MAGNETIZATION LOSSES IN HIGH TEMPERATURE SUPERCONDUCTING TAPES DUE TO AC AND DC MAGNETIC FIELDS

Eduard Maievskyi, Marian Ciszek*
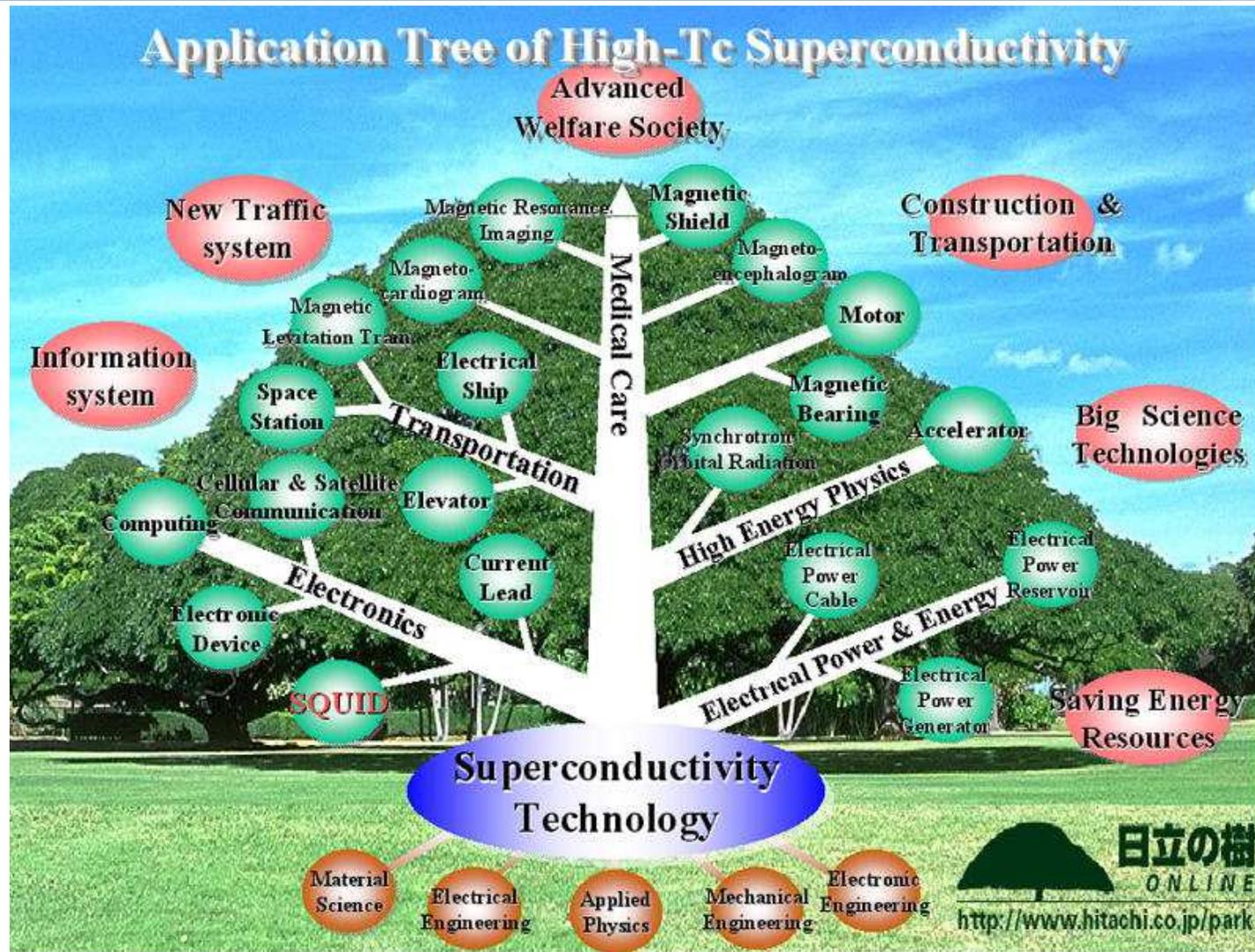
Outline

