# CDMF
# Functional Materials Development Center

# Synthesis and unconventional properties of novel oxides, intermetallic compounds, magnetic nanoparticles, and borides

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***Education and Knowledge Diffusion Coordinator*** **:** Prof. Antonio Carlos Hernandes
***Technology Transfer Coordinator***: Prof. Edson Roberto Leite

**+ 10 PI's + over 60 PhD students & PD**

**FAPESP Grant 13/07296-2**

**March 2016**

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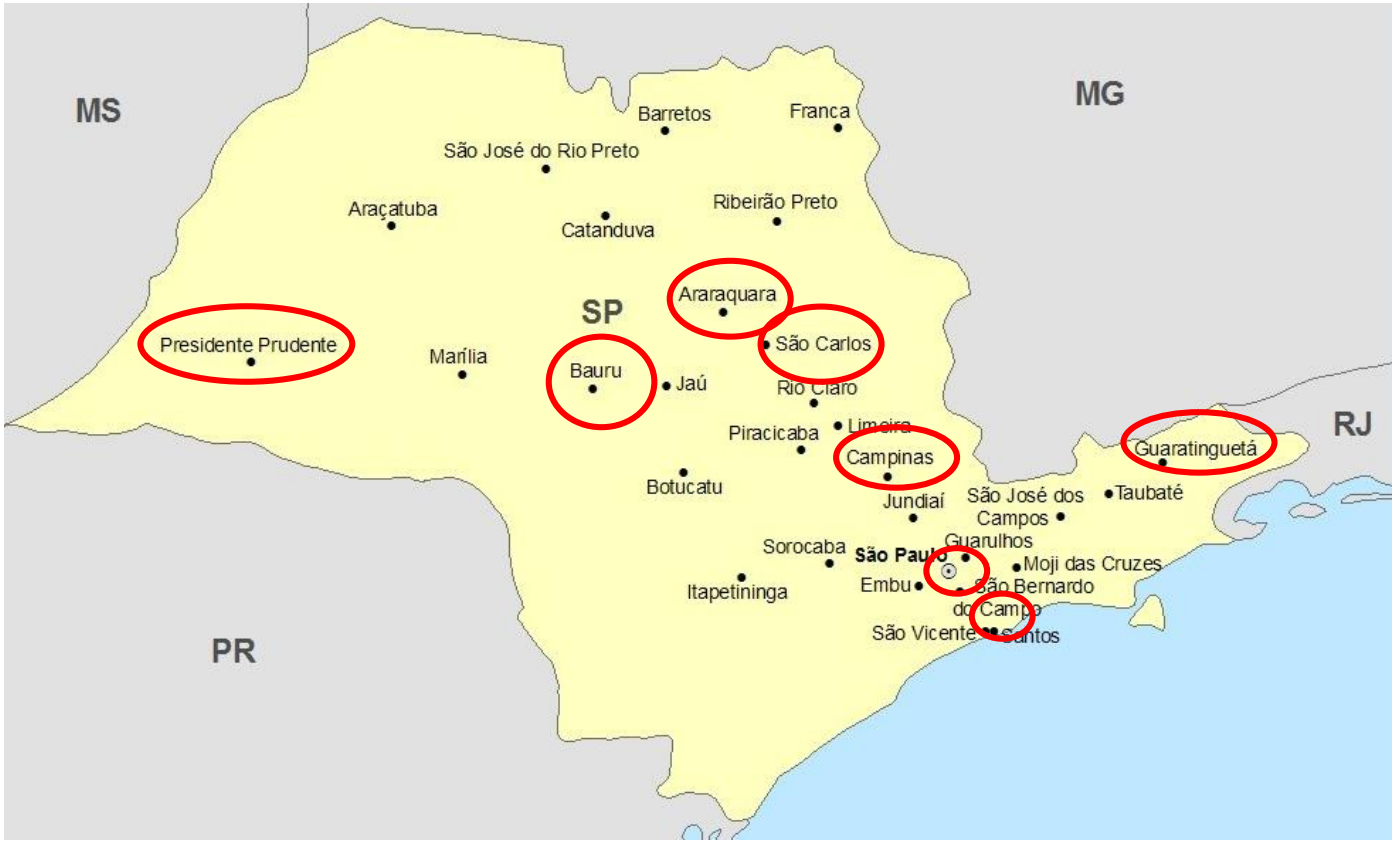


