The domain wall structure of SDW of chromium

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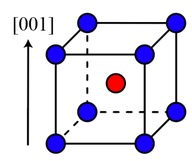
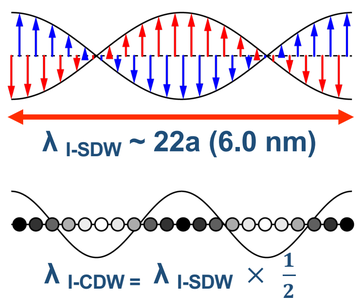
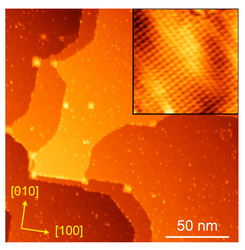
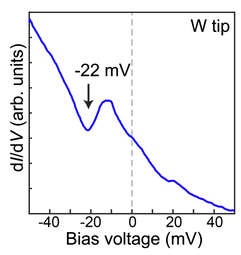
Introduction

Incommensurate spin density wave (SDW) & charge density wave (CDW) in Cr

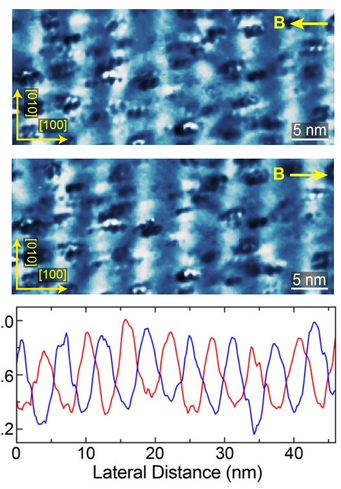


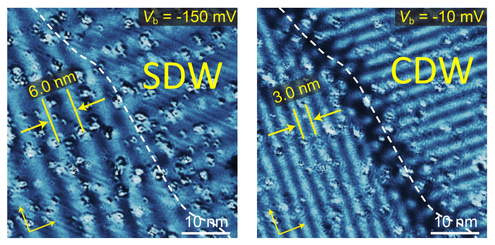




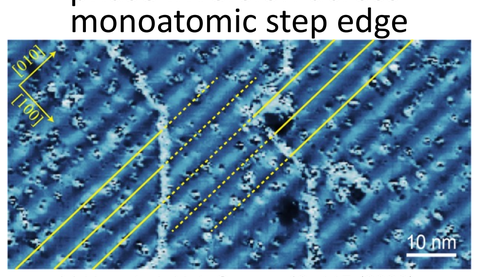


Longitudinal I-SDW wave vector Q//[100]