1. Application of superconducting materials

2. Object of studying

3. AC-losses

4. Experimental method and results

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Application of Superconducting Materials
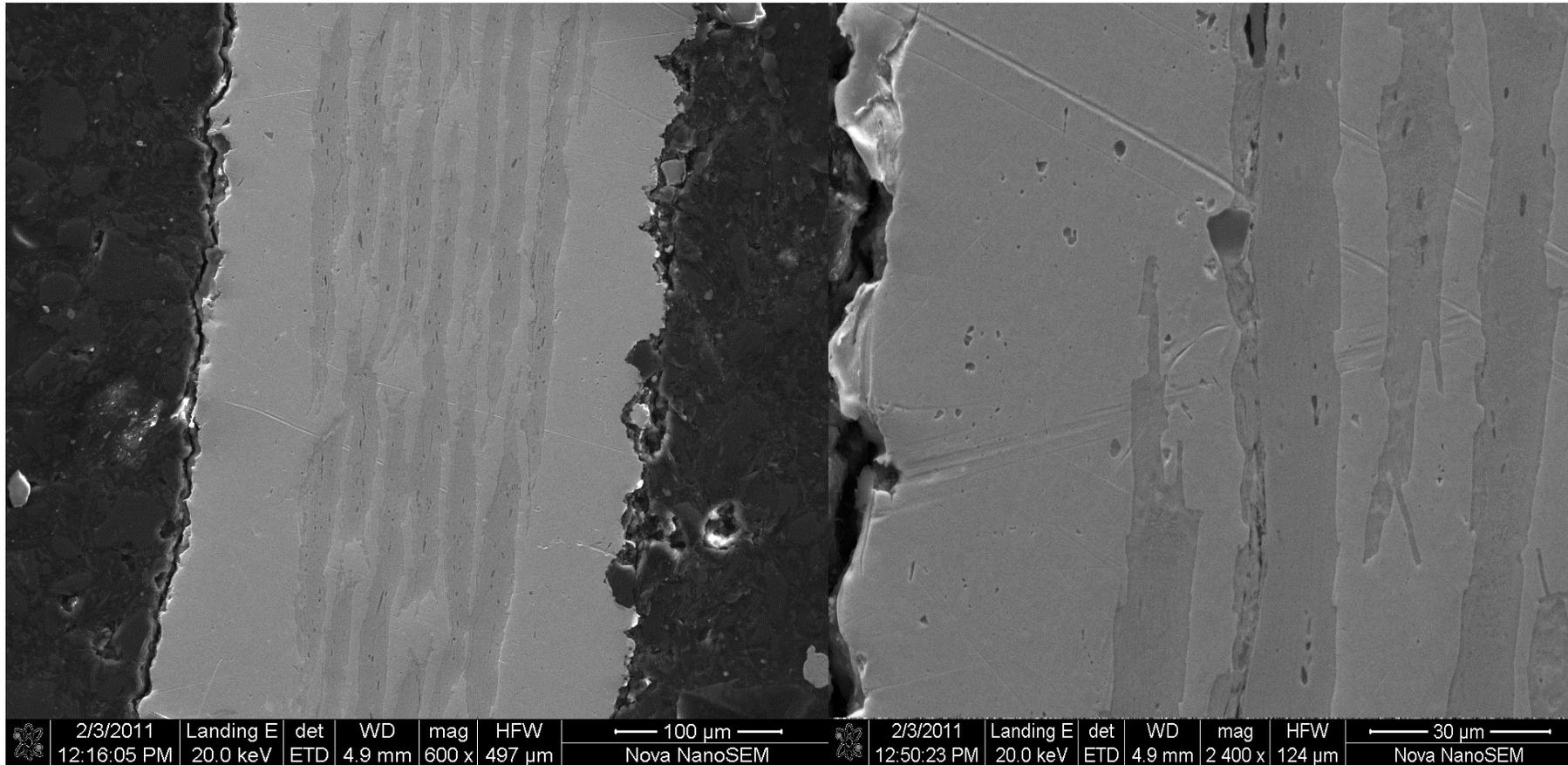

Application Tree of High-Tc Superconductivity

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HTSC-tapes

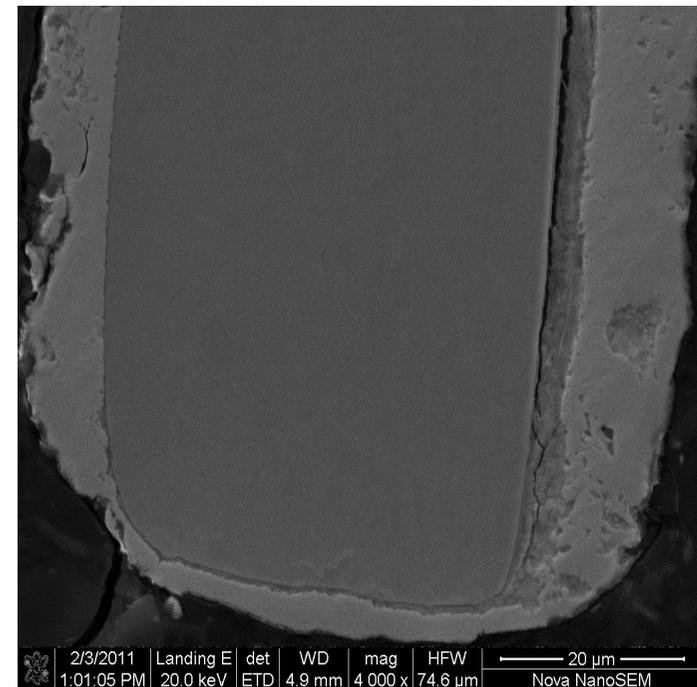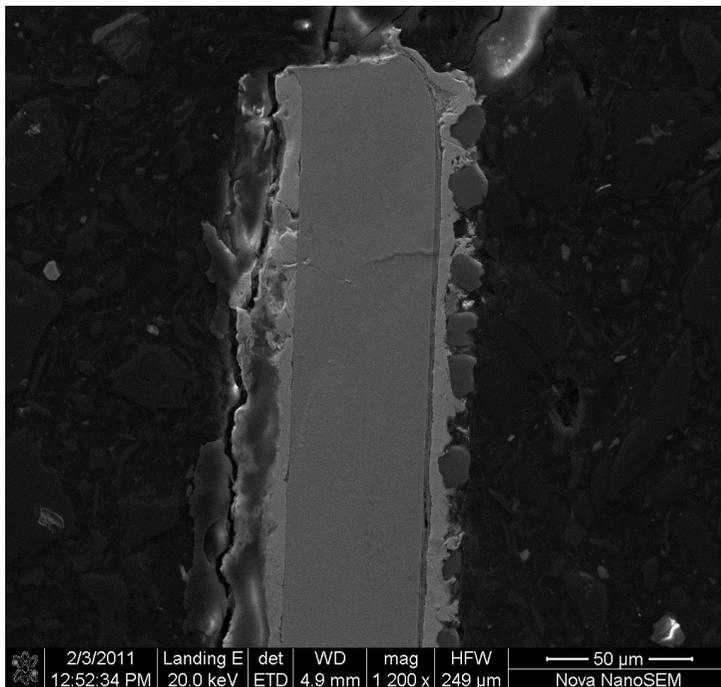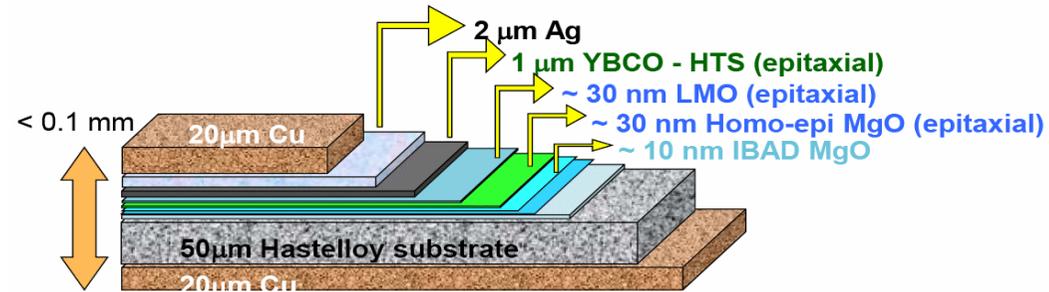## Cross-section of Sumitomo BSCCO-2223 composite tape type H

