Key microstructural features of Bi2212 and Bi2223 wires

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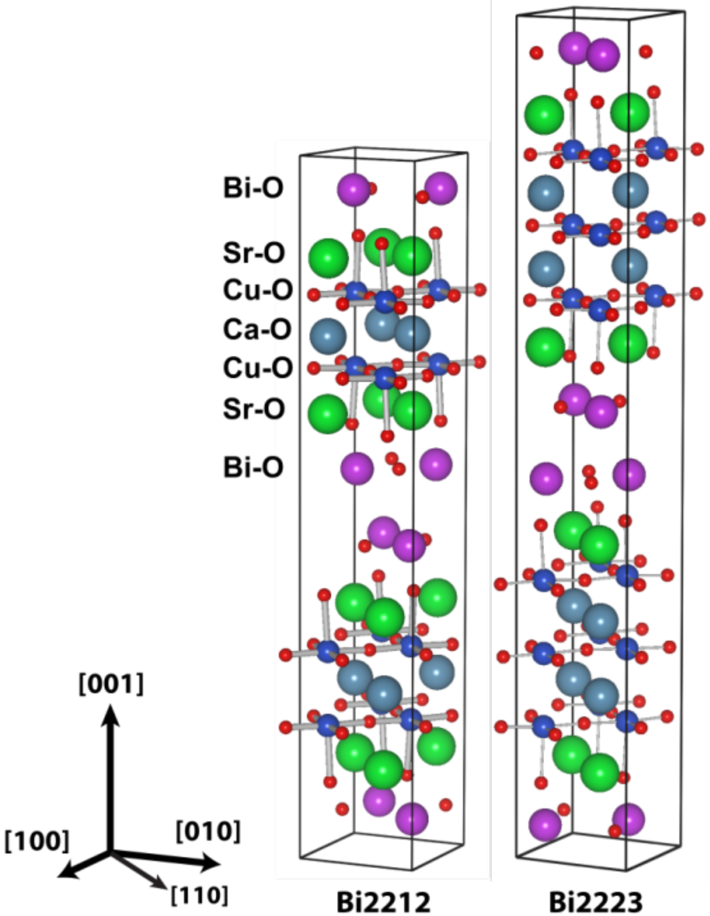
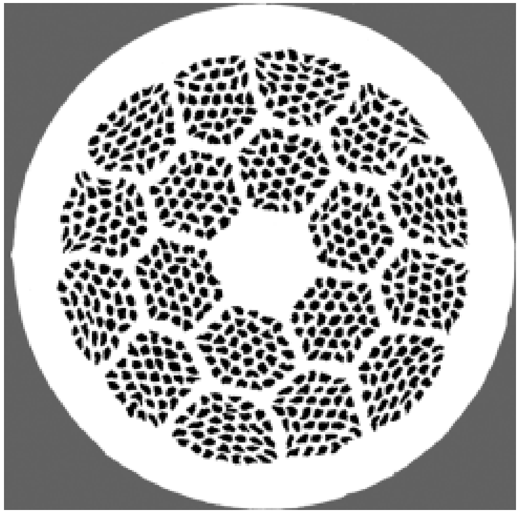
Sibling materials, but different architectures are needed for high J_c



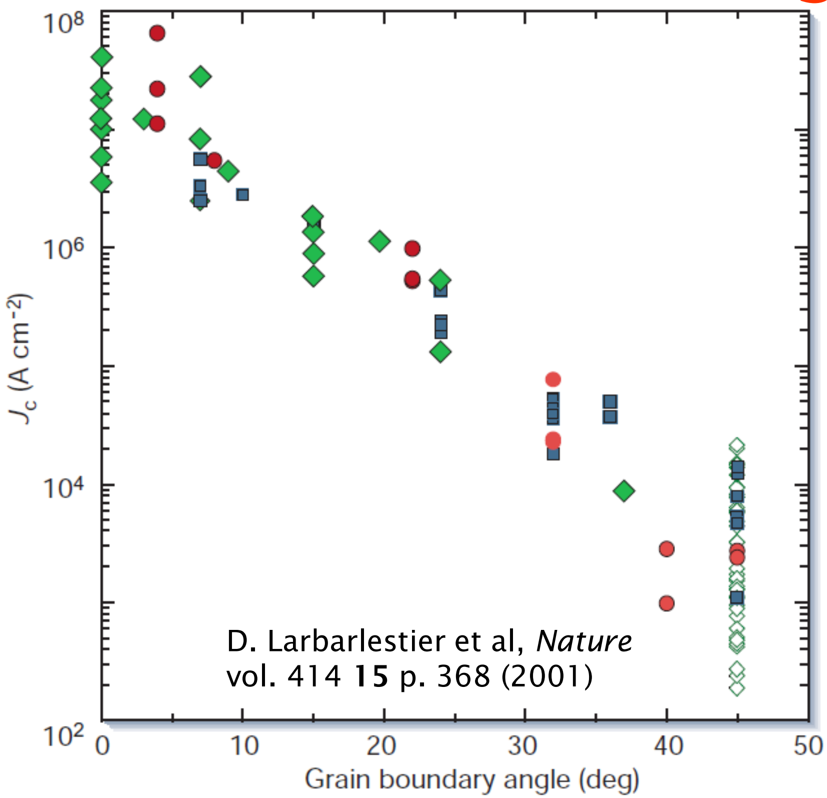
$Bi_2Sr_2Ca_2Cu_3O_x$ (Bi2223) conductors – Flat tape

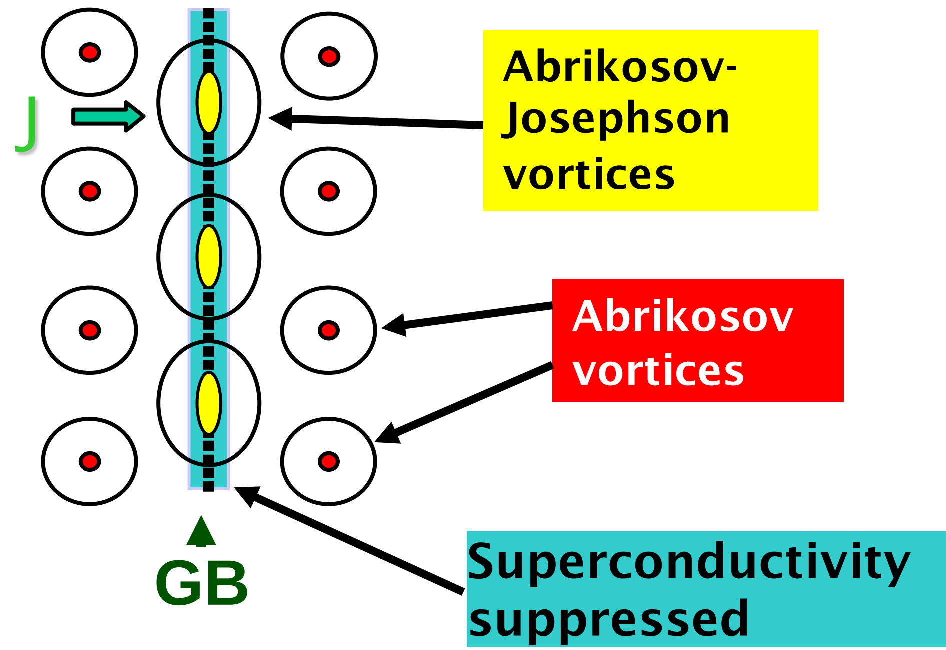
$Bi_2Sr_2Ca_1Cu_2O_x$ (Bi2212) conductors – Round wire