phase inversion across monoatomic step edge

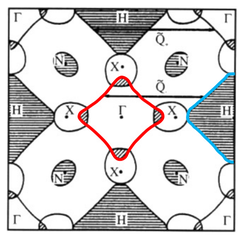


Y. Hu, *et al. Nat. Comm.* ***13***, 445 (2022).

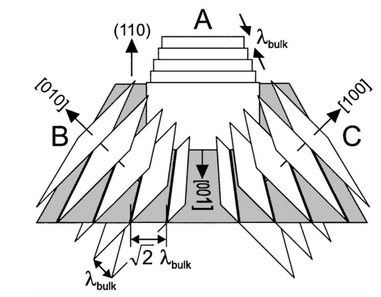
δ ~ 0.05
Incommensurate factor

$$Q_+ = \frac{2\pi}{a}(1+\delta)$$

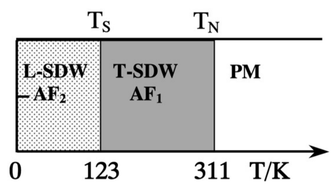
$$Q_- = \frac{2\pi}{a}(1-\delta)$$



E. Fawcett, *Rev. Mod. Phys.* **60**, 209 (1988).



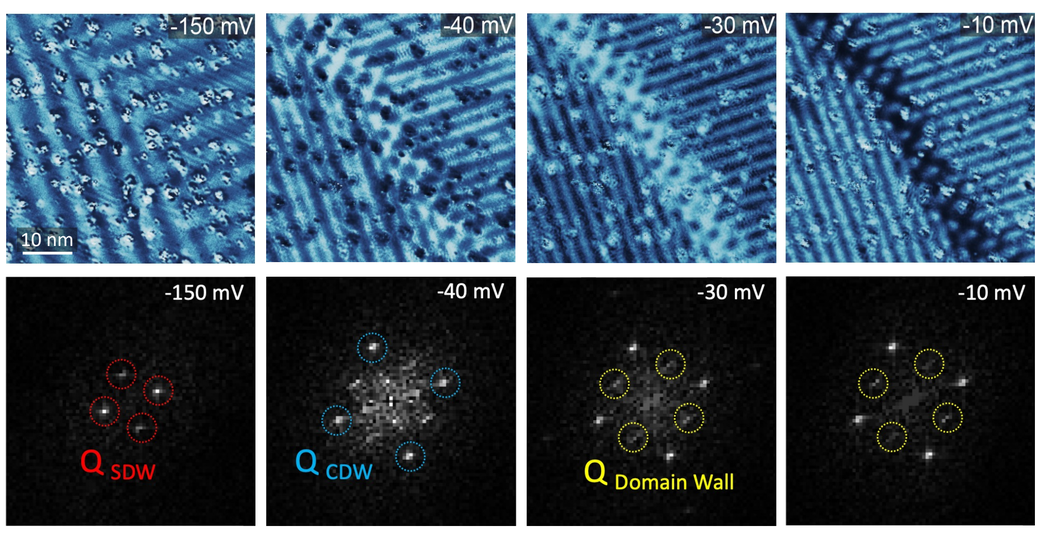
K. Braun, *et al. Phys. Rev. Lett.* **85**, 3500 (2000).



H. Zabel, *J. Phys.: Condens. Matter* **11**, 9303 (1999).

Coherent superposition of density waves

Patterns of density waves near domain wall

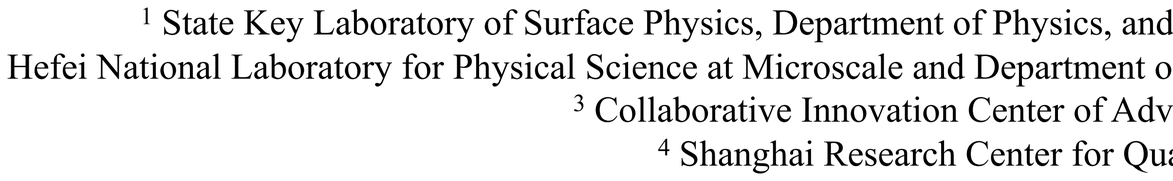


- ❖ Interference of SDW/CDW happens at domain wall (DW)
- ❖ [-30 mV] v.s. [-10 mV]: complimentary to each other
- ❖ New periodic pattern emerges at DW, $Q_{DW} = \frac{Q_{CDW}}{\sqrt{2}}$ (R45°)

What makes the finite width of domain wall?

1. single-Q v.s. Double-Q
The shape of the Fermi surface favors the single-Q SDW

2. Forming SDW v.s. Without SDW
SDW opens a gap at Fermi Surface



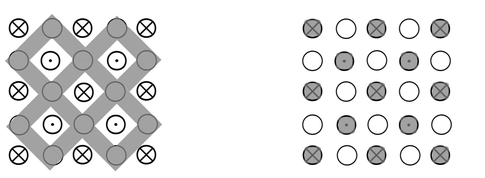
Possible in-plane to out-of-plane transition of magnetic moment

1. From cubic anisotropy energy
Cr (b.c.c.): with <100> easy directions

'energy surface'
A. Hubert & R. Schäfer, Magnetic Domains, springer(2009).