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HTSC-tapes

Cross-section of SCS 4050 2G HTSC tape produced by SuperPower

2 µm Ag
1 µm YBCO - HTS (epitaxial)
~ 30 nm LMO (epitaxial)
~ 30 nm Homo-epi MgO (epitaxial)
~ 10 nm IBAD MgO

< 0.1 mm

20µm Cu

50µm Hastelloy substrate

20µm Cu

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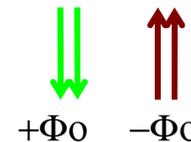# Main contributions to AC losses

1. **Bulk pinning losses:** $\quad Q_b \propto \vec{E} \cdot \vec{J}$

2. **Annihilation losses:** *vortices of opposite magnetic sense annihilate, one pair liberate energy*

$$Q_a \propto 2H_{c1} \cdot \phi_0$$

$$+\Phi_0 \quad -\Phi_0$$

3. **Surface losses:** *arising from a surface barrier*

$$Q_s \propto \Delta H_{eff} \cdot \Phi$$
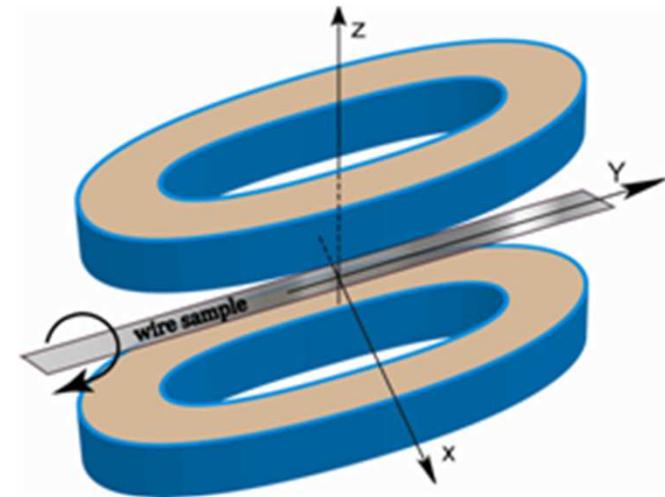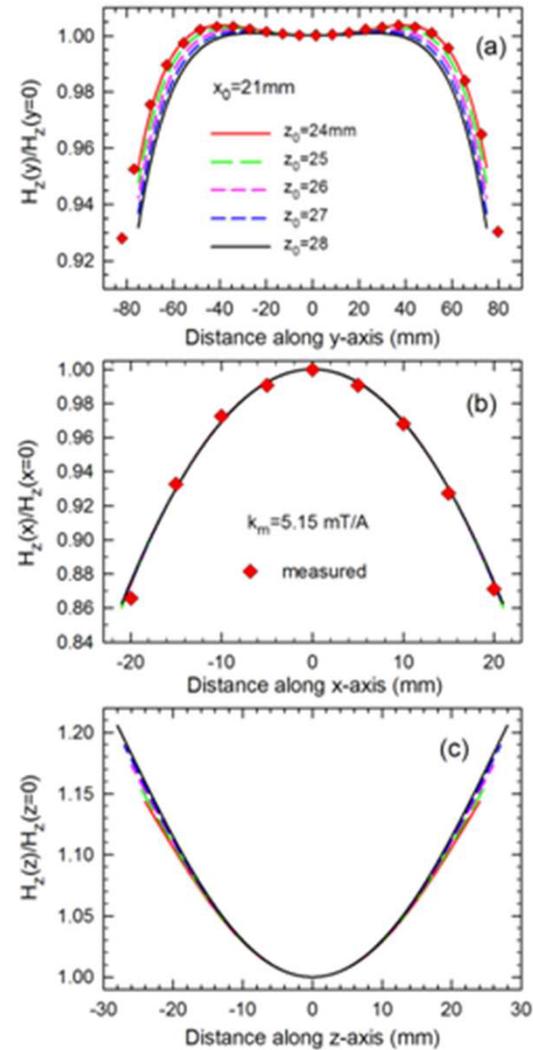
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4. **Flux flow losses:** *when pinning is very low;*

$$\vec{E}_{ff} \propto \rho_{ff} \cdot \vec{J}; \quad \rho_{ff} \propto \rho_n \cdot \frac{B}{B_{c2}} \quad W_{ff} = f\left(b_0^2, \omega\right)$$

5. **In HTSC, additionally, contributions from** *-flux creep, granularity, anisotropy, grain boundaries*

