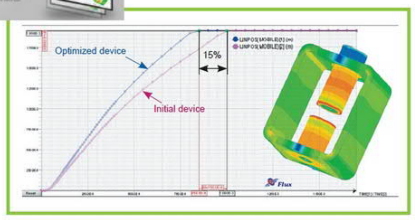


Finite elements modeling of eddy currents in a vehicle

Achievements

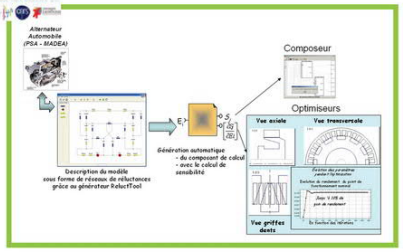
GOT-it

An optimisation software for large complicated problems (Industrialisation by Cedrat)



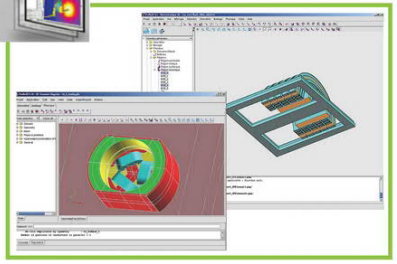
CADES

A modular software platform for components and systems sizing (Industrialisation by Vesta-System)



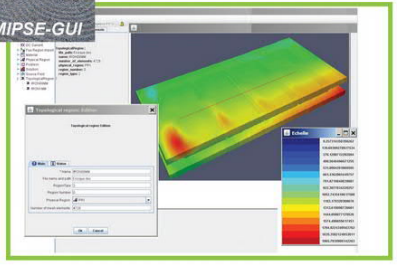
FLUX

An integrated finite elements simulation environnent (Industrialisation by Altair Engineering)



MIPSE

A multiscale and multi-methods simulation framework dedicated to low and average frequency computational electromagnetics



Collaborative projects

University
GSCOP, GIPSA Lab, LEGI, LEPMI, LOCIE, LMGP, SIMAP, AMPERE, FEMTO-ST, IFSTTAR, IRSEEM, LAPLACE, L2EP, LGEP, LMT, SATIE, SEEDS

Corporate
Alstom, Areva, CEDRAT, CEA, CSTB, DCNS, DGA, EDF, Hager, Labinal, Leroy-Somer, Liebherr-Aerospace, LMS-Imagine, Microspire, Onera, Precilec, PSA, Renault, Schneider Electric, Somfy, Valéo, Vesta System

International
University of Mons (Mons, Belgium), Politecnico di Torino (Torino, Italy), TU Delft (Delft,The Netherlands), ULG (Liège, Belgium), RPI (Troy, USA), TU Eindhoven (Eindhoven,The Netherlands), LBNL (Berkeley, USA)

Co-founder with AMPERE of the International Associated Laboratory Maxwell with Brazil (LIA 817)
USP (Sao Paulo, Brésil), UFMG (Belo Horizonte, Brésil), UFSC (Florianopolis, Brésil), AMPERE, G2Elab

MDE Team
ELECTROSTATIC AND DIELECTRIC MATERIALS

Theme-based objectives and endpoints

Studying physical mechanisms resulting from the application of the electrical field to solid, liquid and gaseous dielectrics.

Studying the materials used for electrical insulation of electrical engineering and electronic devices: behaviour under industrial constraints, durability, diagnostic methods, new materials.

Developing processes using electrostatic forces

Scientific activities

Characterization of dielectrics

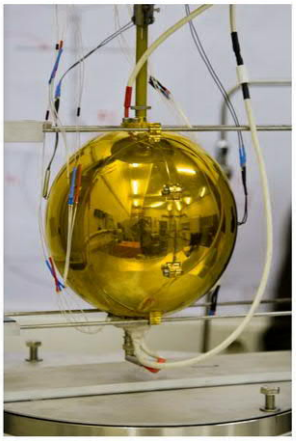
- Thin layers of oxides (Hafnium, MEMS)
- Thin layers of parylene (PPX N, C, D)
- Films of Biopolymers (PLA, PHBV, PCL)
- Insulating liquids under high temperature and high voltage (Fluorene)

Pre-disruptive phenomena studies

- Multi-physic study of pre-disruptive phenomena in solids (Ageing)
- Gas insulation for transfer of energy under very high voltage (HVDC)
- Optical spectroscopy of discharge in liquids (Charges mobility)
- Induced phenomena in a liquid by a highly localized injection of energy (Thermodynamic model)

