MAX-PLANCK-INSTITUT
FÜR EISENFORSCHUNG GmbH

# Interstitial Doping in High-entropy Alloys

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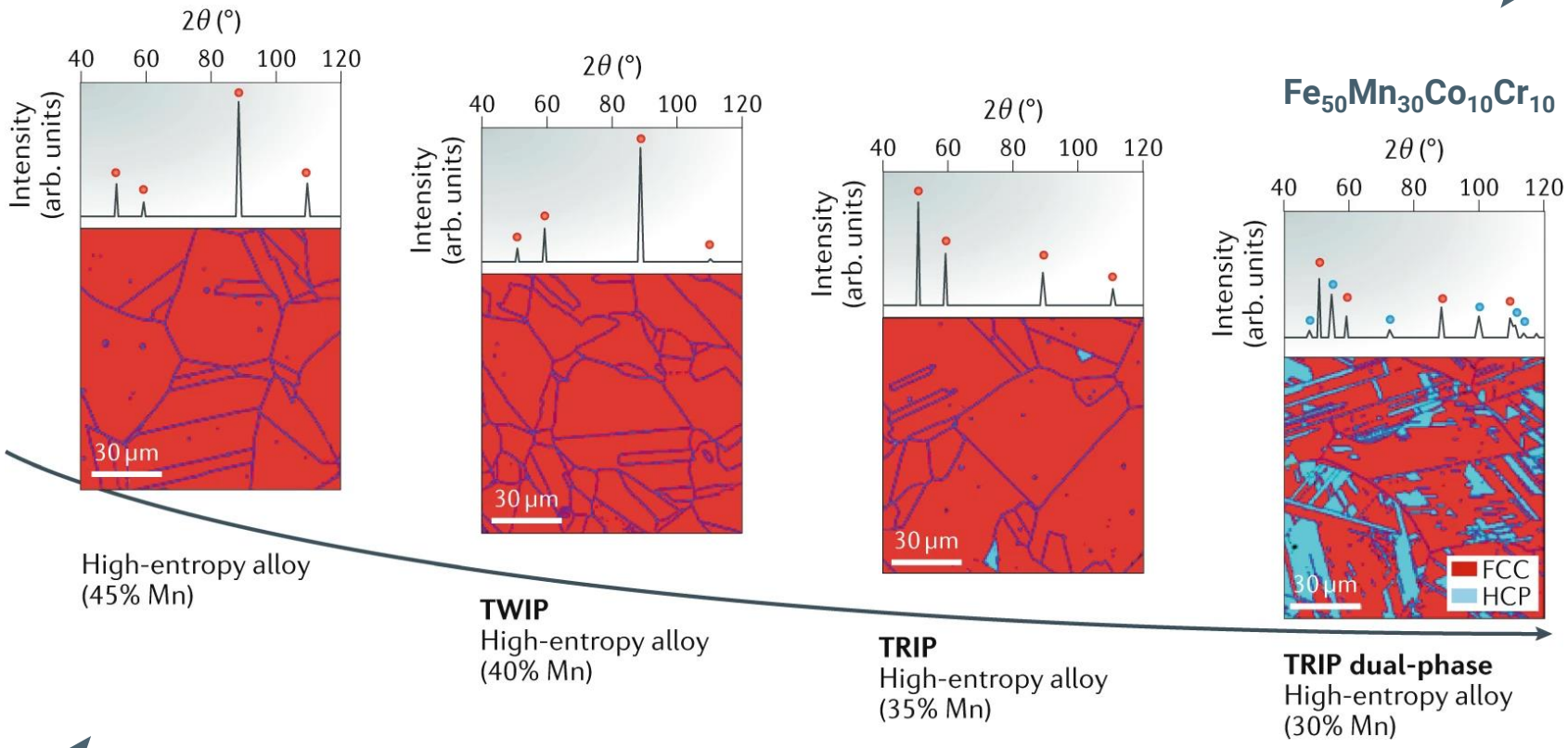
# Interstitial doping in high-entropy alloys

1. Interstitials in FCC high-entropy alloys
   - Tuning deformation mechanisms through alloy design
   - Design of thermally stable bulk nanostructured iHEA
2. Interstitials in BCC high-entropy alloys
   - Tuning deformation mechanisms via ordered oxygen complexes
3. Summary