**~ 12 Laboratories**

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# Ongoing Research Projects

## Outline

1 – Magnetic Nanoparticles NPs
2 – Superconducting Oxides for Practical Applications
3 – Geometrically Frustrated Magnets
4 – Superconductivity in Borides and Intermetallic Compounds

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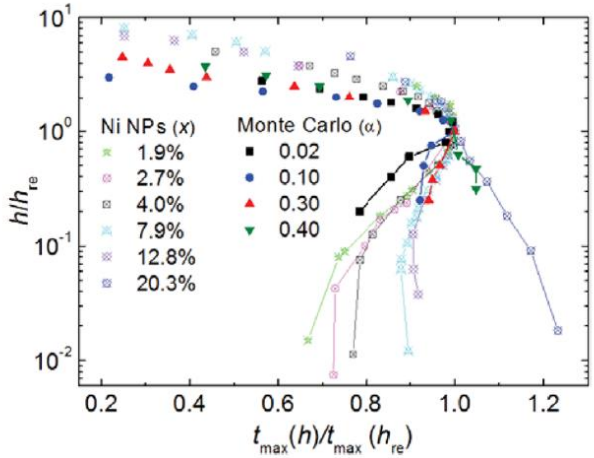
# 1 - Magnetic Nanoparticles NPs

## Research Interests

## 1- Dipolar Interaction between NPs

**Disclosing the Effect of Dipolar Interactions Between Magnetic NPs**

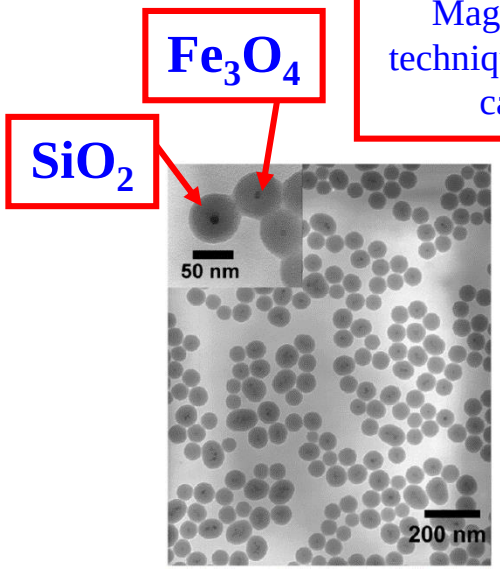
**Synthesis**
**Characterization**
**Monte Carlo Simulations**

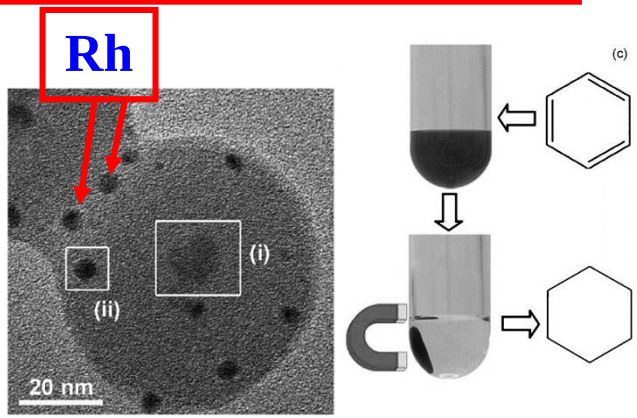



J. Phys. Chem. C **120**, 765 (2016).

## 2- Magnetic Separation in Liquid-Phase Catalysis

Magnetic separation is a very promising technique to improve recovery of metal-based catalysts in liquid-phase reactions




Magnet Separation Avoids Time- and Solvent-Consuming Procedures
Filtration, Decantation, Centrifugation, or Any Other Separation Technique

RSC Advances **5**, 15035 (2015).
ACS Catalysis **2**, 925 (2012).

