Expertise sheet of Professor Frédéric Sirois

Polytechnique Montréal, Montréal (QC), Canada
E-mail: f.sirois@polymtl.ca

Training:

B.A.Sc. : Electrical engineering, specialization in analog electronics and radio frequency
M.A.Sc. : Electrical engineering, specialization in electrical networks and equipment
Ph.D. : Applied physics, specialization in superconducting materials

Main professional experiences:

1998-2005 : Researcher, Hydro-Québec Research Institute (IREQ), Varennes (QC), Canada
2005-... : Professor-Researcher, Polytechnique Montréal, Montreal (QC), Canada
1999-... : Visiting researcher in several major institutions/organizations (EPFL, KIT, CNRS, University of Cambridge, Lawrence Berkeley National Laboratory, CERN, ...)

Expertise:

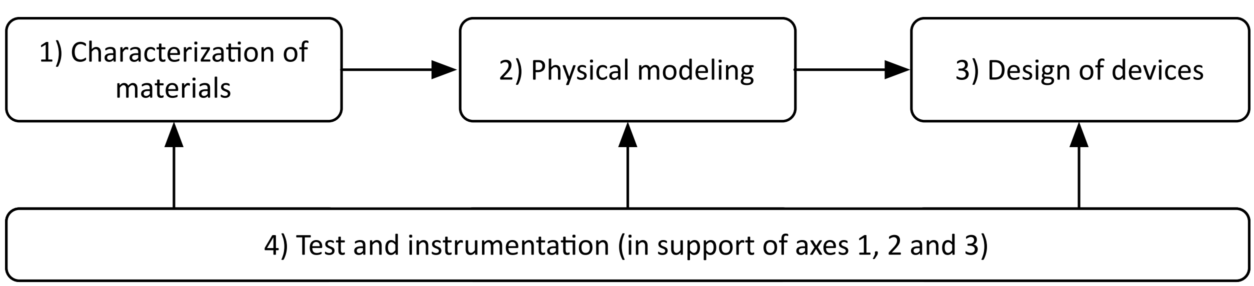
Electrical circuits – Electromagnetism – Applied superconductivity – Cryogenics and thermal problems – Characterization of material properties – Superconducting, metallic, magnetic and composite materials – Conductive coatings – Contact resistances – Mathematical modeling – Numerical analyses: finite elements and integral methods – Device design electromagnetics – Electrical apparatus – Electrical networks – Conversion and distribution of energy – Experimental methods and instrumentation – Design of electronic circuits

Application areas:

Energy – Transport – Biomedical – Industrial processes – Non-destructive testing – Design software – Laboratory tools – Advancement of knowledge

Structure of the research program:

3 research axes + 1 transversal support axis



Prepared by: prof. Frédéric Sirois, Polytechnique Montréal, Oct. 2022

Axis 1: Characterization of materials

Table I – Families of materials covered by Prof. Sirois' research

	Superconductors (S)	Conductors (C)	Magnetic materials (M)	Resistive materials (R)	Insulating materials (I)
Films (tick and thin) (F)	-REBCO films on substrate (coated conductors)	-Metallic conductive coatings (Cu, Ag, Zn, Ni, Cd, etc.)		-Resistive barriers (oxides in thin films <100 nm)	-Insulating barriers (oxides in thin films >100 nm)
Laminated materials (L)		-Hastelloy laminates (substrates for superconducting wires)	-Silicon steel laminations (for transformers and electric machines)	-Carbon fiber composites	
Bulk materials (B)	-REBCO bulks -REBCO tubes	-Conventional metals and alloys (Cu, Al, etc.)	-Magnetic steels and superalloys -Permanent magnets (all types)	-Power semi-conductors	-Fiber glass composites

-Experimental characterization of material properties

-Electrical properties (V-I measurements based on different equipment)

-V-I curves, critical current measurement (I_C): 2, 4, and multi-probe measurements
-Resistivity/Electrical Resistance: 2, 4, and multi-probe measurements
-Contact resistance: different methods depending on the material considered
-Current transfer length, surface potential: electrode matrices, multi-probe measurements

-Magnetic properties (specialty: large bulk samples)

-B-H curves: home-made hysteresis meter (20-900 °C), VSM (small samples only)
-Iron losses: custom setups
-Magnetization of permanent magnets: custom giant magnetometer