# From HEA to iHEA

## Tuning deformation mechanisms through alloy design (SFE-guided alloying concept)

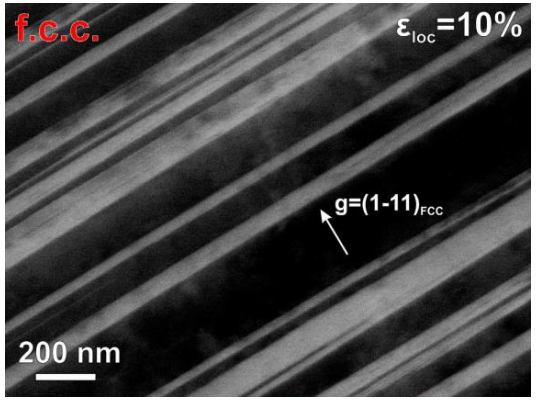
$Fe_{80-x}Mn_xCo_{10}Cr_{10}$ HEA — Increasing Fe content




Increasing stacking-fault energy (SFE)

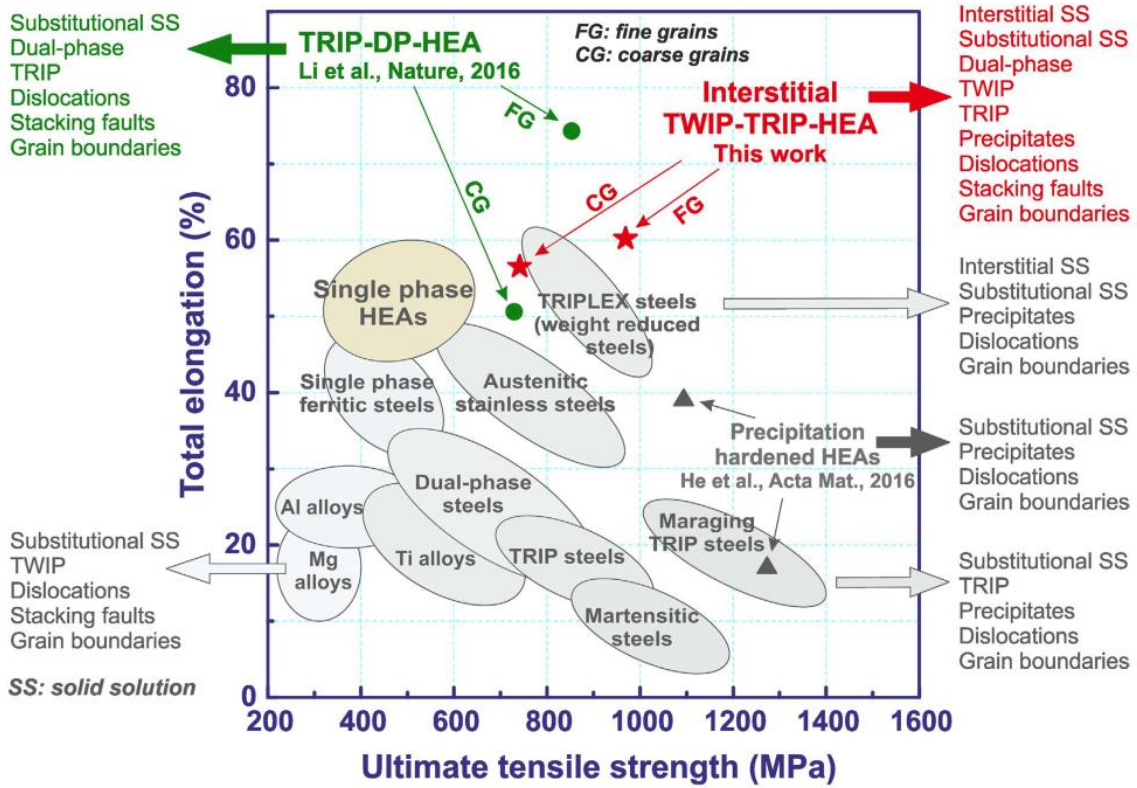
$Fe_{50}Mn_{30}Co_{10}Cr_{10}$ + interstitial C

- a slight increase in SFE to ~18 mJ/m²
- activation of the TWIP effect
- TWIP+TRIP iHEA