Development of electrostatic processes and of specific techniques

- Energy harvesting through electrostatic process using Electro Active Polymers (EAP)
- Discharges in microgaps (MEMS)
- Electro-coalescence of water droplets in an insulating liquid (EC)
- Discharge based processes in liquids (Cleanup, Extraction)
- Calorimetry by thermal radiation: measurement of losses in power components (Measurement)



Loss measurement by calorimetry in power components

Measurements under high voltage in liquid Helium

Experimental facilities and Achievements

Very High Voltage Measurement
Marx Generator (500kV) / DC (360 kV) & AC (300 kVrms) high voltage power supply / steep waves impulse voltage generator / Measurement of losses, measurement of partial discharges

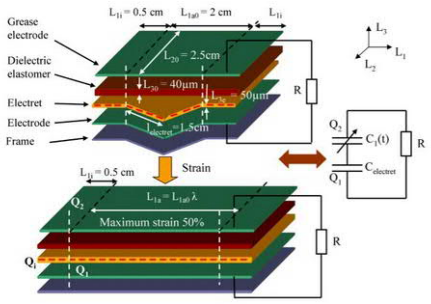
Electrical and dielectric analysis
Low-voltage dielectric spectroscopy (1 µHz-10 MHz) and high voltage dielectric spectroscopy (1 mHz- 1 kHz/20 kVrms) / 4-point measurements / measurement of: weak current, surface potential, space charges in solids (LIPP &PEA) / resistivity meter for liquids

Chemico-physical analyses
SEM, UV-visible spectrophotometer / FTIR / rheometer / Dynamic mechanical analysis (DMA)/ contact angle measurement/ drying oven, climate chamber, UV chamber, vacuum chamber

Material and sample elaborations
Sputtering and evaporation equipment for thin metallic film applications/ lapping machine

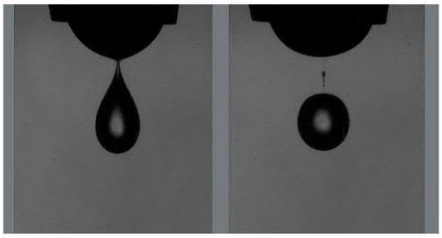
Opticals
Spectroscopy (200-1000nm) / high-sensitivity rapid imaging / streak camera

Specific devices
Cryostats 4.2 K/ high pressure and very high voltage test cells / calorimeter for losses in component

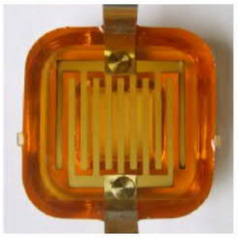


Design of electret-dielectric elastomer generator prototype: at rest and maximal state

HVDC 350 kV test cell for the measurement of dark currents through pressurized gases



Photos illustrating injection of a non-charged water droplet in a dielectric liquid (polybutene oil) generated by electrostatic pulse



Experimental model of an interface silica/resin studied with inter-digitated electrodes

Collaborative projects

University
Laboratories LAPLACE (Toulouse), IES (Montpellier), Pprime (Poitiers), LCEE (Poitiers), LPCML (Lyon), LMPB-IMP (Lyon), UTC (Compiègne), IMN (Nantes), LMSSMat (Ecole Centrale Paris), LaMCoS (INSA Lyon) Grenoble : LEGI, Institut Néel, LTM, CERMAV ...

International
SINTEF (Norway), Joint Institute for High Temperatures (Institution of the Russian Academy of Sciences, Moscow, Russia), Institute of Mechanics (Sofia, Bulgaria), University of Bucharest (Romania), Leicester (UK), Bizerte-Tunis (Tunisia), Western Ontario (Canada), Cordoba (Spain), University of Pennsylvania: Penn (USA), California State University at Northridge (USA), Northwest University of Xi'an (China) ...

Corporate
Areva, EDF, Schneider Electric, CEA- LETI, Renault, ST Microelectronics, Alstom, EADS, Boréalis, Siemens, CTP, Nexans, Varioptic, Comelec...

Theme-based objectives and endpoints

Optimisation of the Electricity (production - transmission - distribution - usage) chain

Network architectures and integration of producer, storage and consumers;
Control of local and global energy flows - ancillary services;
Security and availability;
Economic, environmental and societal impacts.