- Bi2223: Uni-axial texture
- Bi2212: No macroscopic texture

Planar bi-crystal studies have shown strong J_c decay at HTS GBs

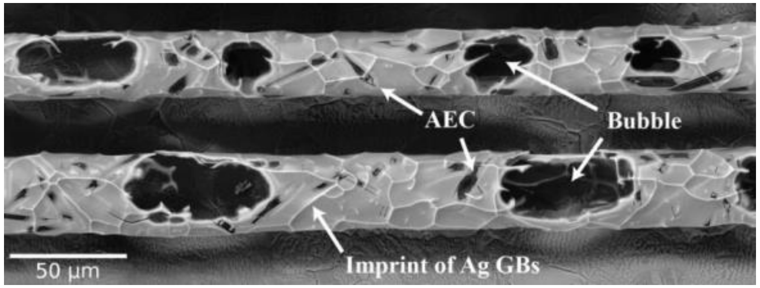




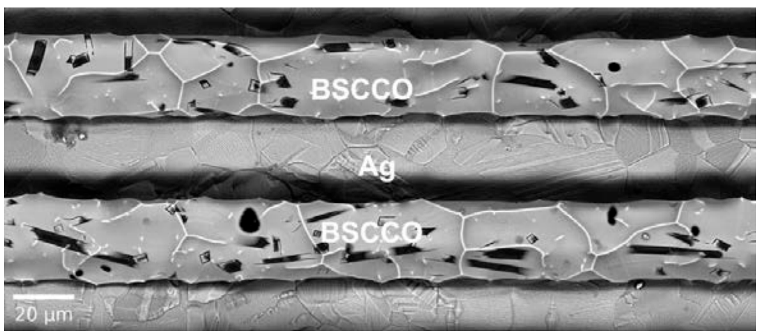
A Gurevich and E.A. Pashitskii, PRB 57, 13875 (1998)
J. Mannhart and H. Hilgenkamp, APL 73, 265 (1998)

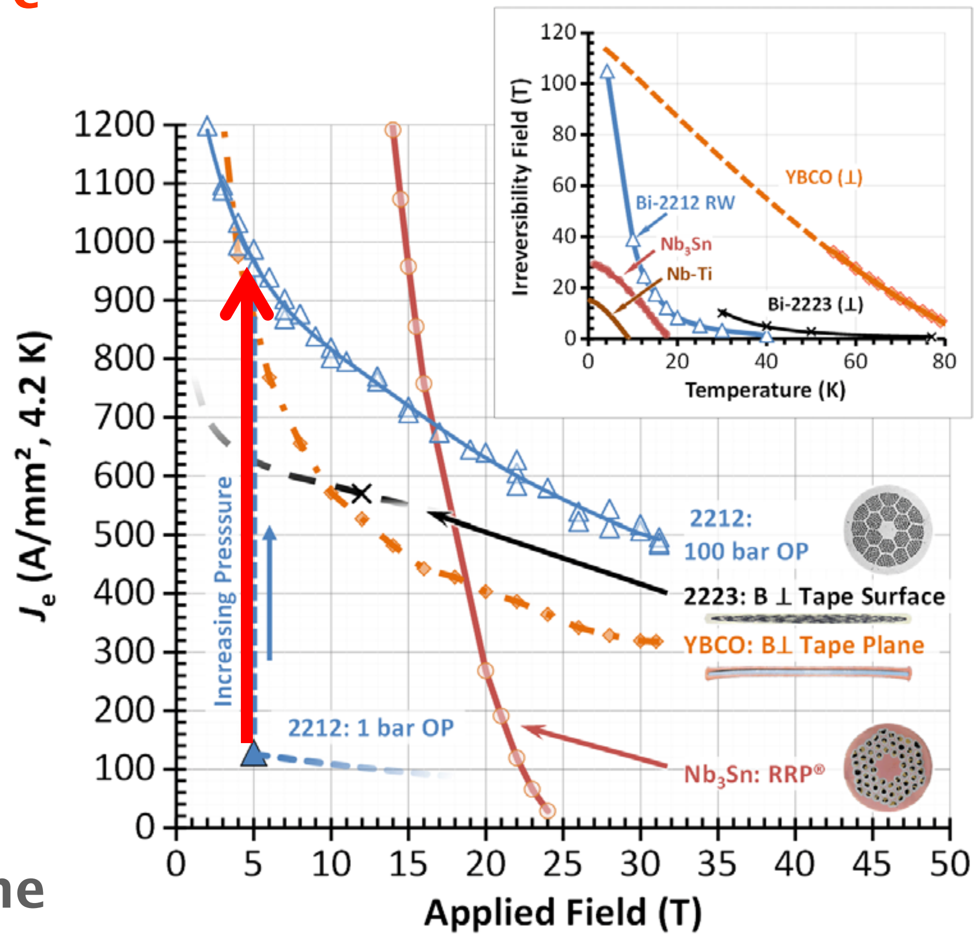
- Generally high angle GBs should be avoided
- Typically the J_c of highly textured HTS is better than that of untextured

