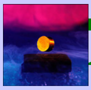
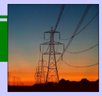
Advanced Energy Materials

Condensed Matter Physics and Materials Science Department, Brookhaven National Laboratory

Abstract

A bird's eye view is provided of superconducting and thermoelectric materials research at the Advanced Energy Materials Group*. We study both the microscopic and macroscopic properties of complex and nano-structured materials and develop their application in energy related technologies.

Superconductors

are capable of carrying electrical current without loss, and hence offer powerful opportunities for increasing the capacity and efficiency of the power grid. The superconducting materials program at BNL studies the basic relationships between structure and properties of superconductors to provide understanding of fundamental materials science and physics required for energy applications. We develop high temperature superconducting (HTS) wires for use in electricity transmission, HTS transformers for wind energy, ship drive motor, MRI, etc.

Applications

LIPA commissioned the 1st high temperature superconducting power transmission cable (138 kV) system on June 25, 2008 at Holbrook site, Long Island, NY, capable of carrying 574 megawatts of power.

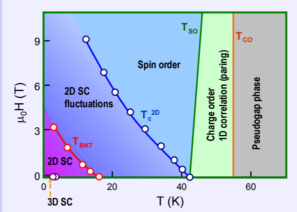
36.5 MW HTS Ship Drive Motor
Image courtesy of American Superconductor

Wind turbine
Image courtesy of American Superconductor

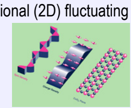
MRI

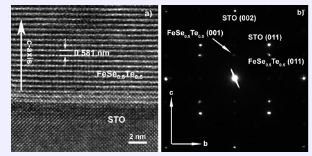
Basic Science and Applied Superconducting Materials Research at BNL

We investigate physical properties such as the superconducting transition temperature T_c and the critical current density J_c because they determine limits to energy applications. We perform coordinated studies involving synthesis, structural characterization, and superconducting property characterization, augmented by strong collaborations with other basic energy science and applied programs at BNL, as well as our industrial partners



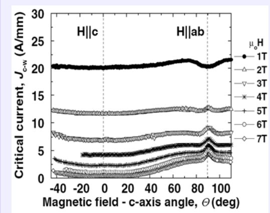
Discovery of two dimensional (2D) fluctuating superconductivity in the stripe (left Illustration) ordered HTS – Li, et al





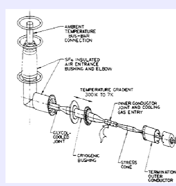
High resolution TEM & elec. diff. pattern of superconducting $FeSe_{0.5}Te_{0.5}$ thin film. – Si, *et al*

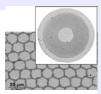
Magneto-optical image of flux in C-doped MgB_2 superconductor – Li *et al*



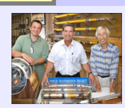
Strong and isotropic flux pinning in the 3-μm-thick record high $J_c(H)$ and T_c $YBa_2Cu_3O_7$ (YBCO) films at liquid N_2 temperature. - Solovyov, *et al*

Superconducting transmission lines at BNL





Nb-Ti multi-filamentary wire produced in Brookhaven in 70s - Suenaga et al



Layout of Nb_3Sn superconducting transmission line built in BNL in 1982. The line could carry 1000 MWt of electric power without losses

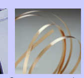
Technology Transfer

- Cooperative Research and Development Agreements (CRADA) of BNL with

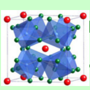
American Superconductor® SuperPower

- BNL patents licensed by AMSC for second generation HTS wires

AMSC wire



Superpower wire




Thermoelectrics

are capable of converting heat into electricity directly with no-moving parts and zero emissions. They can also be used in solid-state refrigeration devices. The thermoelectric materials research at BNL explores new directions to significantly increase thermoelectric performance of a few promising materials, and opportunities in alternative/renewable energy applications, for example: direct conversion of waste heat from vehicles into electricity.

Waste Heat and Thermoelectric Power Generator (TEP)

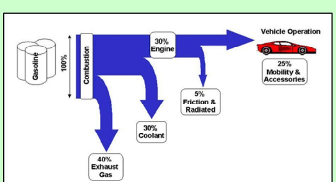
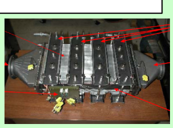
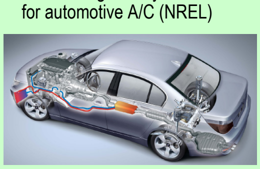


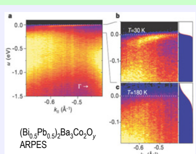
Fig. 1 Typical energy path in gasoline fueled internal combustion engine vehicle (Source: GM)

- TEP 350 W corresponds to fuel economy improvement of ~ 3%
- For every 0.8 mpg/vehicle increase, we save ~ 1.9 **Billion** gallons of gasoline/year (PNNL and DOE EERE)
- 7-8 billion gallons/yr of fuel use for automotive A/C (NREL)

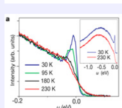




Basic Science and Applied Thermoelectric Materials Research at BNL

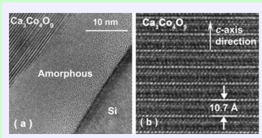
Our research focuses: 1) Unconventional thermoelectric materials (e.g. oxides) and new avenues for tuning thermoelectric properties, for example, exploring the resonant structure in e-DOS near Fermi-level in cobaltates; 2) Developing cost-effective and industrial-scalable processing for advanced thermoelectric materials and technology for power generation and refrigeration



$(Bi_{0.5}Pb_{0.5})_2Ba_3Co_2O_y$ ARPES



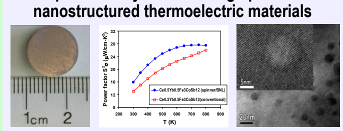
- Valla, et al



High resolution TEM images of oxide thermoelectric films on Si and glass (not shown). This work opens the potential of

- **Crystalline films on amorphous**
- **On chip power generation and cooling for CPU** - Hu, Si & Li

Non-equilibrium synthesis of high performance nanostructured thermoelectric materials

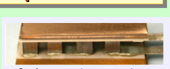


Key advantages of the BNL's process & materials

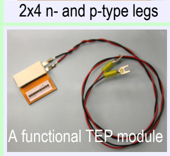
- Superior thermoelectric and mechanical properties
- Low-cost and industrial scalable
- Applicable to a wide range of thermoelectric and other energy-related materials - Li et al

TEP Module Development at BNL

TEP module parts



2x4 n- and p-type legs



A functional TEP module

Technology Transfer

BNL/GM

CRADA - Advanced thermoelectric Materials for Vehicles Waste Heat Recovery (DOE-EERE)

BROOKHAVEN NATIONAL LABORATORY

*Funding provided by US Dept. of Energy, Offices of BES, EE, EERE, BNL/GM CRADA, and BNL-Tech Maturation Fund.