Research issues:
Multi-scale and multiphysics models adapted to understand problem-solving phenomena;
Multi-criteria optimisation methods: applied to architecture and sizing choices;
New suitable supervision control, protection laws and architectures;
Demonstration and validation of proposed solutions.

Support objects:
Transmission, distribution and private networks and embedded networks;
Distributed generation systems;
Non-conventional loads.

G2Elab
Grenoble Génie Electrique
Grenoble Electrical Engineering

SYREL Team
SYSTEMS AND ELECTRICAL NETWORKS

Scientific actiuities

The central theme

Intelligent power systems in their broadest sense, « smart grids «, microgrid, supergrid: a global problem that can be handled from component to macro system.
Electrical networks are indeed complex systems, in which many elements are in strong interaction. The researches have a highly multidisciplinary content (economics, control, electromagnetic, mechanic, hydraulic, among others) and are linked to many stochastic phenomena.

Three structuring areas

1/ Unconventional connected systems
(controllable energy sources, loads, storage and microgrids)

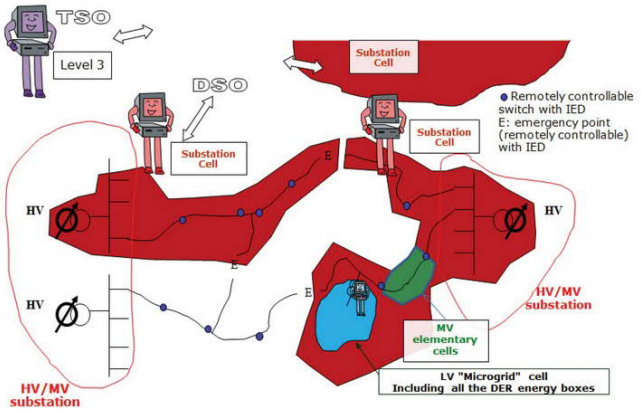
- Design/model of modular architectures
- Find decentralized management rules which need only a few data
- Integrate behavioral models (human, V2G, among others)
- Integrate technico-economic models of production and storage systems

2/ Analysis and optimization of advanced power systems - Towards a fusion smartgrids/supergrids ?

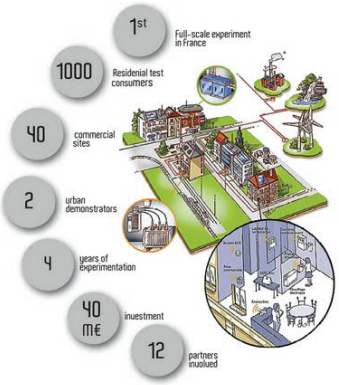
- Model and plan very large systems with strong interdependency
- Develop innovative control and observation laws
- Integrate the societal factor in the methodologies

3/ Advanced methods in understanding and securing complex infrastructures

- Use of new concepts (invariance of scale, fractals among others)
- Develop robust architectures of power systems
- Capitalize and hybridize methods coming from the study of complex systems (interdependencies and coupled infrastructures)



DREAM FP7 european project :
heterarchical management of complex electrical power grids

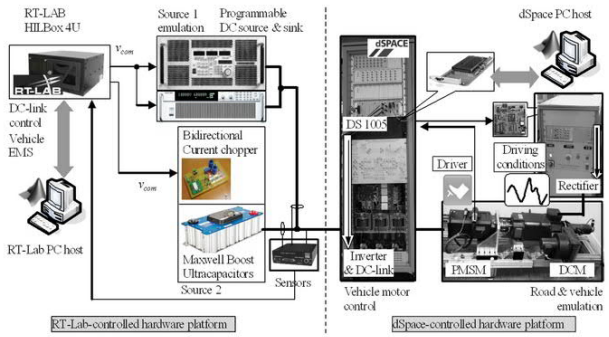


GreenLys french project :
smart grid full-scale demonstrator

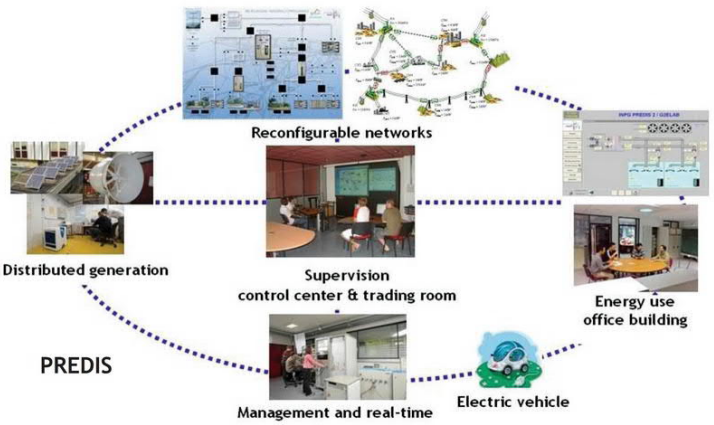
Superconducting Faut Current Limiter
for meshed HVDC grids