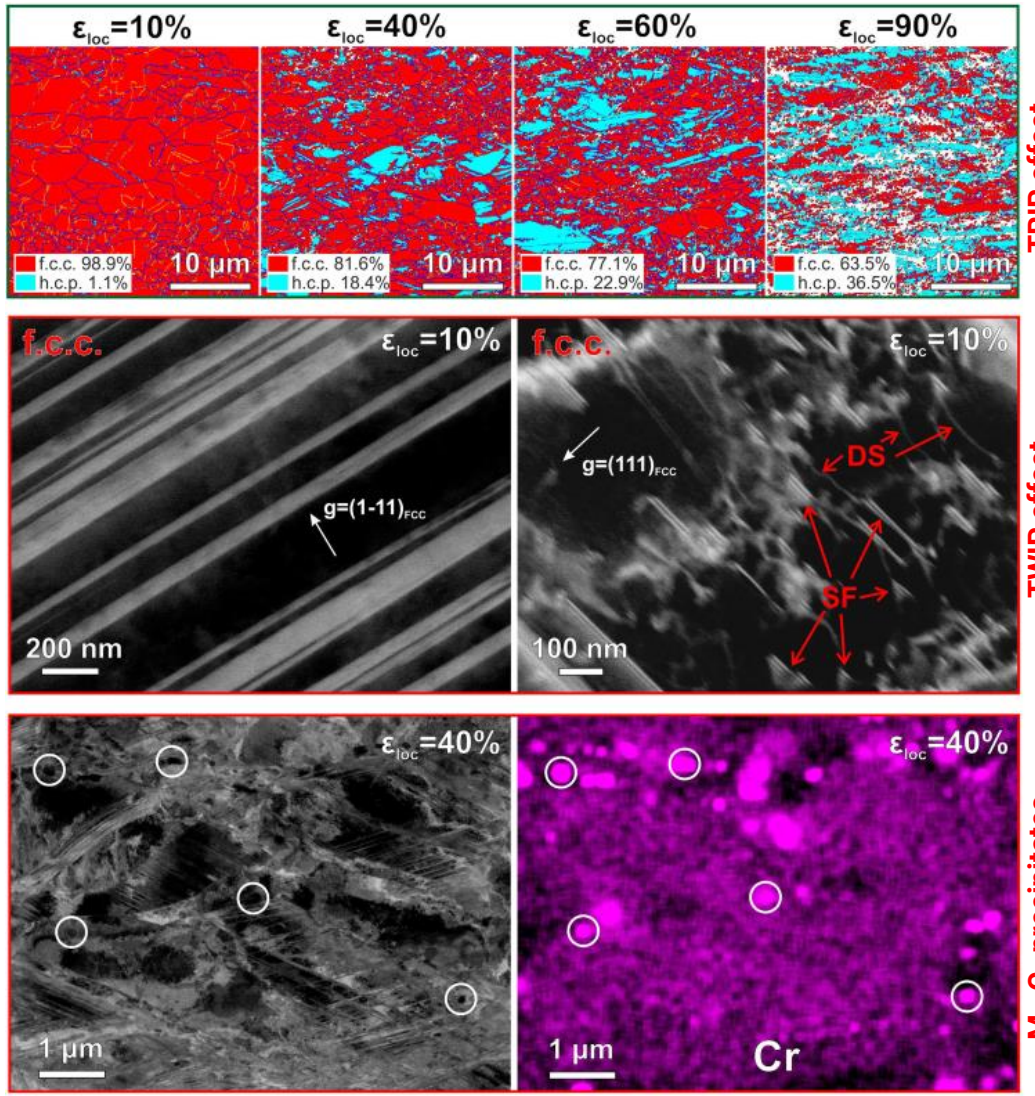
# Interstitials in FCC HEA

## Tuning deformation mechanisms through alloy design



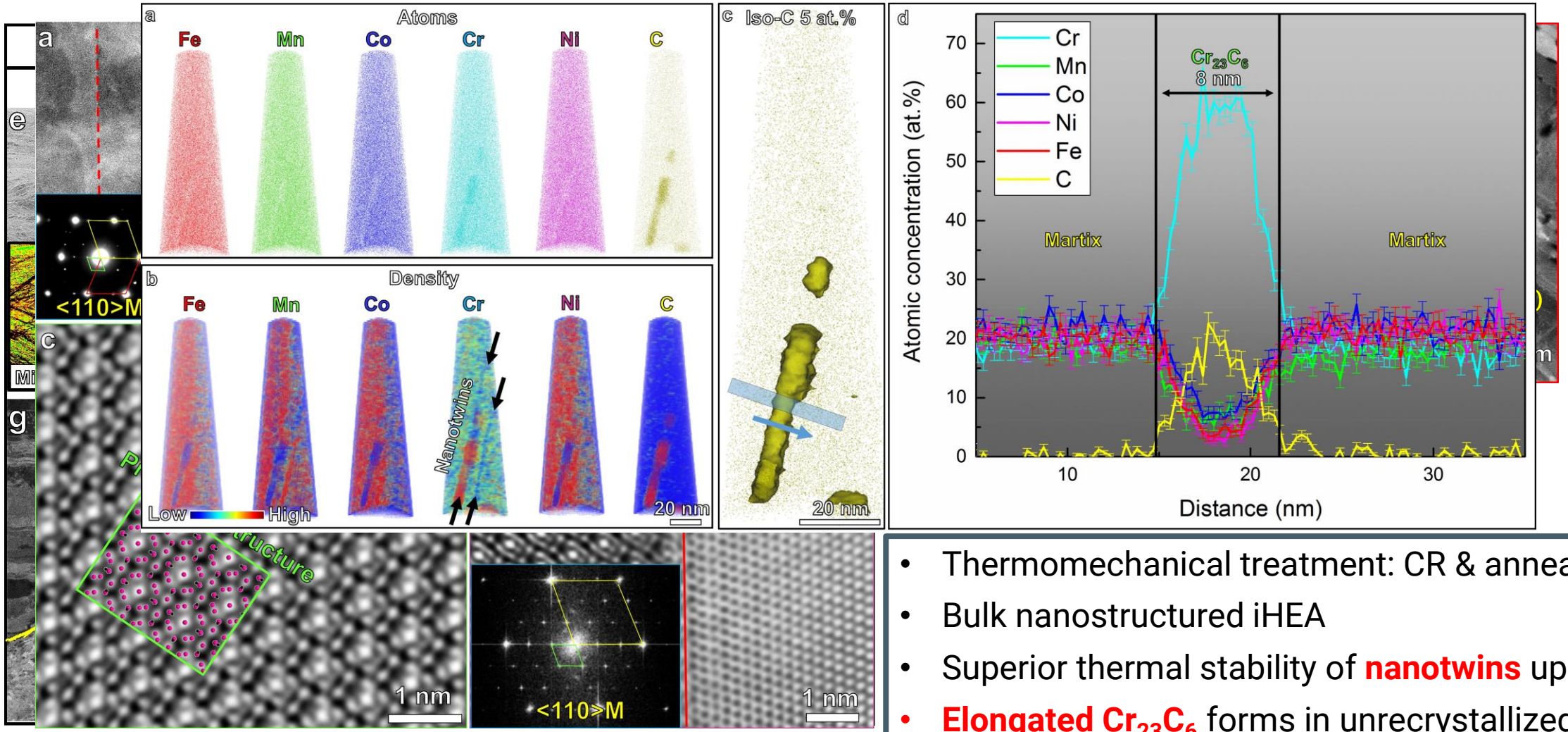

- **Carbon addition** effectively tunes the stability of the metastable FCC matrix.
- SFE is ~18 mJ/m$^2$, triggering both **TRIP and TWIP effects**.
- **All strengthening mechanisms** are realized in one HEA.