6. **In composites**: *coupling between filaments, eddy currents in matrix*

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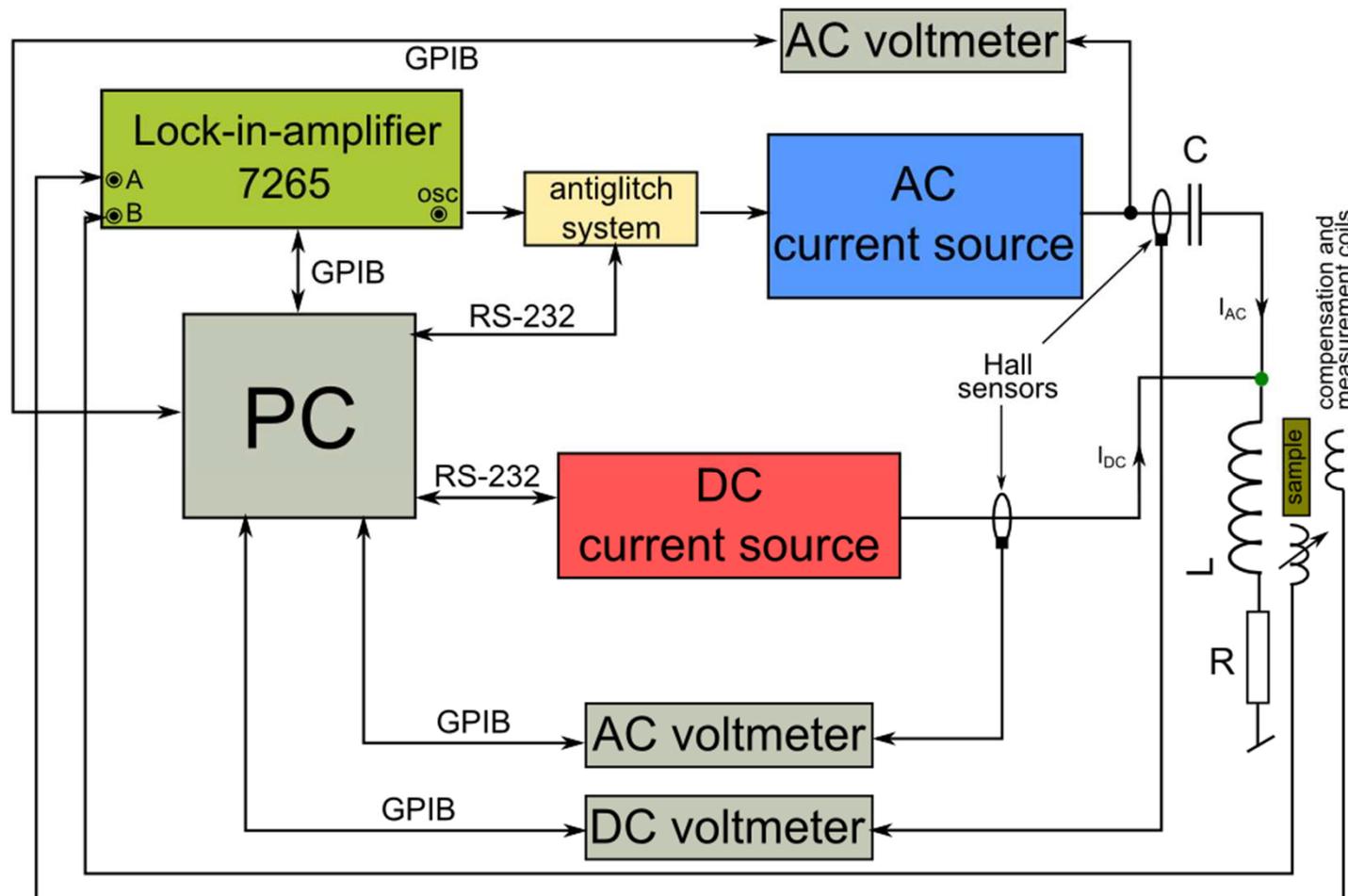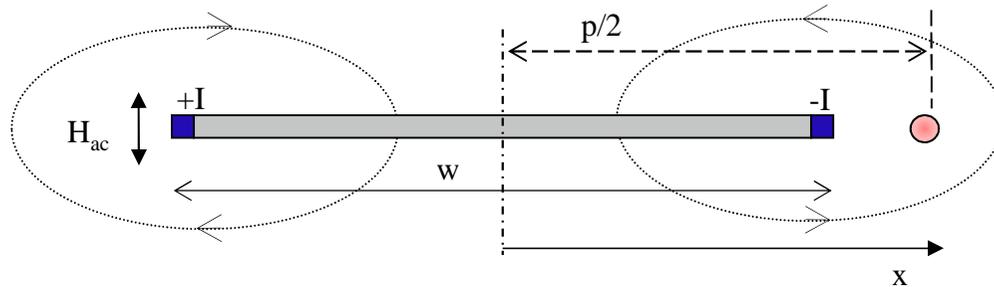
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Race-Track Coil

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Measurement equipment

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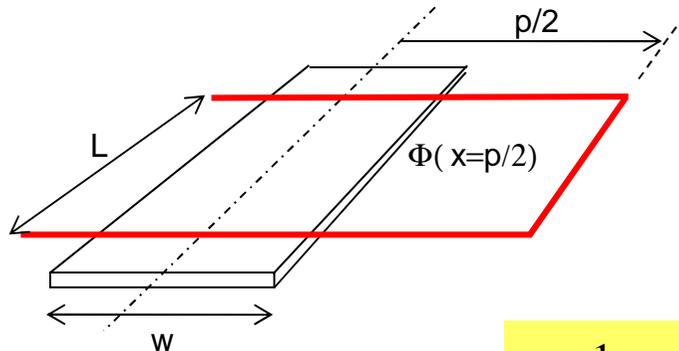Maievskyi Ciszek

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Measurement equipment

$$B(x) = \frac{\mu_0 I}{2\pi} \left(\frac{w}{x^2 - \left(\frac{w}{2}\right)^2} \right)$$

$$B(x) = \frac{m}{l} \cdot \left(\frac{1}{2\pi x^2} \right)$$

$$\Phi\left(\frac{p}{2}\right) = -\frac{m}{\pi p} \Rightarrow \Phi(p) = -\frac{2m}{\pi p}$$

$$V(t) = \frac{2}{\pi p} \frac{\partial m}{\partial t}$$

$$m(t) = m' \cos \omega t + m'' \sin \omega t$$

$$m''(t) = \frac{V''(t) \pi p}{2 \omega}$$

$$P = \frac{1}{L} \oint H \, dm = \frac{1}{L} \int_0^T H(t) \frac{\partial m}{\partial t} \, dt$$

$$P = \frac{\pi p}{2Lf} H_{rms} V''_{rms}$$

Loop has to be extended from the edge of a tape

M Iwakuma,.. *SUST* **16** (2003) 545
D N Nguyen,...*SUST* **19** (2006) 1010
Y Yang,...*J. App. Phys.* **96** (2004) 2141