Elimination of Bubbles is the key for high J_c Bi2212 RWs



Densification

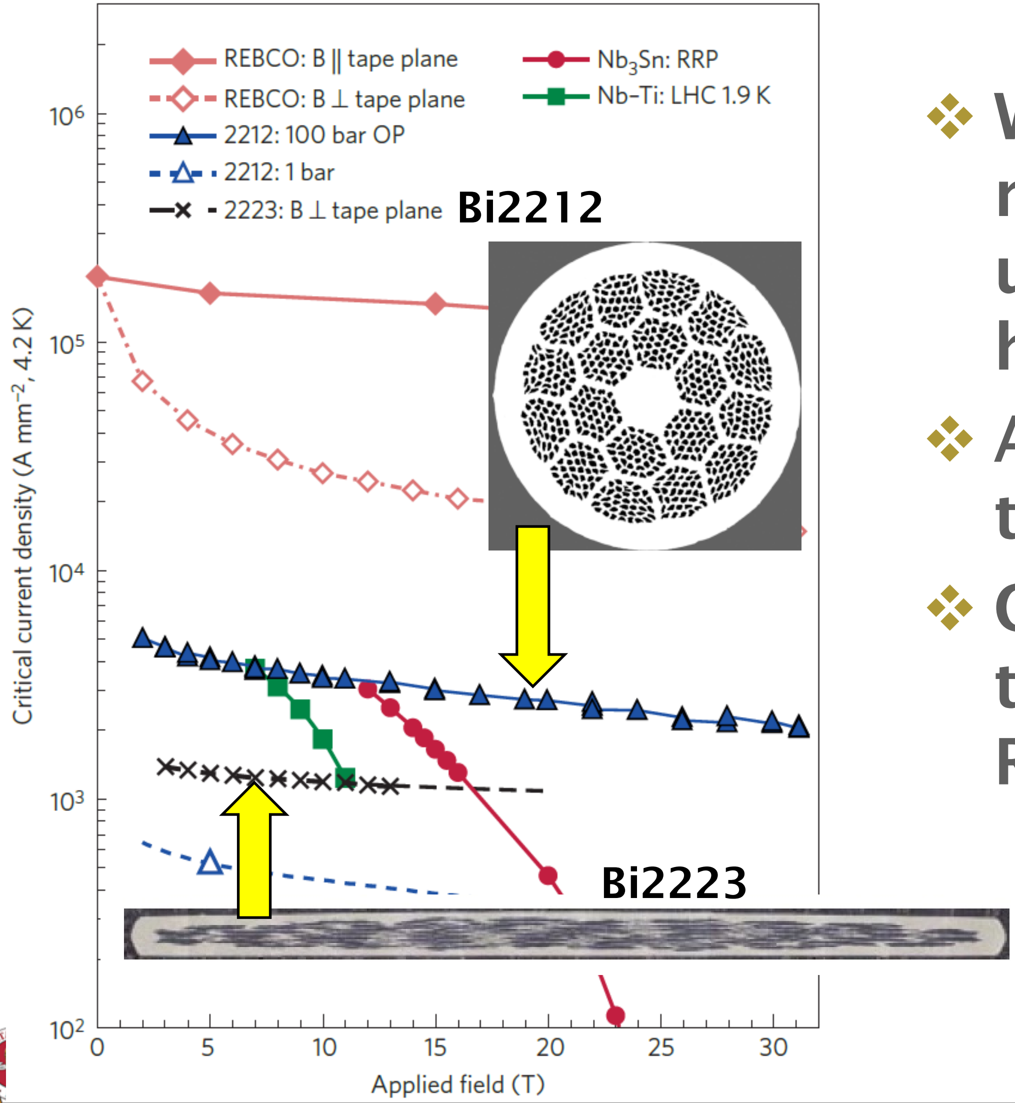




- High angle GBs were not the primary current limiting mechanism in Bi2212 RWs

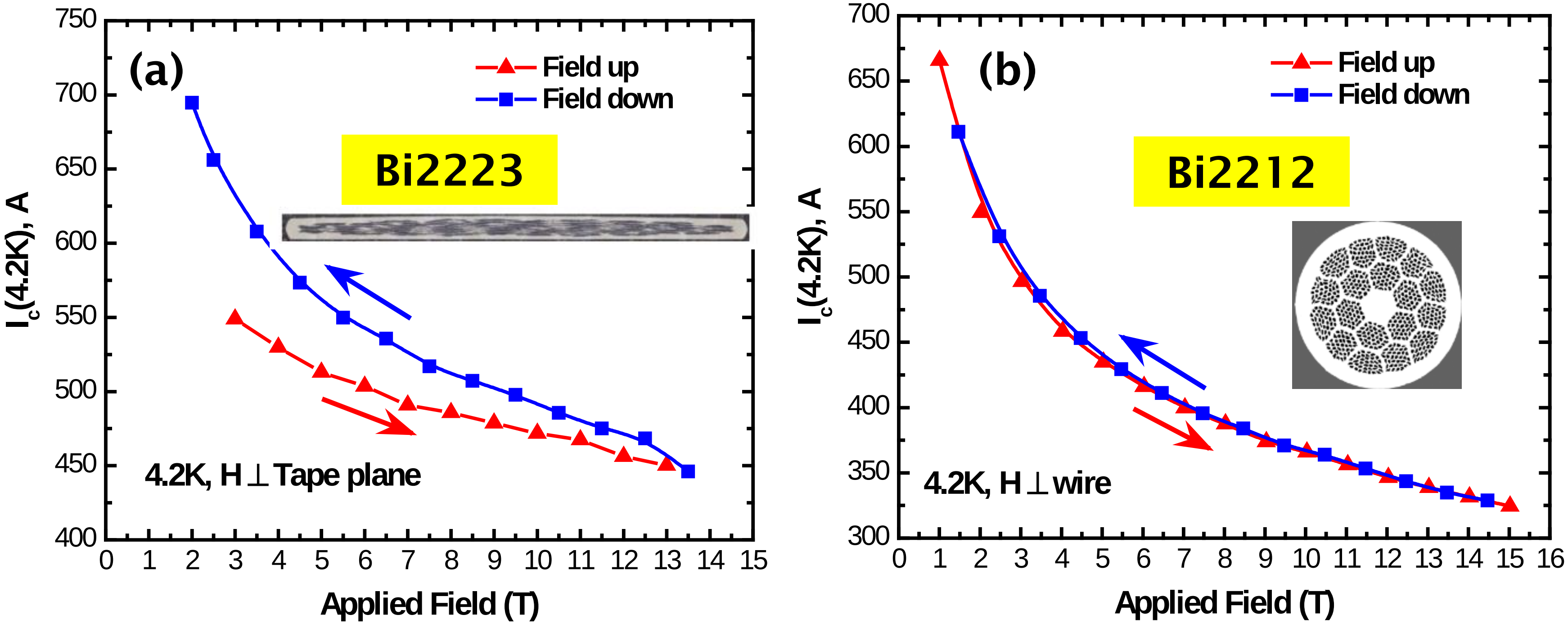
J. Jiang et al, *SuST* **24** 082001 (2011)
D. Larbalestier et al, *Nature Material* **13** 375 (2014)

Fully dense Bi2212 RWs now show higher J_c than highly textured Bi2223 tapes



- Why do the macroscopically untextured RWs show higher J_c?
- Are HAGBs more transparent in Bi2212?
- Or any mechanisms that compensate the RW architecture?