2. From experimental results

Electron max ~ |***M***|min Hole max ~ |***M***|max



⊗⊙↗ Represent magnetic moment ***M***
■ Represent electron/hole maximum

Coherence length ξ_0 of SDW

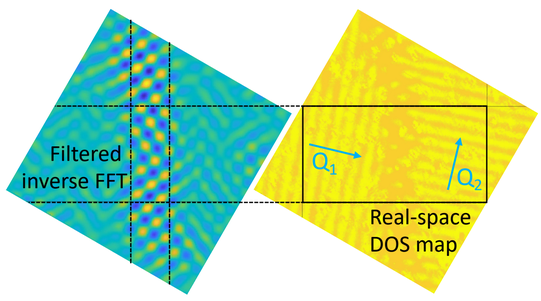
SDW Order parameter $\Delta = |\Delta|e^{i\emptyset}$ **SDW Coherence length** $\xi_0 = \frac{\hbar v_F}{\pi|\Delta|}$

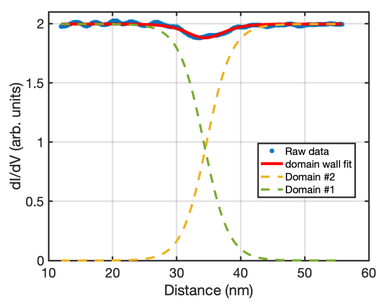
Δ can't change quickly across DW, otherwise it would destroy SDW state

ξ_0 : A characteristic length over which a change of Δ can be made

CASE#1 Orientation DW

$\overrightarrow{Q_1} \perp \overrightarrow{Q_2}$, both in-plane
SDW gap opens at different point in k-space
Δ decays to zero across the DW





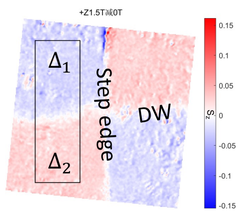
$d = 0.226 \pm 0.014\ nm$

$\xi_0 = 3.9 \pm 0.2\ nm$

$y_1(x) = A * \left[\left(\tanh\left(\frac{x-(x_0+d)}{\xi_0}\right)+1\right) + \left(tanh\left(\frac{-x+(x_0-d)}{\xi_0}\right)+1\right)\right]$

CASE#2 Phase DW

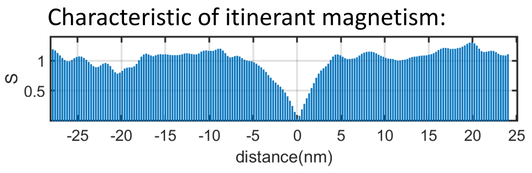
$\overrightarrow{Q_1} \parallel \overrightarrow{Q_2}$, both out-of-plane
$\Delta \propto \vec{M}$, $\Delta_1 = -\Delta_2$

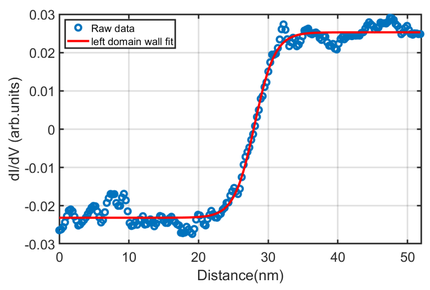


$|\boldsymbol{S}| = \sqrt{S_x^2 + S_y^2 + S_z^2}$

S changes its magnitude, but doesn't rotate at DW.

Characteristic of itinerant magnetism:





$\xi_0' = 2.9 \pm 0.2\ nm$

$y_2(x) = A' * \tanh\left(\frac{x-x_0'}{\xi_0'}\right) + C'$

Summary

1. We present the behavior of SDW/CDW domain wall, which is distinct from the traditional exchange-interaction based magnetic domain wall.
2. Interference of SDW introduces double-Q region at domain wall, and induces a related charge order.
3. Two types of SDW domain walls give similar value of SDW coherence length (close to half the period of SDW).
4. The novel magnetic domain wall structure resolved microscopically in real space would inspire more study on the basic mechanism of SDW. (Unpublished)

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