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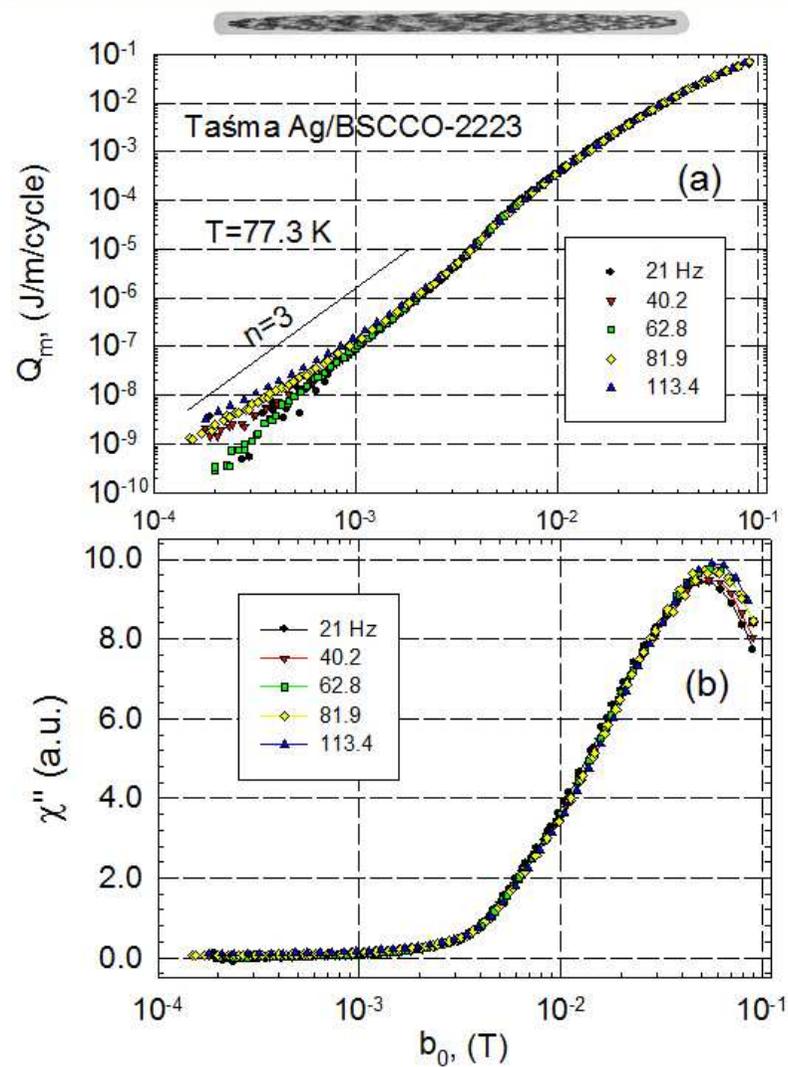
Energy dissipation in YBCO-123 tape (AC-field only)

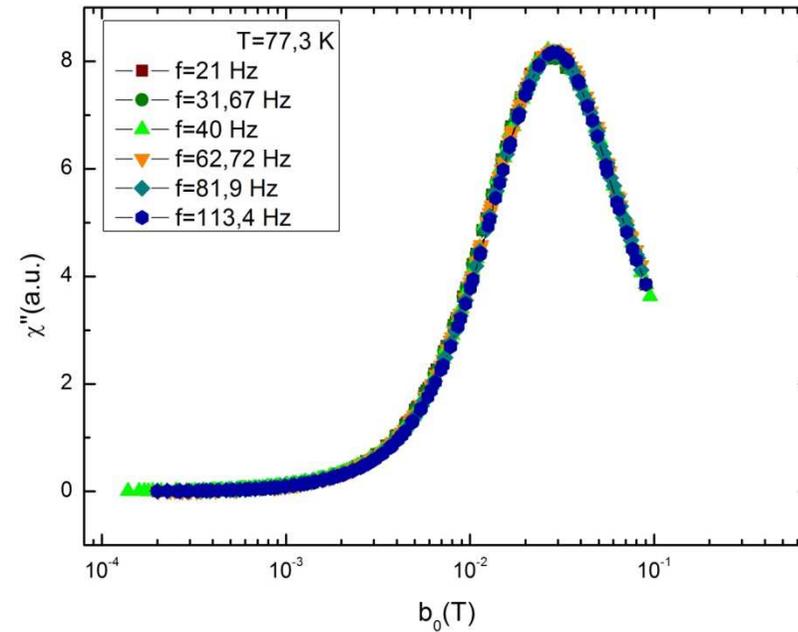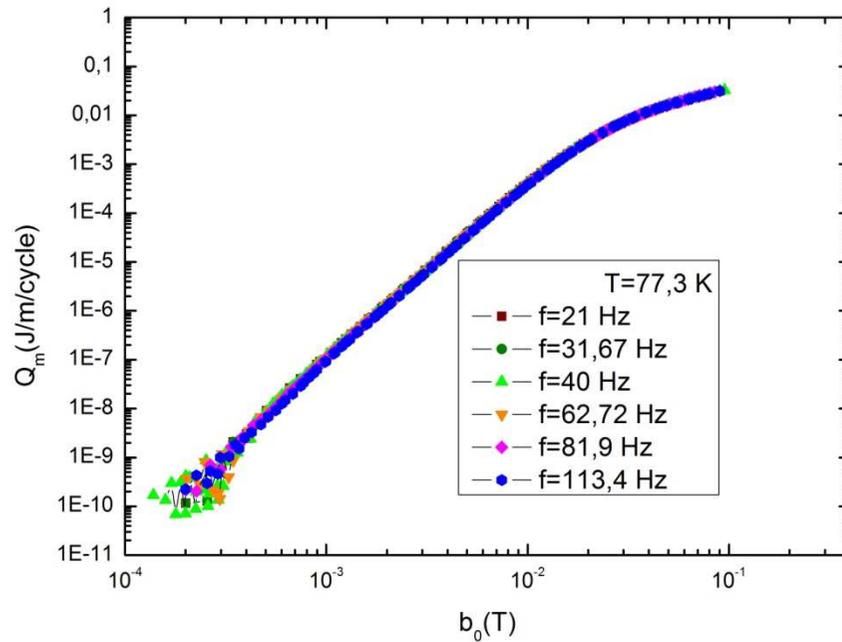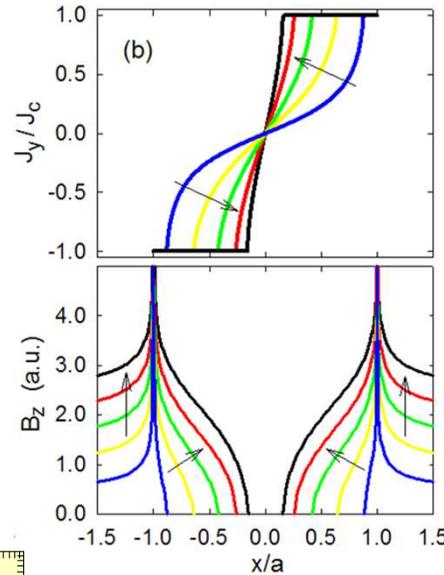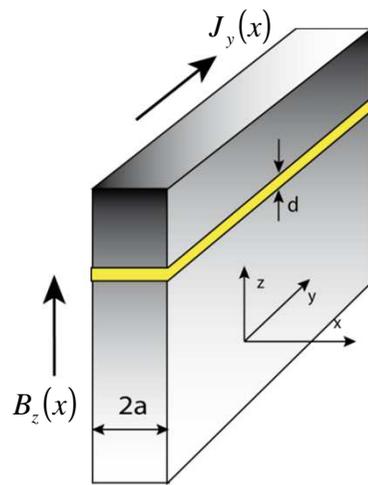Eduard Maievskyi   Marian Ciszek