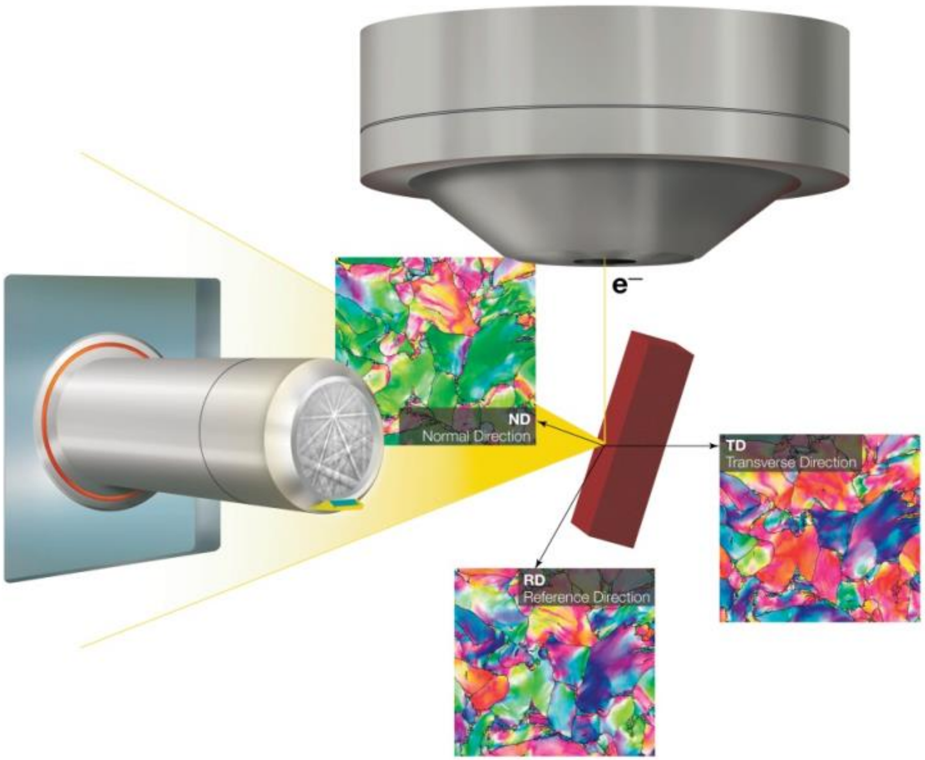
Comparison of I_c in fields between Bi2223 flat and Bi2212 round wires

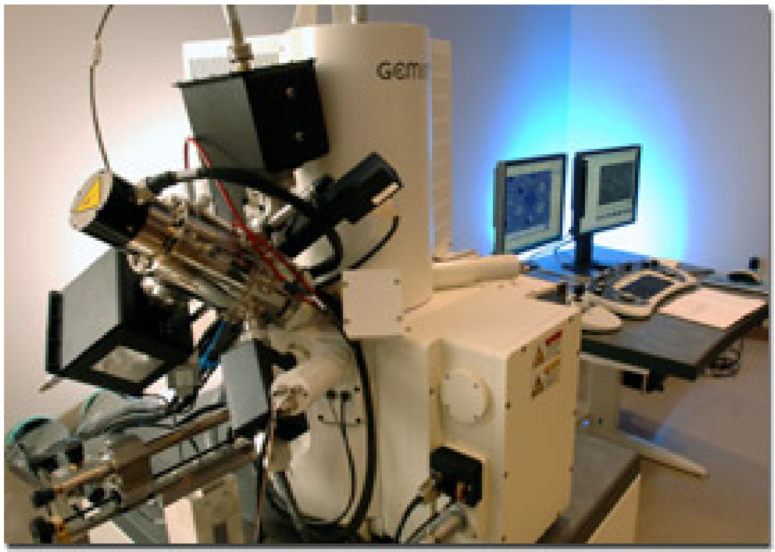


By J. Jiang and D. Abraimov

- I_c hysteresis in fields is caused by granularity of superconductors
  - Transport current passes through weak links in Bi2223
  - Weak links may be absent in Bi2212

Electron Backscatter Diffraction (EBSD) was used to visualize and analyze the microstructure of BSCCO