Facilities

PREDIS platforms :
Analysis, demonstration and benchmarking tools common to the research program
e.g.: the real-time hybrid simulator of electrical systems and distribution microgrids



Real-time Power-Harware-In-The-Loop
simulation of electric vehicle



Collaboratiue projects / Paternships

University
CEA-LITEN, GIPSA, GSCOP, LEGI, LEPMI, L2EP...

Industry
Airbus, Alstom, APC by SE, Areva, ATOS WorldGrid, EDF, ERDF, GDF Suez, GEG, Nexans, RTE, Schneider Electric, Thalès, TSV, SNCF, ...

International
Algeria, Belgium, Bulgaria, China (Beijing and Hong Kong), Colombia, Spain, Iran, Morocco, Romania, Sweden, USA, Venezuela, Vietnam, Ecuador, ...

European projects
ALP ENERGY, CRISP, DREAM, ECCOFLOW, EvolvDSO, FEBUSS, FENIX, FINSENY, FINESCE, FLEXMETER, GRID, INTEGRAL, KIC INNOENERGY, MOET, POA, SEESGEN ICT

National projects
ANR, OSEO, FUI, ADEME
DLDPV, ENERGETIC, ESPRIT, GREENLYS, MODECO, MULTISOL, REACTIVHOME, SINARI, SOGREEN, SOLUTION PV, SUPERBAT, SOGRID

Goals & Methods

Design, develop & test innovative devices:
- Power-MEMS : generators, actuators, sensors, supply & control
- Bio-Mag-MEMS : µfluidics for biomedical applications

Approach:
- Scale reduction laws & magnetic interactions

Analytical calculation tools and MEF:
- Dimensioning / optimisation of Mag-MEMS

Technologies:
- Prototypes, demonstration modules, models
- Integration of materials: µ-magnets, active hybrid materials
- Integration of functional devices

G2Elab
Grenoble Génie Électrique
Grenoble Electrical Engineering

Magnetic µSYSTEM
MAG-MEMS : MAGNETIC MICROSYSTEMS

Scientific actiuities

• ***Micro-energy:***
Energy harvesting, µ-sources of energy µ-actuators / µ-motors/ µ-generators

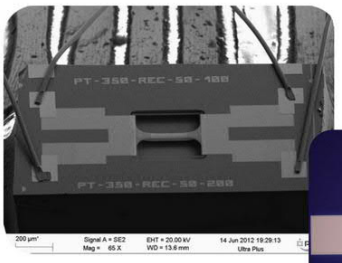
• ***Bio-Mag-MEMS:***
µ-fluidics for biomedical, lab-on-chip, µTAS
Diamagnetic levitation: digital µFluidics, µObjects

Experimental facilities

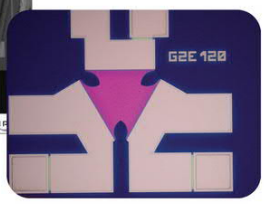
Embedded within CIME Nanotec @ MINATEC:
- Microsystems shared platform ($C^2µ$) (characterisation, prototypes, tests)
- PTA clean room
- Nano-Bio & µ-fluidic shared platforms

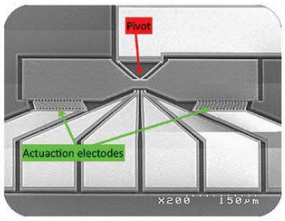
We benefit from the pioneering know-how of Institut Néel & CEA-LETI: creation & integration of functional materials, Si micro-technologies...