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Energy dissipation in YBCO-123 tape (AC-field only)
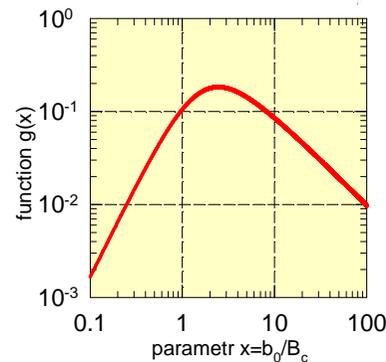
Loss model for a thin film (perpendicular field)

$$J_y = -\left(\frac{\partial H_z}{\partial x} - \frac{\partial H_x}{\partial z}\right) \qquad \underline{\text{when } d<<a}$$

$$J_y(x) = -\frac{c}{4\pi d}\left[B_x(x, z = d/2) - B_x(x, z = -d/2)\right]$$

$$Q_m = \frac{4\pi}{\mu_0} a^2 b_0^2 \cdot g(x)$$

$$g(x) = \frac{1}{x}\left[\frac{2}{x}\ln\cosh(x) - \tanh(x)\right]$$

$$Q_m \propto a^2 b_0^4$$

$$Q_m \propto I_c a^2 b_0$$

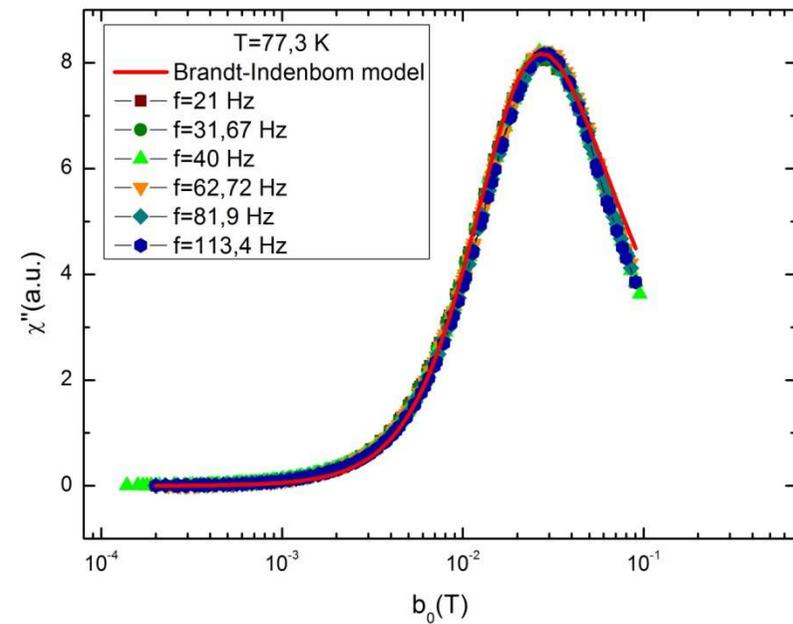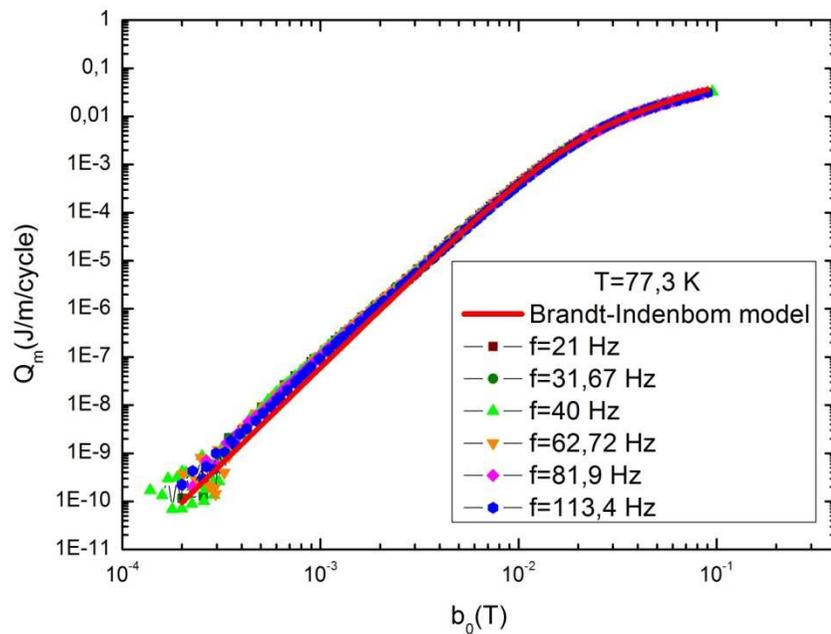$$x = b_0/B_c$$