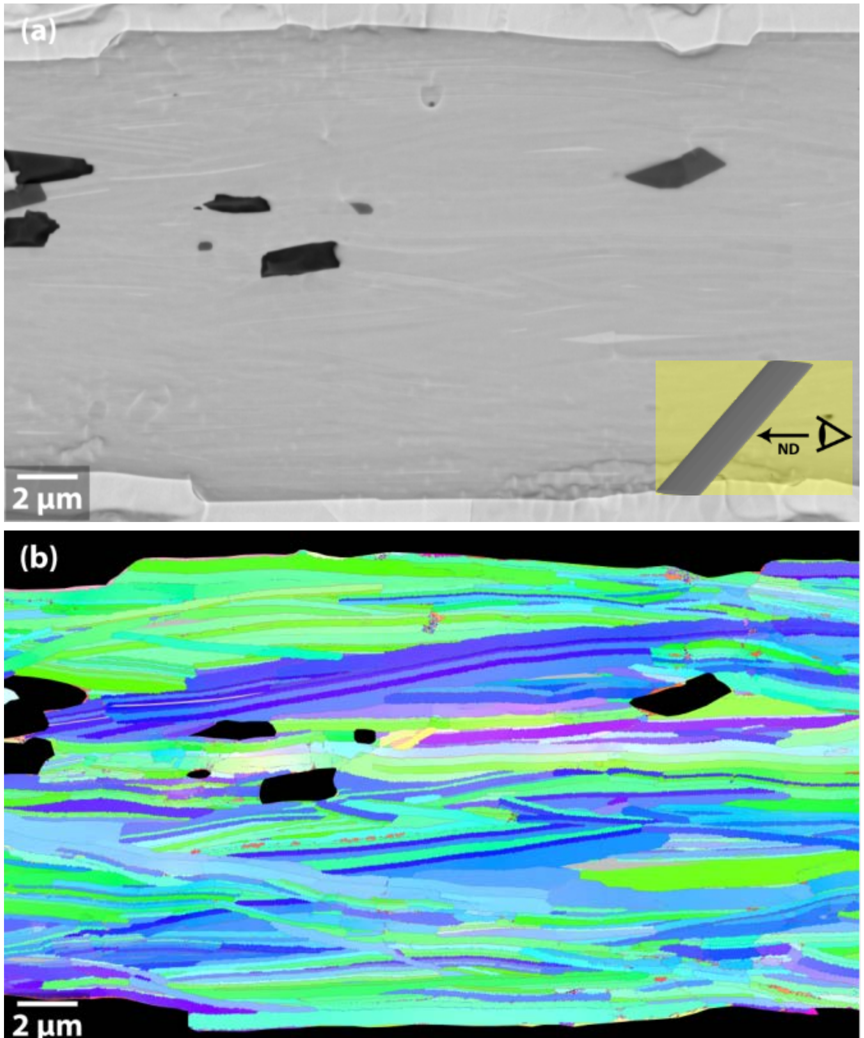


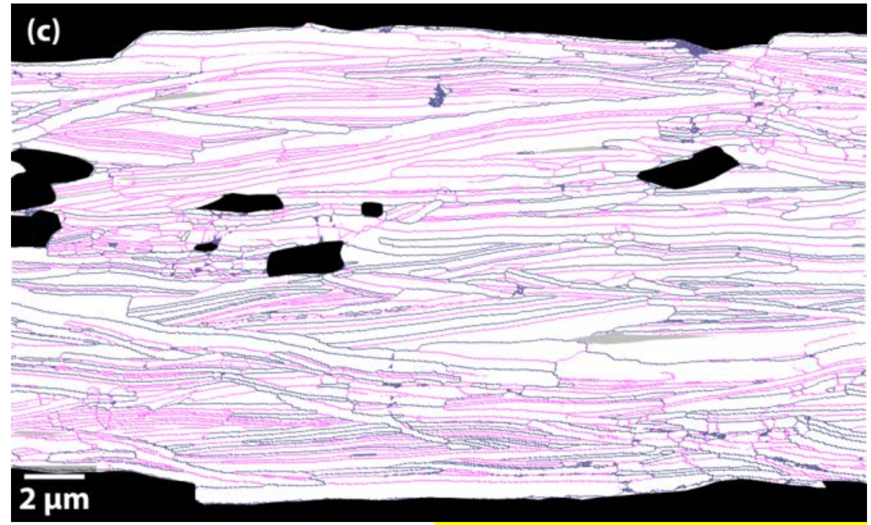


Carl Zeiss 1540 EsB Field Emission SEM

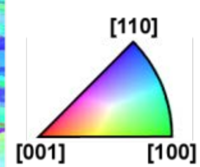
- The sample surface must be very clean – otherwise the diffraction signals will be blocked

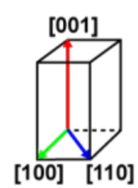
Uniaxial [001] texture is clearly seen in a Bi2223 tape conductor





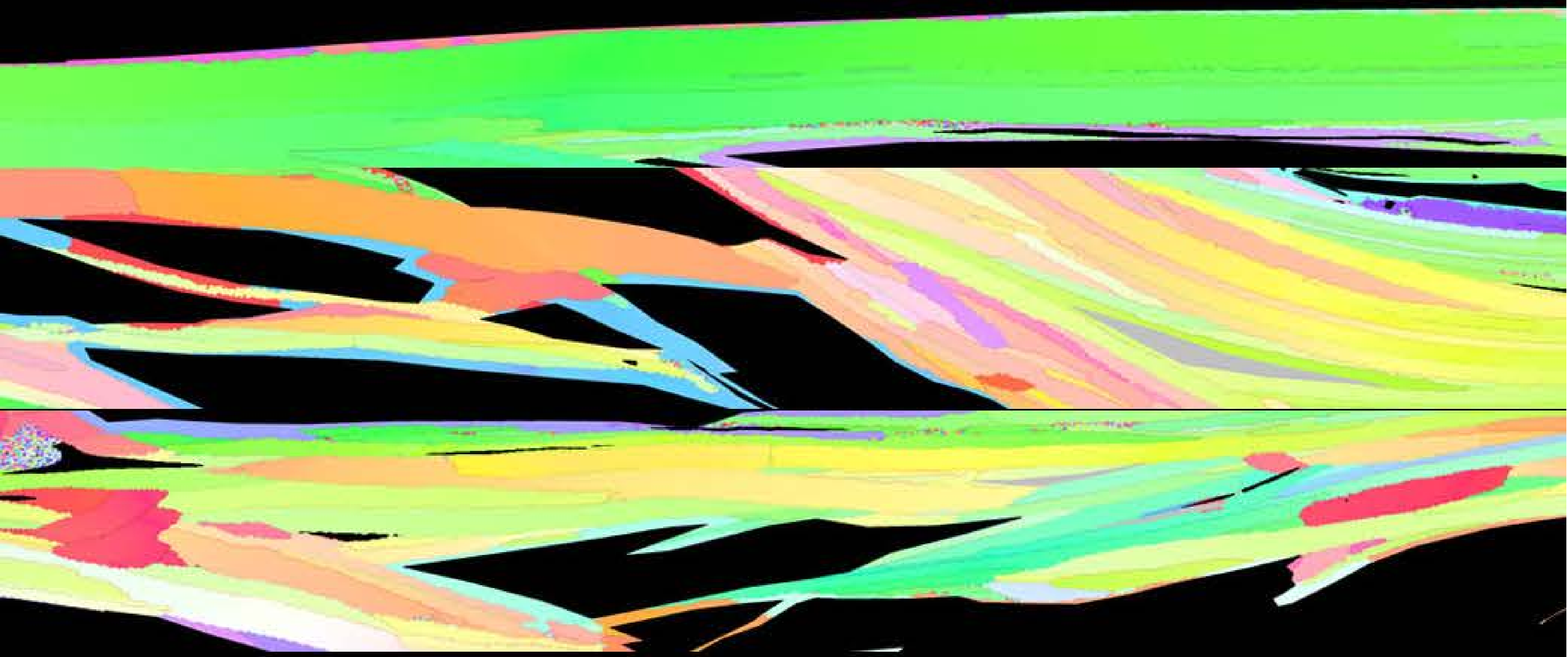
Magenta: <20˚
Dark Blue: >20˚





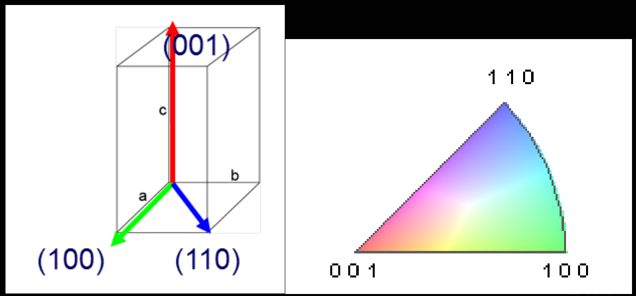
- Transport current mostly passes across HAGBs with >20˚ misorientation