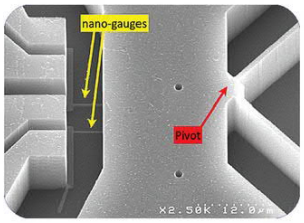
Integrated actiue materials



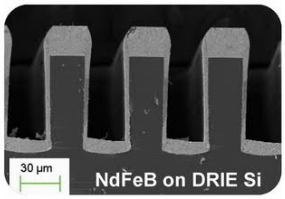
Hybrid transducers for voltage controlled actuation piezoelectric / magnetostrictive multilayers (@ CEA-LETI)







M&NEMS multi-modal sensor (directional magnetic & inertial) : Co-integration of nano-structured anti-ferromagnet multilayer, nanometric strain-gauges, & electrostatic feedback control (@ LETI)



Integrated high-performance magnets : thick NdFeB µ-magnet layers (30 µm) deposited onto textured Si substrate (Institut Néel, with LETI)

Productions

1- Integrated 8 mm Ø 3-phase dual-layer stator on Si for planar µ-machine / µ-generator (with LETI for DGA)

2- Array of 1 mm^2 µ-switches (bistable, 30~120 µm out-of-plane) Integrated FeCoP magnets, Si / Glass flip-chip-assembly (w/CEA-LETI)

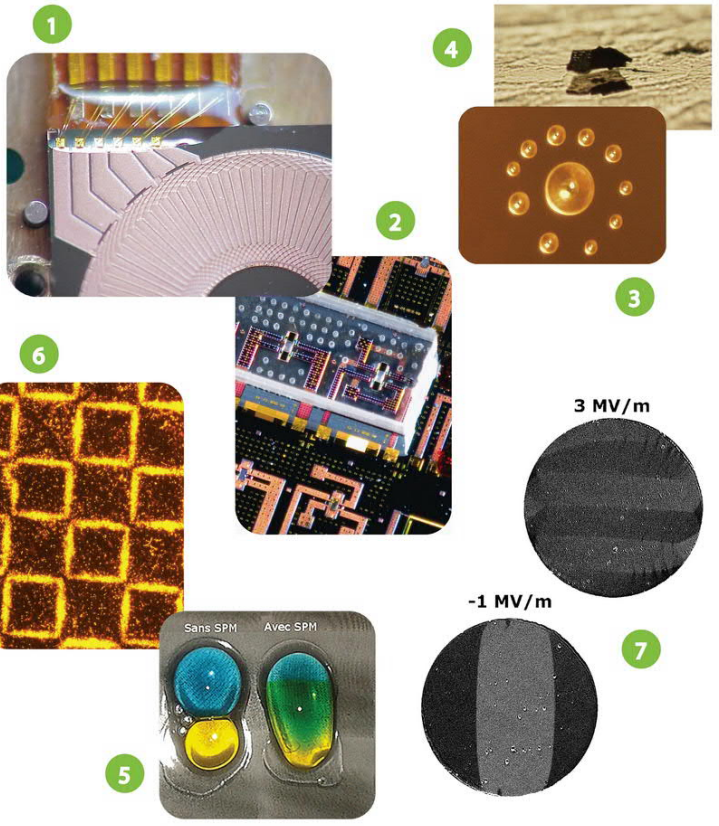
3- diamagnetic µ-droplets (H2O 30~150 µm) in levitation in a magnetic pit, in electrostatic repulsion (w/ CEA-LETI)

4- NdFeB magnet flake (thickness 5 µm) in levitation over diamagnetic HOPG graphite substrate (with I. Néel)

5- Bio-chemical reaction enhanced by superparamagnetic tagging. µ-fluidics for easy & fast diagnostics (with LMGP+Néel)

6- Bacteria tagged by magnetic nano-beads, trapped on 50 µm µ-magnet array (with I. Néel & Ampère /Lyon, for ANR Emergent)

7- Voltage control of magnetic easy axis orientation in nano-structured piezo-magnetic multilayer (with CEA-LETI)



Collaboratiue projects

MINATEC / $C^2µ$
micro-characterization, clean room (CIME Nanotec)

Institut Néel
integration of high performance magnets, exotic magnetic materials, diamagnetic levitation, bio-medical devices

LETI-CEA
integration on Si, µ-fabrication clean room, integrated active materials:
- PZT, magnetostrictive, shape memory

LMGP & IAB micro-fluidic bio-medical applications
TIMA energy harvesting, Ultra-Low-Power

Ampère-Lyon (& Biomis)
micro-manipulation of cells :
- superparamagnetic nanoparticles tagging
- diamagnetic trapping & selection

G2Elab
- ***ERT-CMF & SYREL*** magnetic sensors for Smart Grid supervision
- ***MAGE*** analytical design of Mag-MEMS design & constrained optimization
- ***EP*** smart power management
- ***MDE*** energy harvesting electrostatics for µ-fluidics & droplets