$$B_c = \mu_0 I_c / 2\pi a$$

E.H. Brandt and M. Indenbom, PRB 48 (1993) 12893
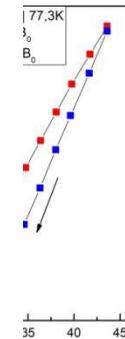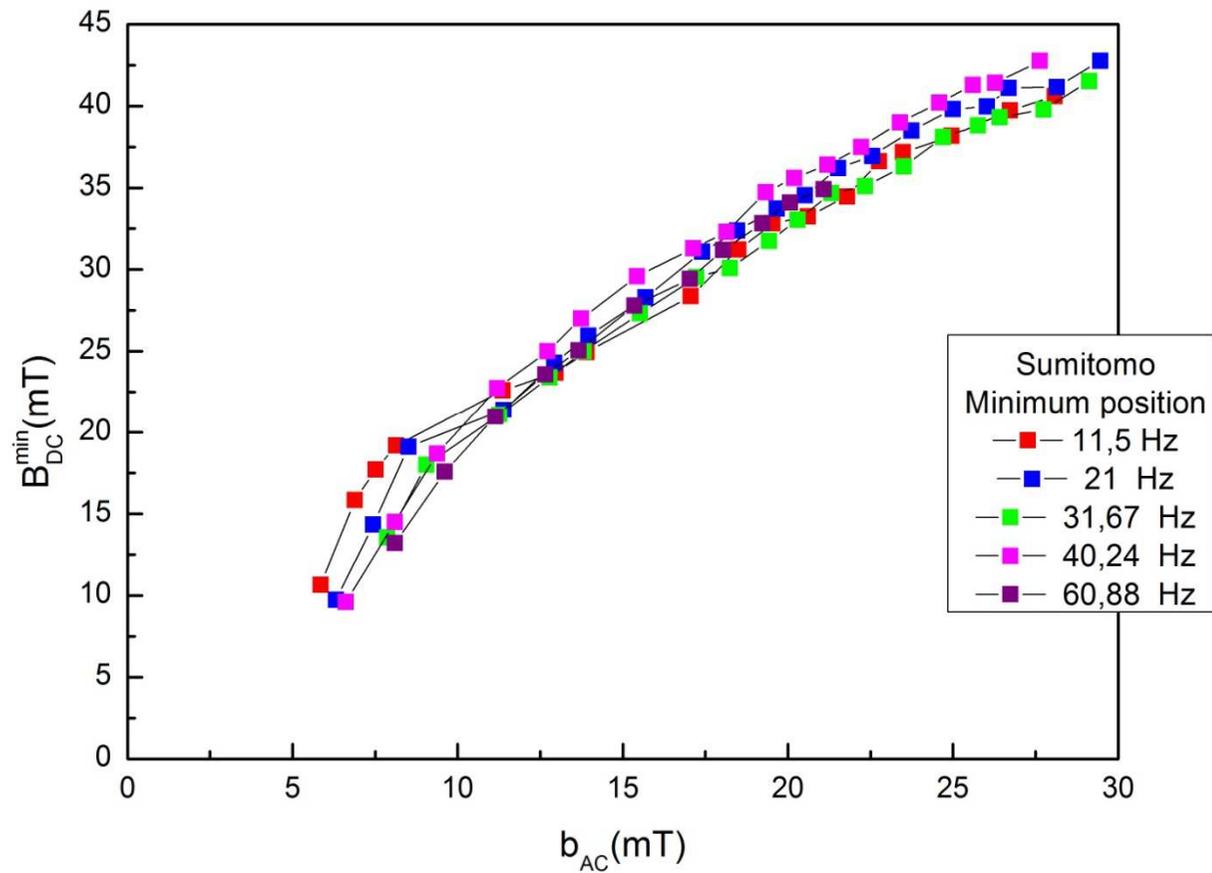J.R. Clem, E. Zeldov, PRB 49 (1994) 9802.

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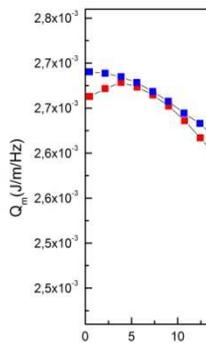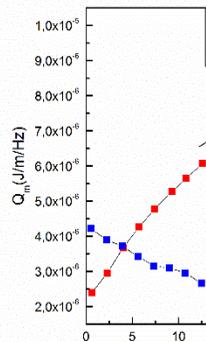
Energy dissipation in YBCO-123 tape (AC-field only)