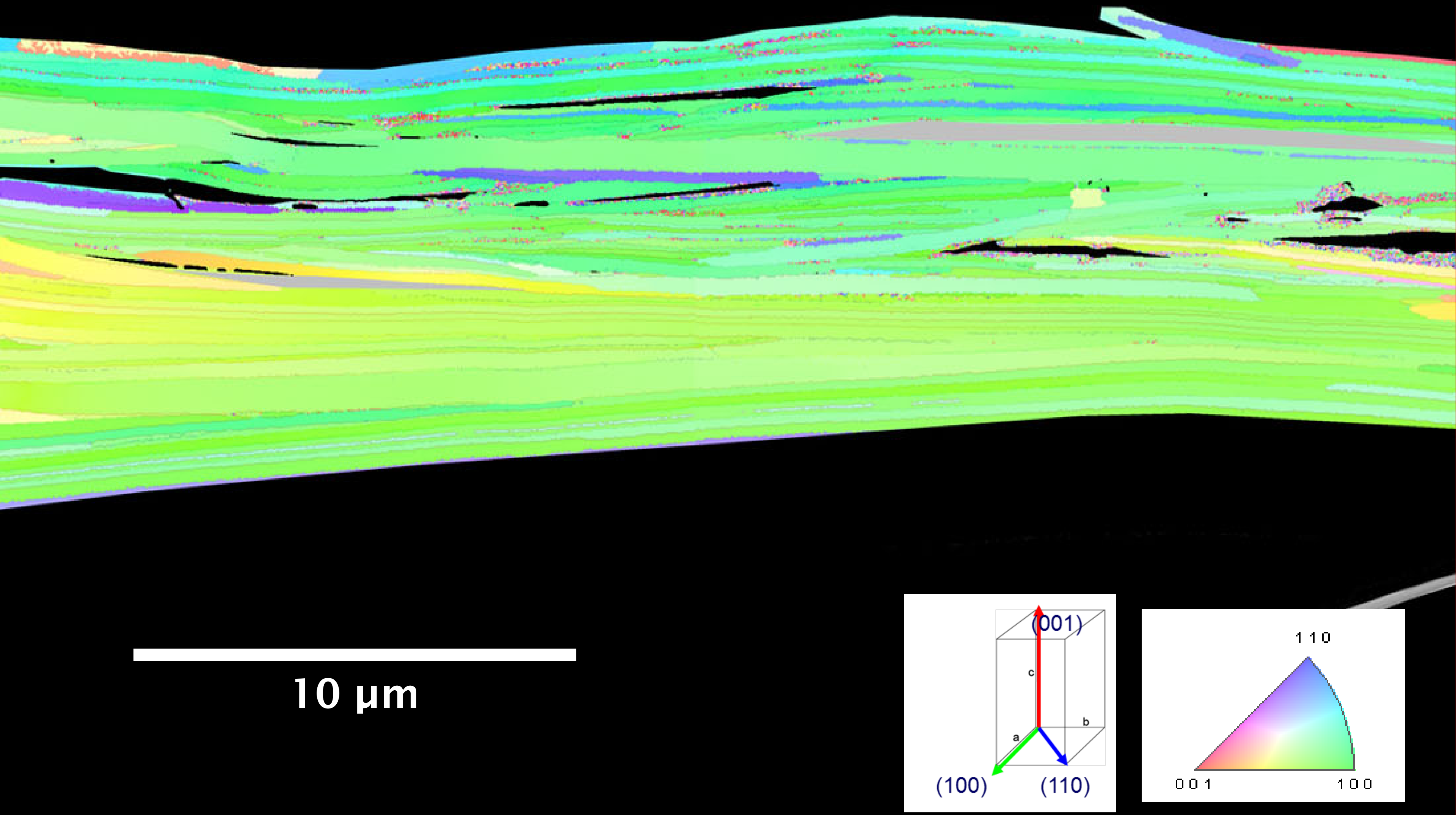
Grain/GB structure in a Bi2212 filament



10 µm

*Animation made by P. J. Lee

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