-Mechanical and structural properties

-Thickness of thin layers, surface roughness: profilometer (resolution: nanometers)
-Structure of matter: wide variety of microscopes (collab. with CM2 and GCM)
-Hardness: Vickers hardness test, other tests as needed (collab. with LAPOM)
-Thermal contraction: custom setups

- Concentration of gas diffused in the solid state

-Oxygen/hydrogen concentration: TDS or differential pressure measurement

-Range of experimental parameters*

-Temperature:	10 to 300 K (in vacuum), 64 to 90 K (in liquid nitrogen) 300 to 900 K (in a low pressure Argon atmosphere)
-Magnetic field:	0 tp 5 T (in vacuum or in cryogenic liquid)
-Current:	DC: 0-500 A – Pulsed: 0-1800 A (<10 ms) or 0-1600 A (5-500 μs)
-Measurable voltage:	100 nV to 250 V, up to 80 simultaneous readings

*Depending on the type of sample and its size, the experimental conditions may be restricted.

Axis 2: Physical modeling

-Modeling of the electromagnetic and thermal behavior of various devices
- -Short-circuit current limiters / Hot-spot propagation phenomena
- -Magnetic levitation systems
- -Power transmission cables
- -Motors/Generators, etc.

-Algorithms for numerical simulation of electromagnetic and thermal problems
- -Finite element method: home-made and commercial codes
- -Integral methods: home-made and commercial codes

-Materials modeling
- -Mathematical models of materials from measurements
  - -Superconducting materials
  - -Magnetic materials (including hysteresis) and permanent magnets
  - -Thin films and resistive barriers
- -Integration of material models in numerical simulation software programs
- -Algorithms to improve the convergence of nonlinear materials in numerical simulation software programs

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Axis 3: Design of devices

-Design assisted by numerical simulation (see axis 2)
- -Proof of concept by computer
- -Parameterization and automation of numerical simulations
- -Optimization of dimensions
- -Performance prediction

- Manufacturing techniques
- -Surface plating: electroplating, sputtering, chemical methods (electroless)
- -Etching of surfaces: electro-polishing, masking + chemical attack
- -Oxidation of surfaces: chemical attack + anodization
- -Oxygenation of superconductors: oven with gas flow or pressure (up to 700 °C)
- -Soldering: regular, with special alloys, of Litz wires, at low temperature
- -Low temperature materials: cryostats, custom fixtures and sample holders, etc.

-Quality and performance
- -Solder quality: measurement of contact resistance, porosities, etc.
- -Thermal cycles and aging: evolution of material properties
- -Performance Metrics: see axis 4

Axis 4: Testing and instrumentation (in support of axes 1, 2 and 3)

-Data acquisition equipment

-Acquisition cards: many types, from very slow to very fast (up to 500 MS/s)
-Oscilloscopes and other conventional measuring instruments

-Custom electronic circuit design

-Pulsed current sources: several types (5-1000 μs, 1-100 ms, DC)
-Voltage measurement systems: 16/40/80 differential inputs (1 mV to 250 V)
-Automated signal multiplexers: synchronized scanning of input signals
-Interconnection and signal conditioning boxes: custom designs

-Specialized measurement test benches

-Zone normal propagation velocity (NZPV) in superconducting tapes
-Critical temperature of superconductors
-3-D mapping of magnetic field around magnetized bodies (such as permanent magnets)
-Oxygen/hydrogen desorption measurements by differential pressure

-Specialized instrumentation for power tests

-2 test areas: three-phase AC: 600 V/400 A/400 kVA, DC: 500 V/200 A/50 kW
-Power amplifiers: 2 x 5 kW/50 A/100V/50 kHz, 6 x 50 kW/200 A/250V/1 KHz
-Lightning current generator: 10-50 kA, 5 μs of rise time
-Real-time simulators: OPAL-RT, Hypersim (for prototyping of controllers)
-Conventional measuring equipment: power analyzers, current transformers, etc.

-Other specialized infrastructure

-Electromagnets (up to 7 T, several models)
-Cryostats for low temperature tests (10 to 300 K, several types)
-Ovens for heat treatments or aging tests (up to 900 °C)
-Custom fixtures and sample holders (for operation between 10 and 1000 K)

-Specialized personnel for the operation of equipment and the performance of tests