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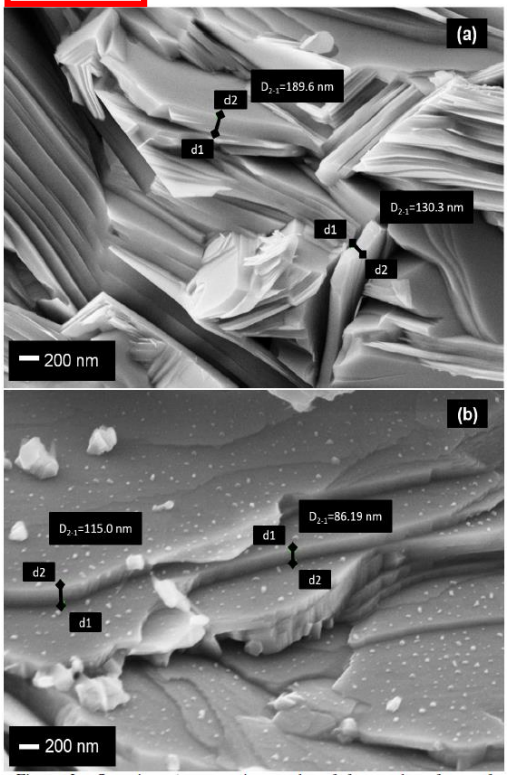
# 2 - Superconducting Oxides for Practical Applications

**SPS**




**SPT – New Method**

**Bulk materials for Electric Power Applications – Low-loss Power Cables & Fast Current Limiters (dense, textured, and carrying high current density (*J*))**

| | D (g/cm$^3$) | $\rho_{wl}$ (m$\Omega$cm) | $\gamma$ ($J^{ab}/J^{c}$) | $J^{ab}$ ($10^8$ A/cm$^2$) @ 5 K |
|---|---|---|---|---|
| SPS | 5.7 | 0.45 | 19 | 0.26 |
| SPT | 6.3 | 0.31 | 2 | 1.27 |

**Very Large Value of $J^{ab}$**

**Increase in $J^{ab}$ of ~ 5 x !**

**~ 97 % of the Theoretical Value !**

To appear in J. Alloy Compd. (2016).
J. Appl. Phys. **117**, 043903 (2015).

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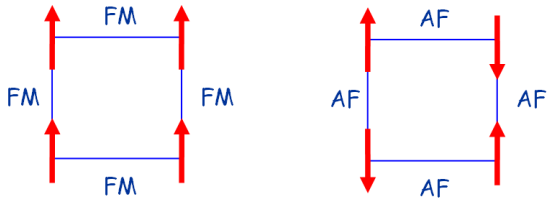
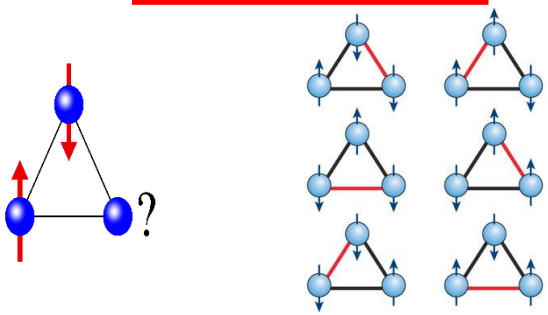
# 3 - Geometrically Frustrated Magnets