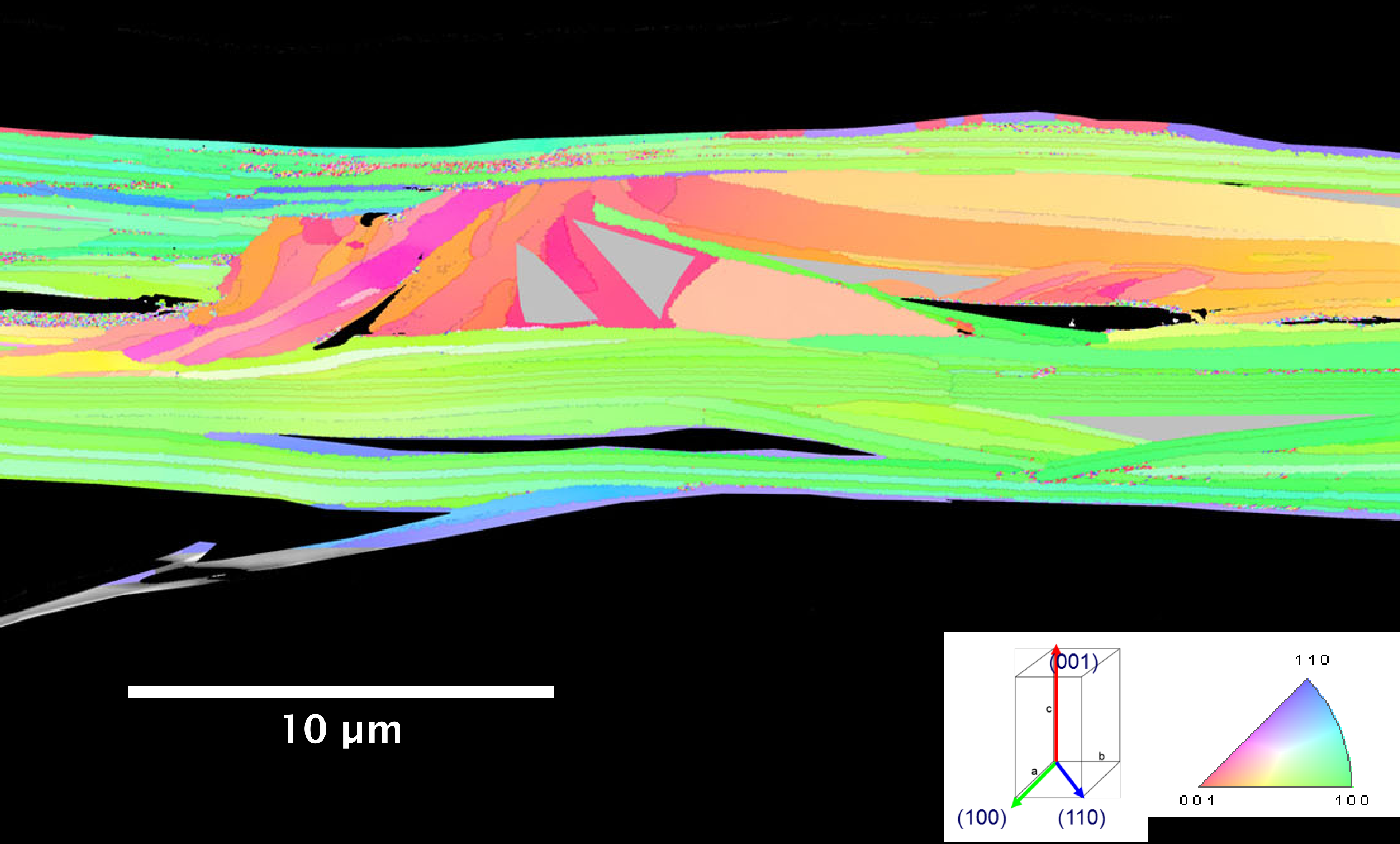
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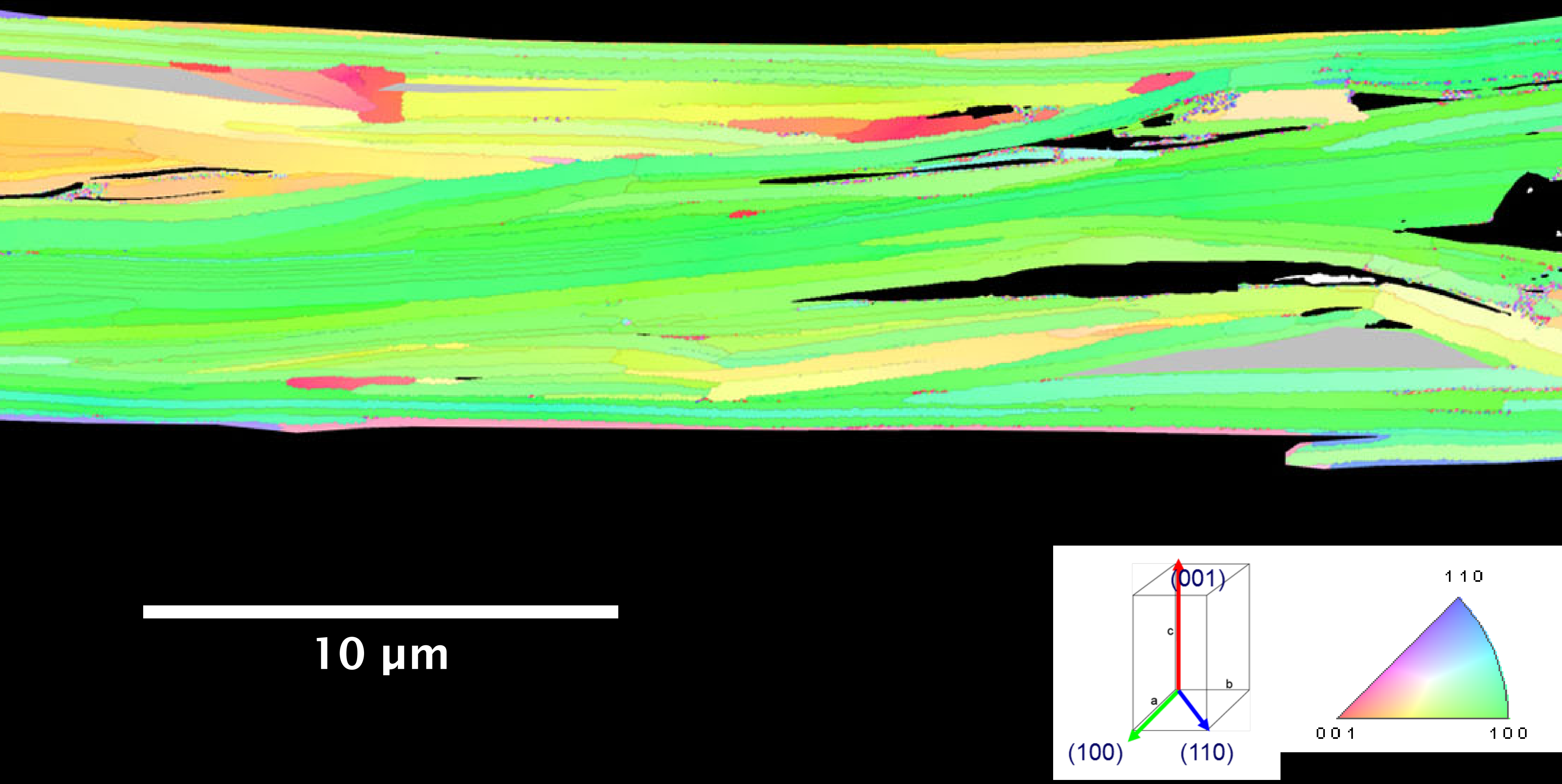