Theme-based objectives and endpoints

- Characterization of low-level and low-frequency magnetic fields (DC-3kHz, µT- nT)
- Identification of electromagnetic sources from external field measurements by resolution of inverse problems
- Attenuation of fields by control of sources and / or by design of passive or active shieldings

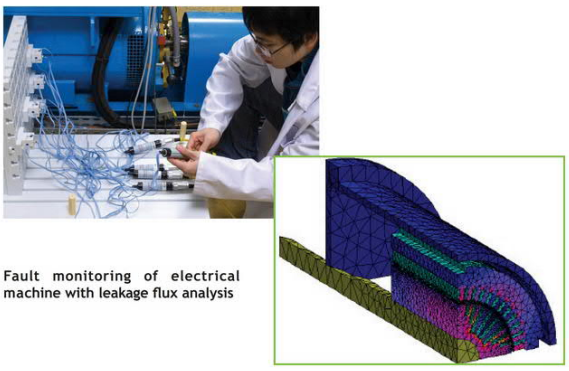
ERT-CMF

ÉQUIPE DE RECHERCHE TECHNOLOGIQUE CHAMPS MAGNÉTIQUES FAIBLES

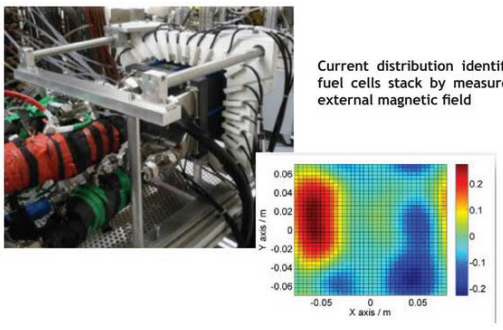
Scientific activities

- Electromagnetic discretion of ships,
- Magnetic discretion of electrical equipments (electrical machines, etc.),
- Reduction of stray fields by passive or active shielding,
- Measurement of low-level and low-frequency magnetic fields,
- Monitoring and calibration of sensors
- Diagnosis of electrical systems (alternators, transformers, fuel cell) with leakage magnetic field analysis,
- Diagnosis of corrosion using electric potential measurement
- Prediction of magnetization variations due to the effects of stresses (magnetoelastic model),
- Electromagnetic bioprocess for sewage problems

Magnetic State of a aircraft carrier in a earth magnetic field (FLUX software)



Fault monitoring of electrical machine with leakage flux analysis



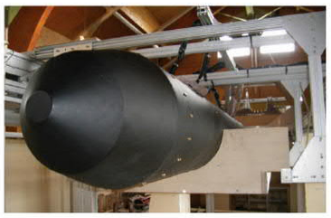
Current distribution identification in fuel cells stack by measurements of external magnetic field

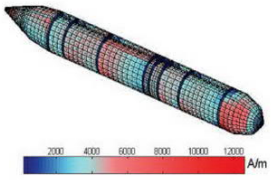
Specific equipment

Low Magnetic Fields Metrology Laboratory (LMMCF) located in Herbeys (10 km from Grenoble, in a magnetically stable environment) and shared with the CEA-LETI

- Magnetic field simulator (2 m diameter, 15 m long) with a very good homogeneity (better than 0.1 %).
- Deperming equipment: 10 square shake coils (1 meter cross section, 4800 A/m) with a frequency from quasi-static (0.01 Hz) up to 40 Hz.
- 100 magnetometers and gradiometers, mostly of fluxgate type (vector measurements), and a high performance data acquisition system is available.
- Metrological Magnetic Characterization Laboratory (LCM).
- A whole set of autonomous and portable equipment to take magnetic measurements on the field.

LMMCF facilities in Herbeys (Grenoble INP / CEA-ETI) Field Simulator and LCM equipment for magnetic characterization





Closed Loop Degaussing of a submarine : Identification of the magnetization form internal magnetic measurements (LOCAPI software)

Collaborative projects

University and Publics Agencies
French Ministry of Defense (DGA), Atlantic Submarine Study Groupe (DGA-TN), CEA-LETI, CEA-Liten, GIPSA-lab, LEPMI, LOCIE

Corporate
DCNS, CEDRAT, GeoEnergy, Schneider Electric, Arcelor / Imphy, MécaMagnetic, CNES, Alcan, Alstom, EDF-DTG, Somfy

International
NSWC (USA), Fincantieri (Italy), WTD71 (Germany), MoD/DSTL (UK), CTMSP (Brazil)