Square Lattice
Unfrustrated




Triangular Lattice
Frustrated



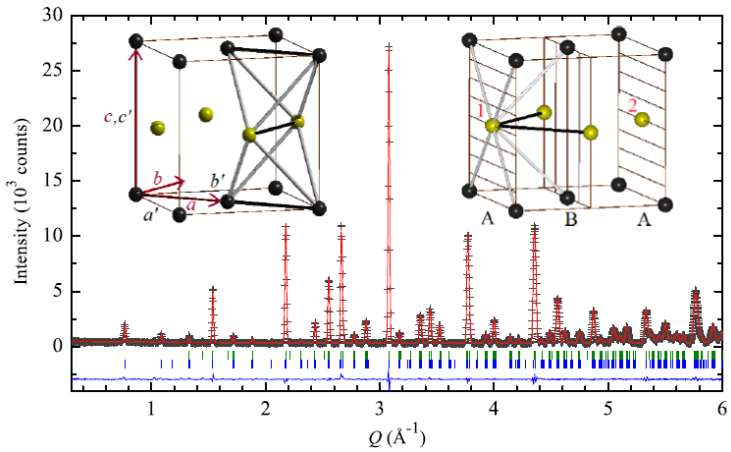

6 Possible Configurations
With Equivalent Energy

**Magnetic properties of quantum spins with AFM coupling on frustrating lattices**

**Widespread interest due to the occurrence of new types of complex quantum ground states**

**Double Perovskite $Sr_2YRuO_6$ with fcc lattice of Ru moments**

**The simplest three-dimensional frustrated magnet model system**




PRB Rapid Commun., in press (2016);
PRL **110**, 017202 (2013).
"Disorder and Geometric Frustration in the Shastry-Sutherland Lattice: $(R_{1-x}Y_x)B_4$" .

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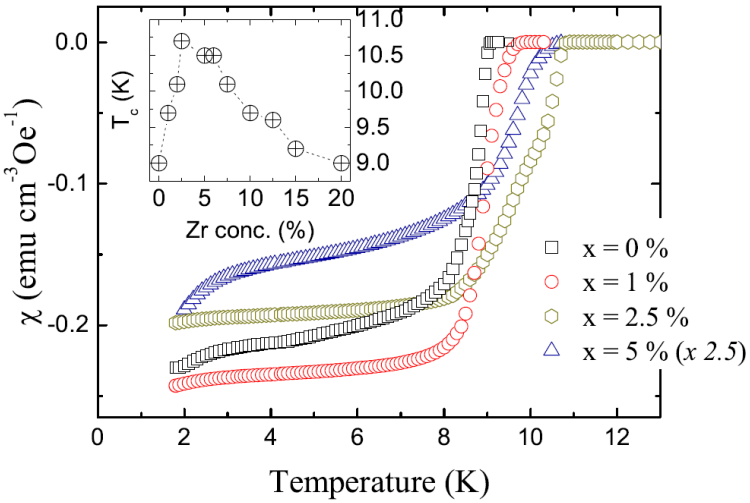
# 4 – Superconductivity in Borides and Intermetallic Compounds

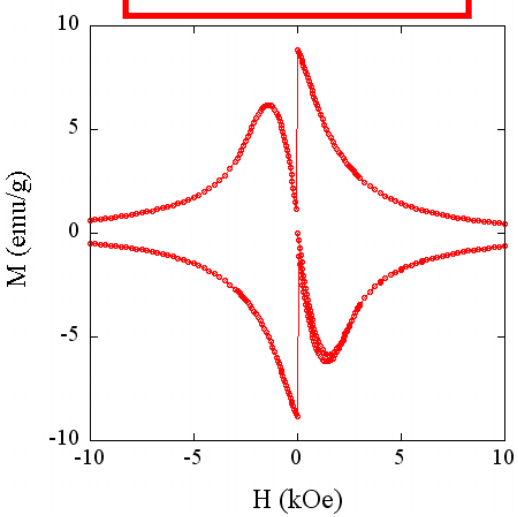
Revisiting some Families of Superconducting Materials