$Fe_{49.5}Mn_{30}Co_{10}Cr_{10}C_{0.5}$, CR&RX, GS=4 μm



# Interstitials in FCC HEA

## Design of thermally stable bulk nanostructured iHEA

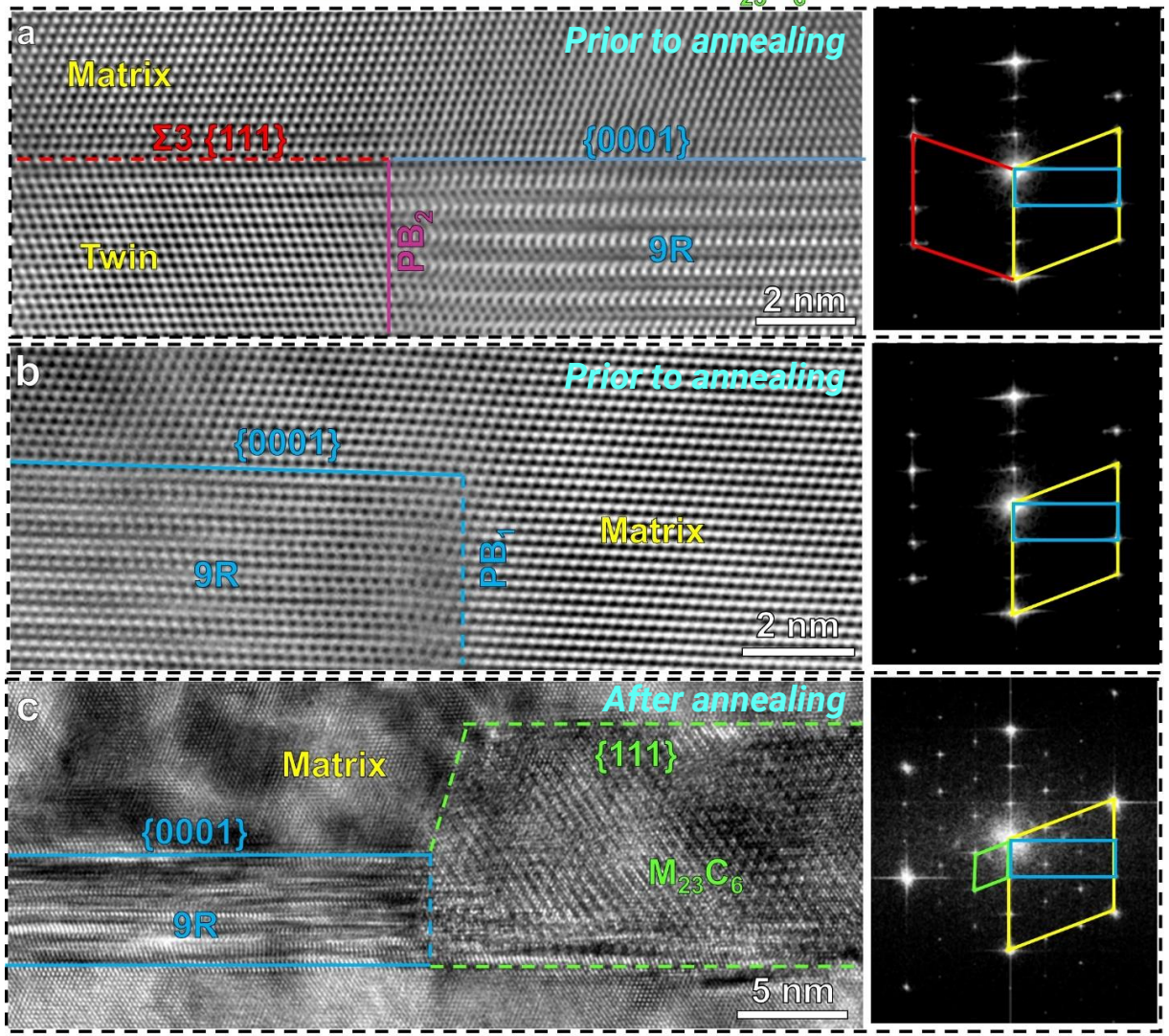


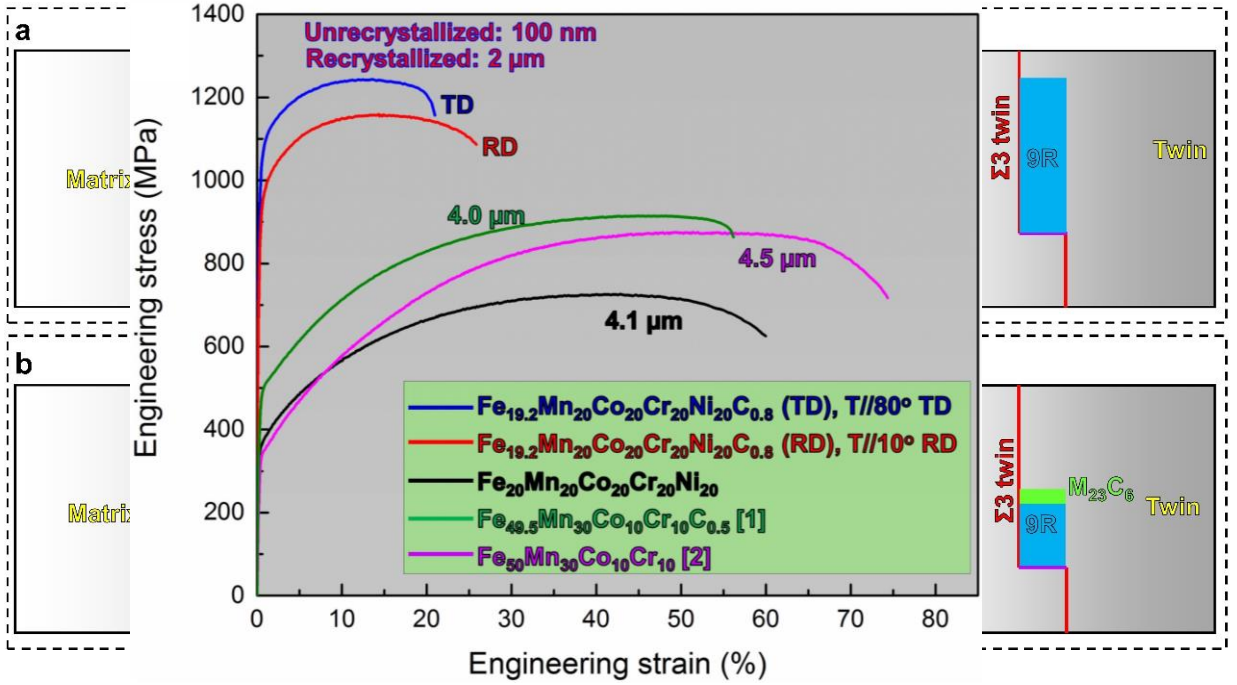

- Thermomechanical treatment: CR & annealing
- Bulk nanostructured iHEA
- Superior thermal stability of **nanotwins** up to 900°C
- **Elongated $Cr_{23}C_6$** forms in unrecrystallized region.
- Nano-carbides retards mobility of twin boundary.