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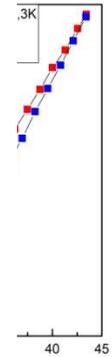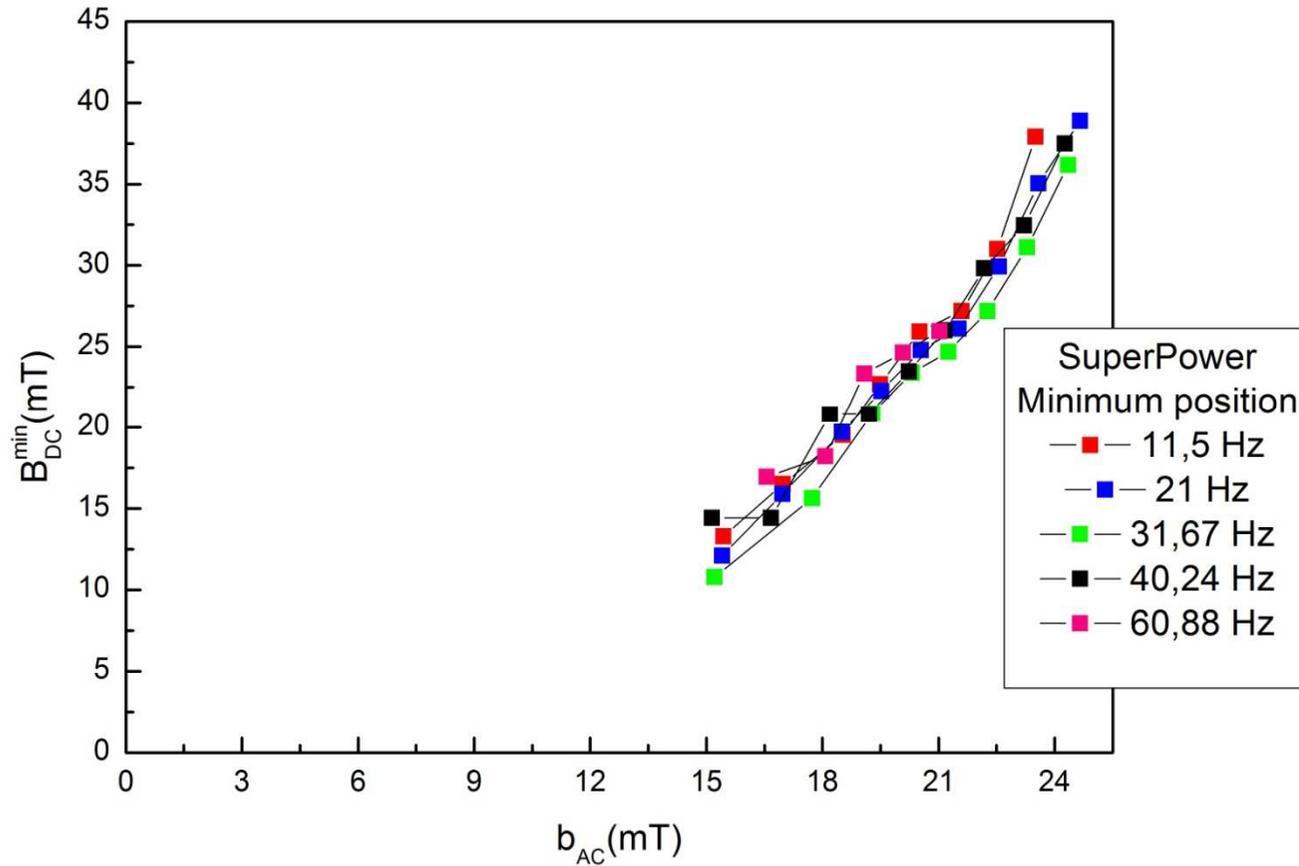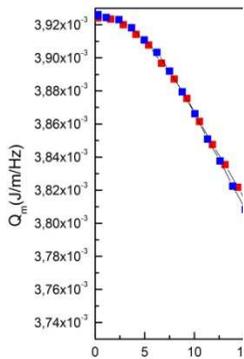
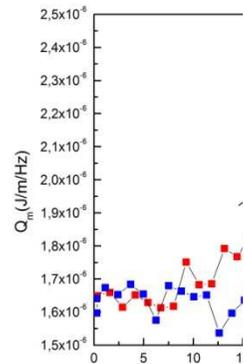# Hysteretic loss minimum in BSCCO-2223 tape

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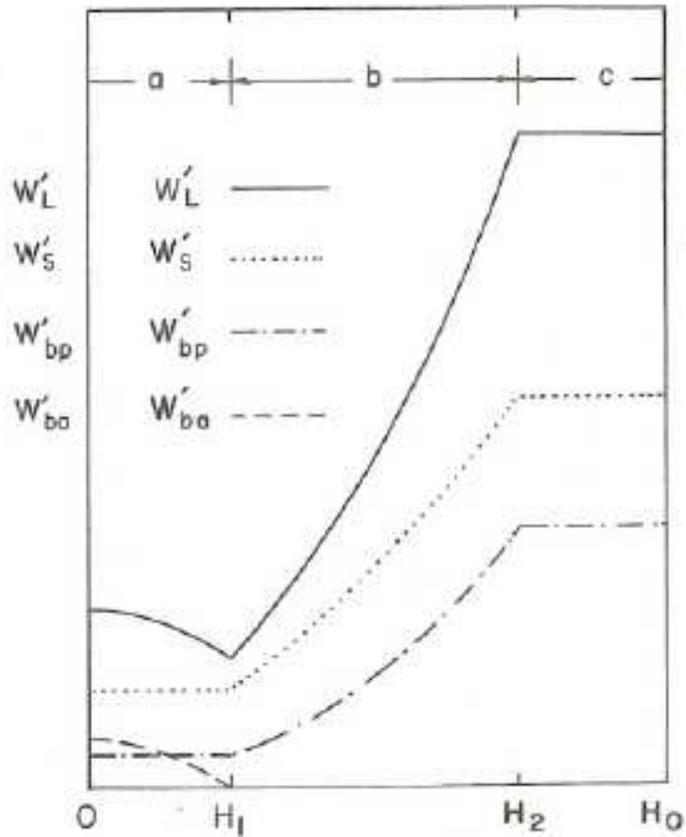Polish Academy of Science, Wroclaw, Poland

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Clem model

$W`_L$ - total losses
$W`_S$ - surface losses
$W`_{bp}$ - bulk pinning losses
$W`_{ba}$ - bulk annihilation losses

John R. Clem, „Theory of AC losses in type II superconductors with a field-dependent surface barier", J. Appl. Phys. 50(5), May 1979

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Thank you for attention !

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