Borides of Transition Metals TM and Their Solid Solutions (TM)B; TM = Nb, Ta, W, Mo

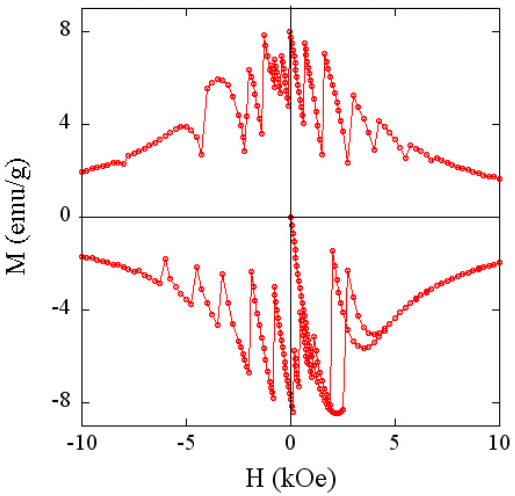
Intermetallic Compounds
The case of $Re_3$(TM); TM = Nb, Ta, W, Mo




Conventional Behavior




Unconventional Behavior




Series of $Nb_{1-x}Zr_xB$
20 % Increase in $T_C$
for x ~ 0.05

At Least two Issues of Interest
1. - Multiband Superconductivity
2. - Superconductivity in noncentrosymmetric Crystal Structures

JAP; under review (2016).
JAL; under review (2016).

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# Scientific Collaborations

**Brazil**
Prof. L. Rossi – Institute of Chemistry, University of Sao Paulo
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Prof. W. Figueiredo – Institute of Physics, Federal University of Santa Catarina
Prof. A. J. S. Machado - School of Engineering, University of Sao Paulo, Lorena
Dr. R. Muccillo – IPEN, Sao Paulo

**Cuba**
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Prof. P. Mune – University of Oriente, Santiago de Cuba

**US**
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Dr. J. Lynn - NIST Center for Neutron Research, Gaithersburg, MD
Prof. Z. Fisk – University of California, Irvine, CA
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**Europe**
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**Japan**
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**Students and PD**
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**M. T. Escote**
**N. Costa**
**M. Jacinto**

Funding agencies/companies that have supported these research projects over the years **(Brazil (FAPESP, CNPq, CAPES, and Petrobras) and the US agencies NSF and DOE)**

FAPESP

# Many Thanks

FAPESP

CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico


NSF

CAPES

U.S. DEPARTMENT OF ENERGY

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# Ongoing Research Projects

**1 – Geometrically Frustrated Magnetic Oxides and Borides**

- "Two-Dimensional Magnetic Correlations and Partial Long-Range Order in $Sr_2YRuO_6$"; (PRL **110**, 017202 (2013))
- "Spin Dynamics and Two-Dimensional Correlations in the FCC Antiferromagnetic $Sr_2YRuO_6$" (PRB Rapid Commun., in press (2016));
- "Spectroscopy and Electronic Structure of $Sr_2YRuO_6$ and $Sr_2YRu_{0.75}Ir_{0.25}O_6$" (Submitted to PRB (2016));
- "Disorder and Geometric Frustration in the Shastry-Sutherland Lattice: $(Gd_{1-x}Y_x)B_4$" .

**2 – Metal-Insulator Transition in Nickelates and their Solid Solutions**

- "Entropy change and electronic delocalization in $Nd_{1-x}Eu_xNiO_3$"; (JAP **117**, 17C105 (2015)).

**3 – New Superconducting Borides**

- "Superconductivity and electron-phonon coupling in some TM borides"; (Submitted to JAP (2016)).

**4 – New Superconducting Intermetallic Compounds**

- "Superconductivity in non-centrosymmetric $Re_3(TM)$; TM = W, Mo, Ta, Nb; compounds"; (currently under investigation).

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A magnetic material in which all of the pairwise magnetic interactions can not be simultaneously satisfied