# Interstitials in FCC HEA

## Interfacial nanophase design enables thermally stable nanotwins

<110>Matrix//<011>Twin//<110>$M_{23}C_6$//<11$\bar{2}$0>9R

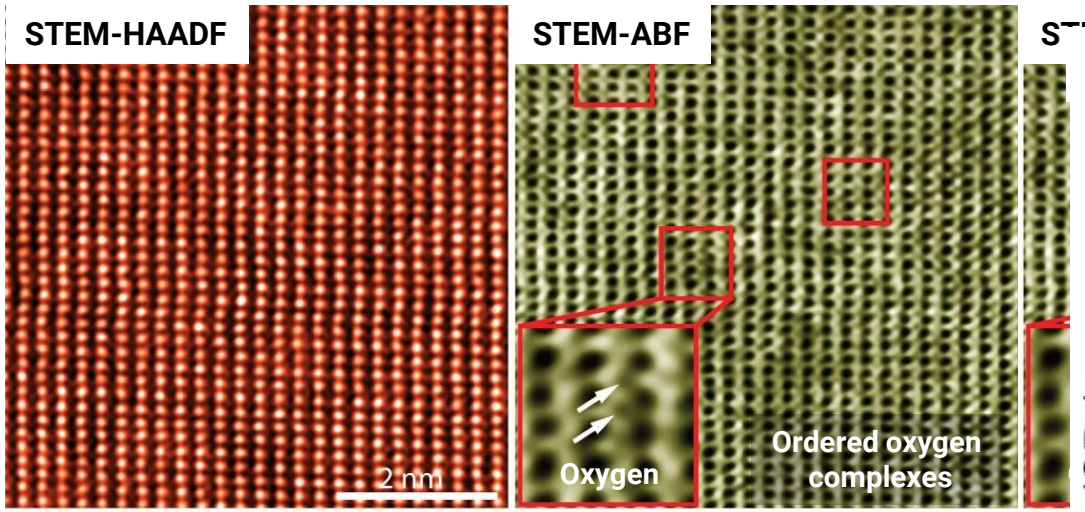


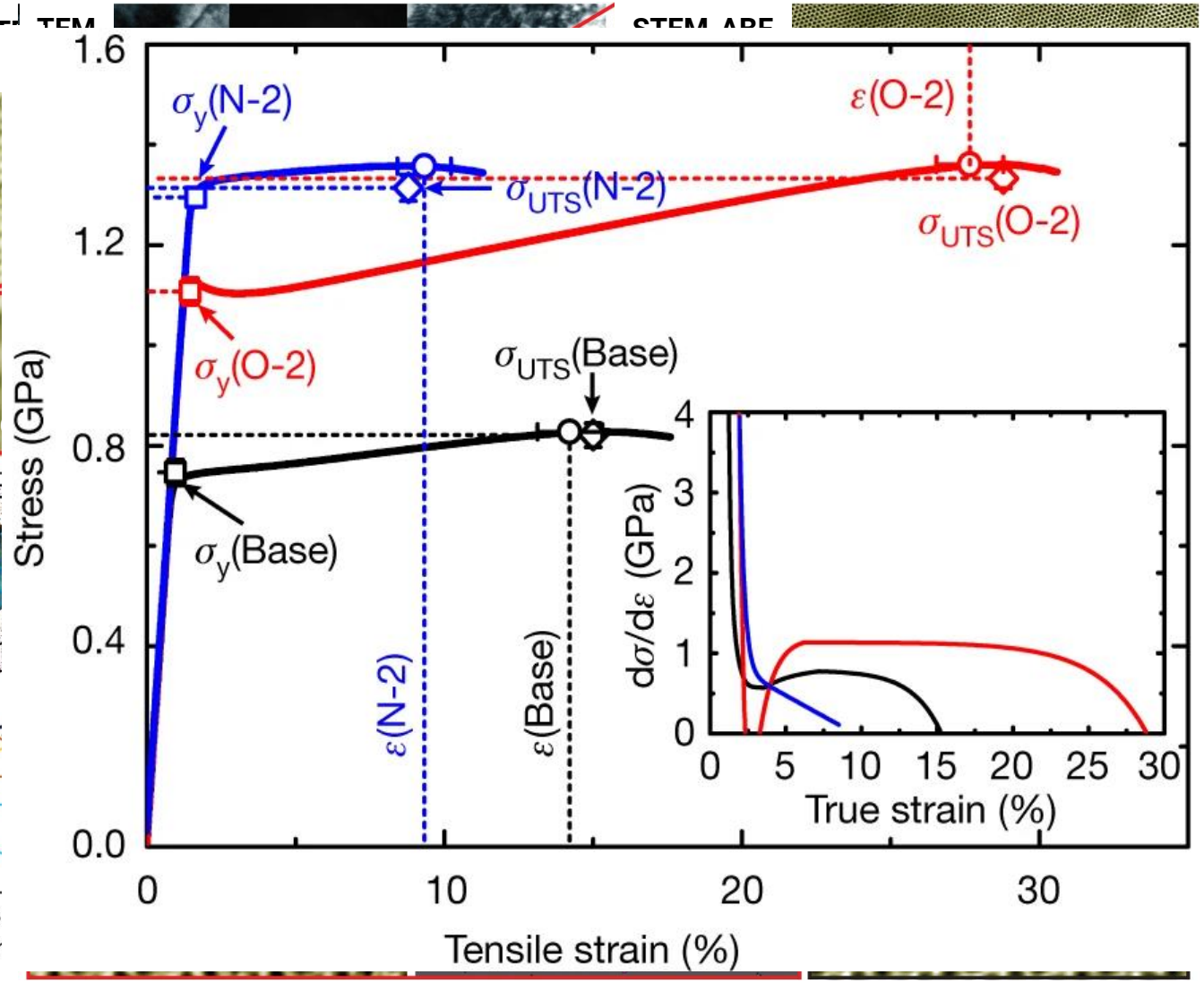

- Co-segregation of Cr and C to **9R structures**
- Formation of elongated nano-carbides at **ICT Σ3 boundary** and grow along {0001} habit plane of 9R
- **Nano-carbides retards de-twinning process**, resulting in superior high-strength.

