BIDIRECTIONAL CHARGE-DENSITY-WAVES IN QUASI-TWO-DIMENSIONAL RARE EARTH TRITELLURIDES

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Outlook:

1. Family of compounds $R\text{Te}_3$ ($R=$Y, La, Ce, Nd, Sm, Gd, Tb, Ho, Dy, Er, Tm). Properties.
2. Motivation
3. CDW sliding in ErTe$_3$.
5. Hall effect in ErTe$_3$, HoTe3 and TbTe3
6. Conclusions
$R \text{Te}_3$

($R=\text{Y, La, Ce, Nd, Sm, Gd, Tb, Ho, Dy, Er, Tm}$)

Layered quasi-two dimensional compounds

Crystal structure
– weak orthorhombic

Fermi surface for TbTe$_3$.

Incommensurate CDW below the temperature $T_{\text{CDW1}}$ through the whole $R$ series with a wave vector $Q_{\text{CDW1}} = (0, 0, \sim 2/7c^*)$. For the heavier $R$ (Dy, Ho, Er, Tm) atoms a second CDW occurs at low temperature $T_{\text{CDW2}}$ with the wave vector $Q_{\text{CDW2}} = (\sim 2/7a^*, 0, 0)$ perpendicular to $Q_{\text{CDW1}}$.

$R\text{Te}_3$ (CDW properties)

**Resistive effect of CDW.**

Inverted anisotropy

(PRL, 112, 036601 (2014))

**CDW sliding**

Linear Dependency $E_t(T)$

(SSC. 188, 67 (2014))

$$E(T) = E(0)(1 - \frac{T}{T_0})$$

$T_0 \approx 1.08T_{CDW}$
Compounds with bidirectional CDWs

“Both CDWs exist within the same Te plane, thus both CDWs modulate the positions of the same Te atoms.” (R. G. Moore, et al., PRB 81, 073102 2010)

“…. each CDW appears unidirectional and completely decoupled.” (R. G. Moore, et al., PRB 81, 073102 2010)

Motivation

1. Is the collective sliding possible for second CDW?
2. What is the temperature dependency of $E_t$ for CDW1 across the second Peierls transition? Or, are these CDWs completely decoupled?
From untwinned single crystals with a thickness typically 0.2–2.0 μm, the stripes with a length of a few millimeter and a width 50–80 μm in well defined orientation, namely [100] and [001] have been cuted.

PRB, 93, 235141 (2016)
CDW sliding in ErTe$_3$ (CDW1)

The temperature evolution of differential IV curves in the temperature range 270–110 K

PRB, 93, 235141 (2016)
CDW sliding in ErTe$_3$ (CDW2)

Contribution of CDW:
\[ \Delta R/R \sim 0.3\% \]
- very low CDW velocity (?)

PRB, 93, 235141 (2016)
E(0) = 235 mV/cm
T₀ = 1.07T_{CDW1}
in accordance with (SSC. 188, 67 (2014))

High T region – $E_t(T)$ – linear, analogously to $E_t(T)$ in unidirectional CDW compounds (TbTe₃, GdTe₃)

$E(T) = E(0)(1 - \frac{T}{T_0})$

Below ~200 K visual deviation from linear law.
Below $T_{CDW2}$ – near linear dependence again.

Conclusion 1: CDW1 and CDW2 are interacting
Nonstationary effects (CDW1)

1D – for one chain-

ErTe$_3$

\[ b^* = 25.02 \text{ Å} \]
\[ a^* = 4.29 \text{ Å} \]

\[ \frac{j_c}{f_0} = 2e \]

\[ \Delta I_{CDW}/f_0 = 6.1 \times 10^{11} \text{ A/Hz} \]
\[ S = 2.1 \times 10^{-6} \text{ cm}^2 \]

Number of chains per cross-section

1.90 \times 10^8

Number of unit-cells per cross-section

1.96 \times 10^8
Nonstationary effects (CDW2)

\[ \Delta I_{CDW}/F_0 = 1.7 \times 10^{-12} \text{ A/Hz} \]

\[ N_{\text{chain}} = 0.53 \times 10^7 \]

\[ S = 0.25 \times 10^{-6} \text{ cm}^2 \]

\[ S_{\text{unit cell}} = 1.07 \times 10^{-14} \text{ cm}^2 \]

\[ N_{\text{unit cell}} = 2.3 \times 10^7 \]
Different number of carriers condensed to CDW1 and CDW2, Or, additional pinning effects, Or, .....
“The onset of a single CDW suppresses $N_{\text{EF}}$ to 77% of the unmodulated value while the second CDW further suppresses $N_{\text{EF}}$ to 74%.”
[R. G. Moore, et al., PRB 81, 073102 2010]

Hall effect. What can one expect?

**MEASUREMENTS**
van der Pauw method
$R_{xy}(\pm B)$ in the range 300 – 4 K at fixed $T$ with $\Delta T=10$ K
Hall effect in ErTe$_3$
Hall effect in ErTe$_3$
Hall effect in ErTe$_3$
Gigantic hysteresis of Hall constant in the temperature region of CDW2 formation (??) + no hysteresis in $R(T)$
Hall effect in:

bidirectional
HoTe₃ (T₁=287K, T₂=110K)

unidirectional
TbTe₃ (T₁=336K)
Hall effect in:

bidirectional
HoTe$_3$ ($T_1=287K$, $T_2=110K$)

unidirectional
TbTe$_3$ ($T_1=336K$)

Hysteresis in the region of CDW2 formation.
Hysteresis of Q-vector ???

New question:
HoTe$_3$ и TbTe$_3$ → two inversion points.
Hall const (cmOhm/T) vs. T (K) for Compounds RTe$_3$ showing (near) compensated metals behavior.
Conclusions:

1. Sliding of low-T CDW is possible in the Q-vector direction.
2. Bidirectional CDWs are interacting.
3. Gigantic Hall effect hysteresis observed in the temperature range corresponding to CDW2 formation that may be indication of hysteresis of the CDW wave vector.

Thank you very much for your attention.