# Interstitials in BCC HEA

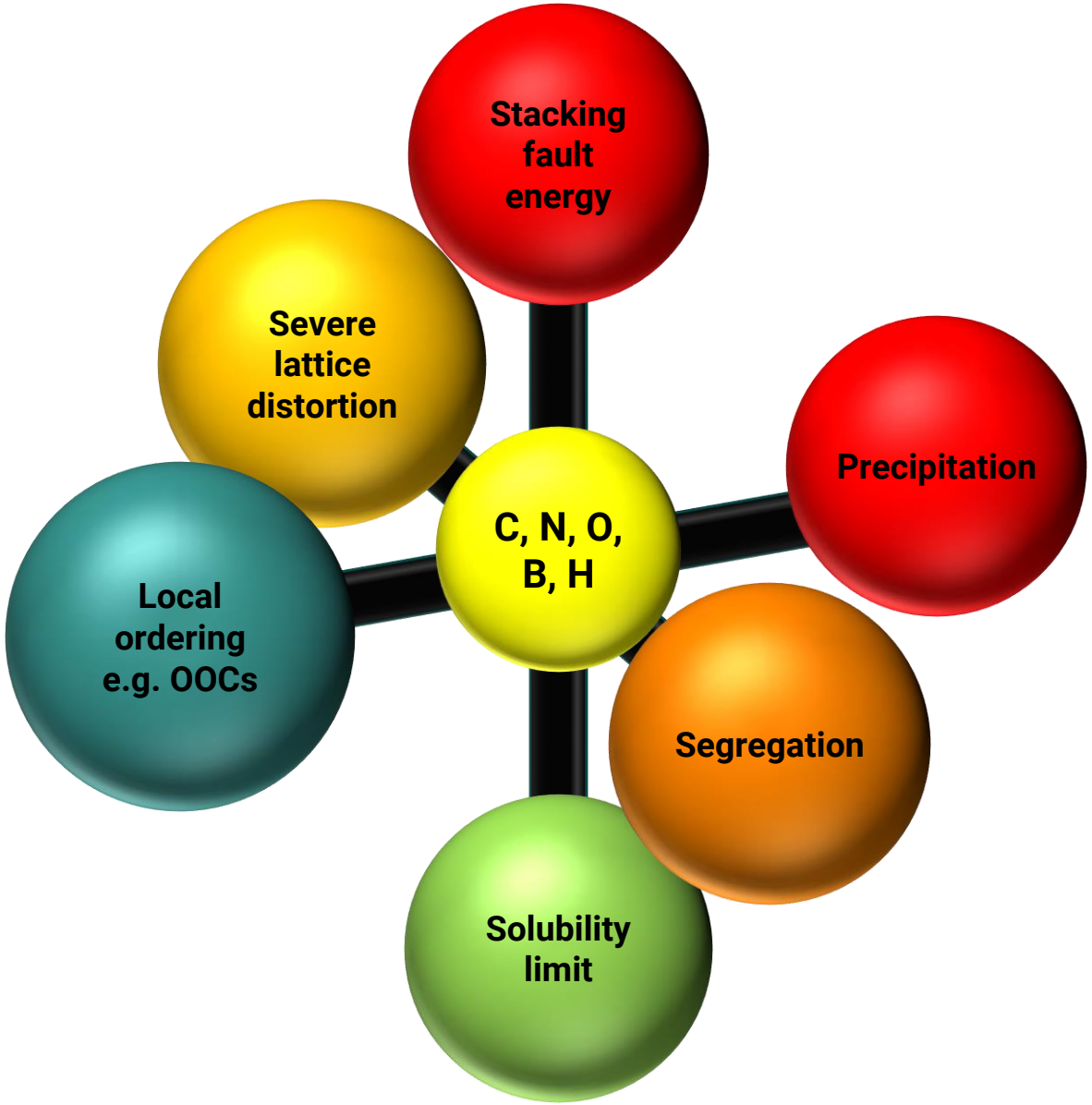
## Tuning deformation mechanism via ordered oxygen complexes (OOCs) in $(TiZrHfNb)_{98}O_2$ HEA

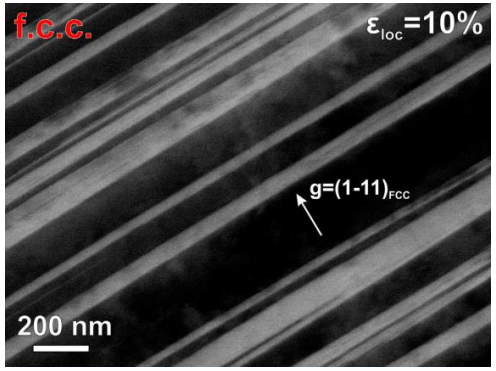


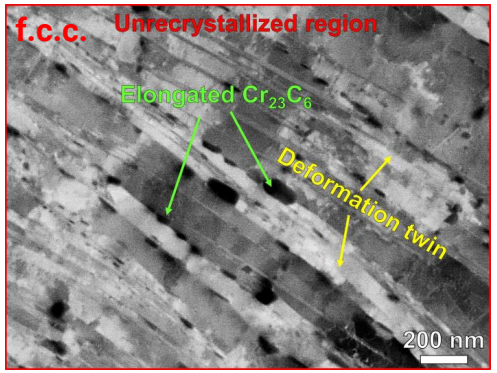

- O prefers interstitial sites in **light-atom-rich (*i.e.* Ti and Zr) lattices** and form OOCs with size of 1-3 nm and space of 2-4 nm.
- OOCs effectively pin dislocations, promoting **cross slip and massive dislocation multiplication**.
- Homogeneous deformation and high strain hardening result in high strength and superior ductility.

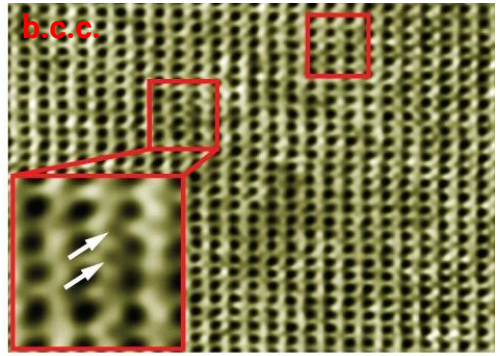


# Fascinating impacts of interstitials on HEAs




b.c.c.

**TiZrNbHfTa + B**
Grain refinement
GB segregation
Hydrogen embrittlement

b.c.c.

**TiZrNb + O**
Solubility limit
SRO/OOCs
Deformation modes

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