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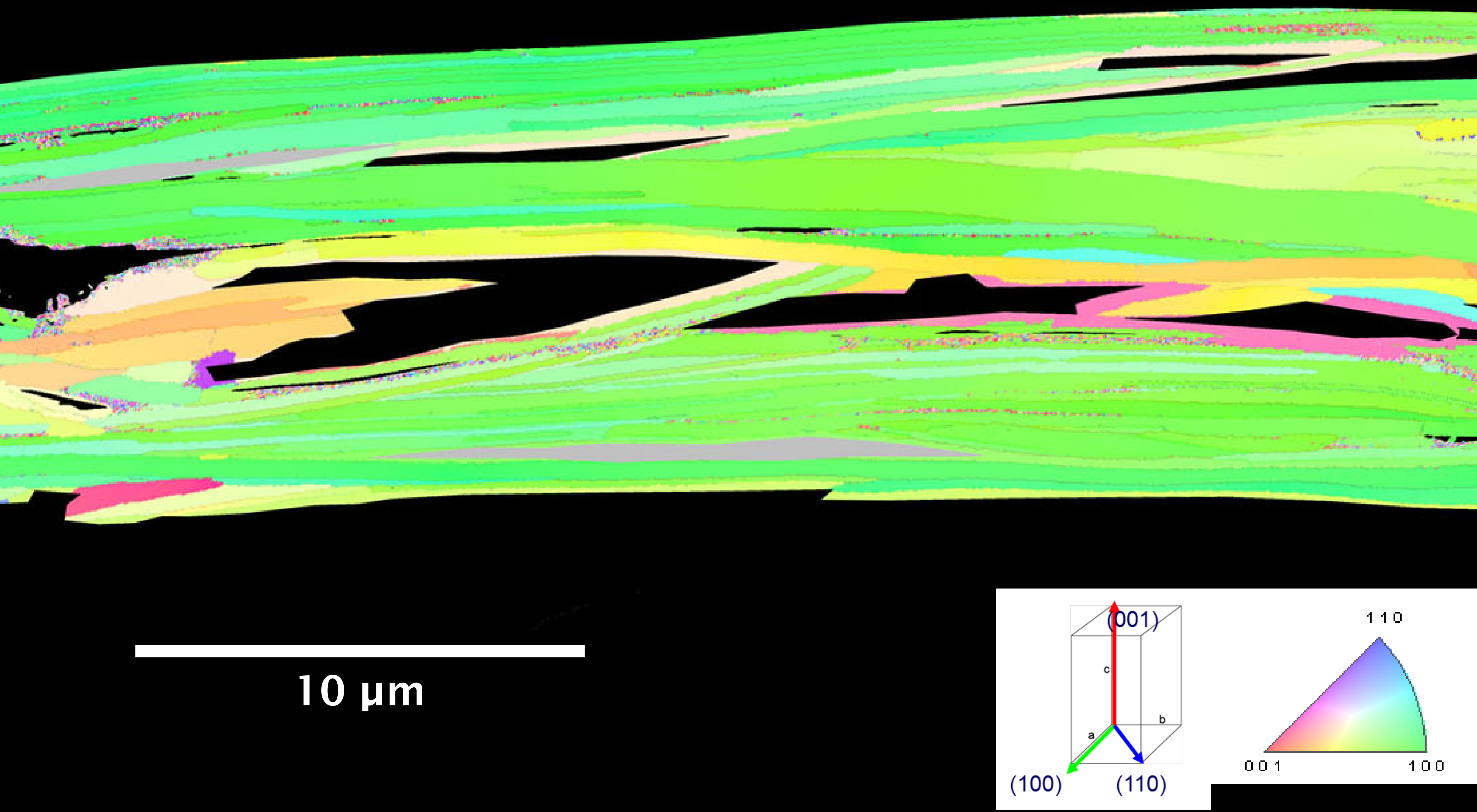
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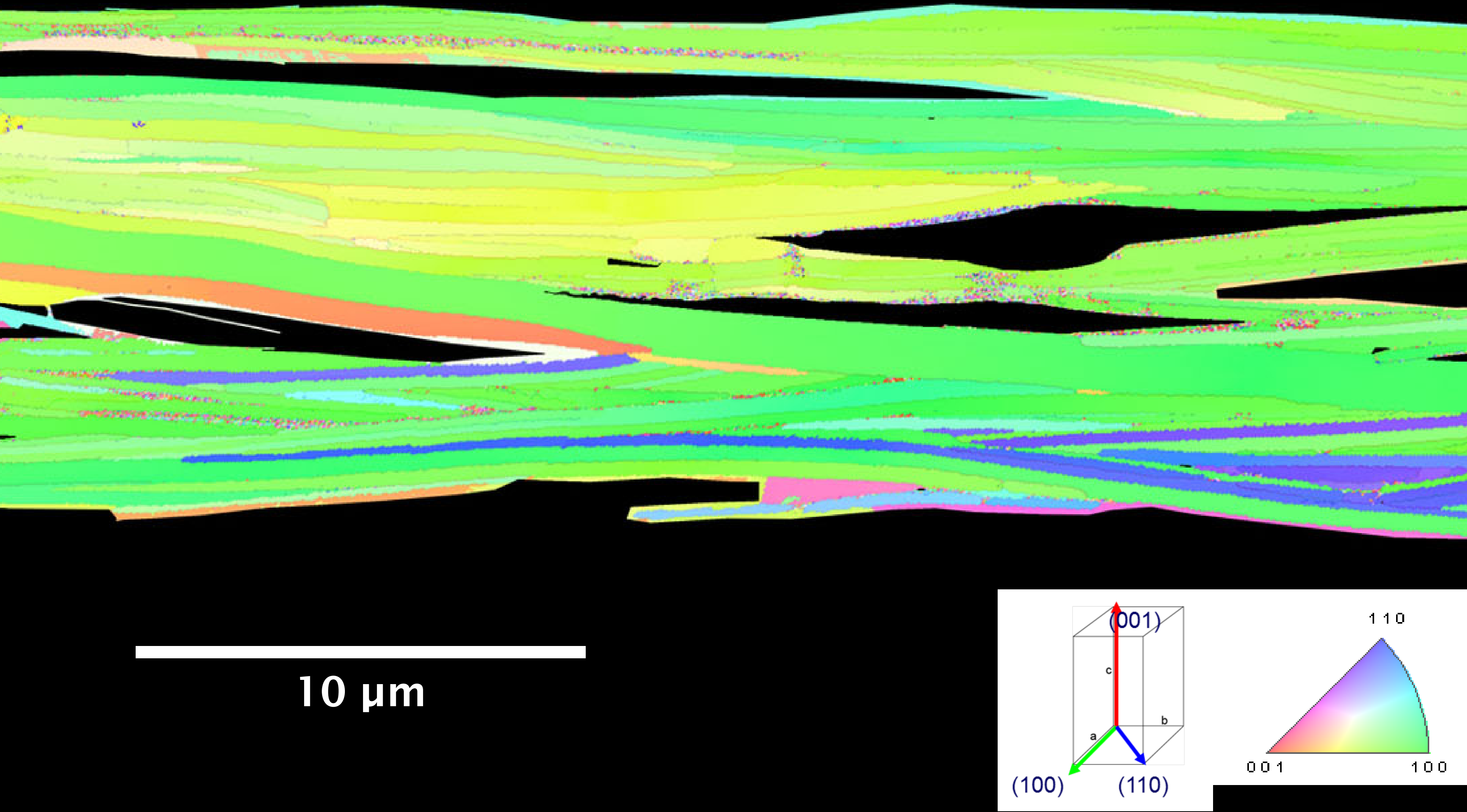
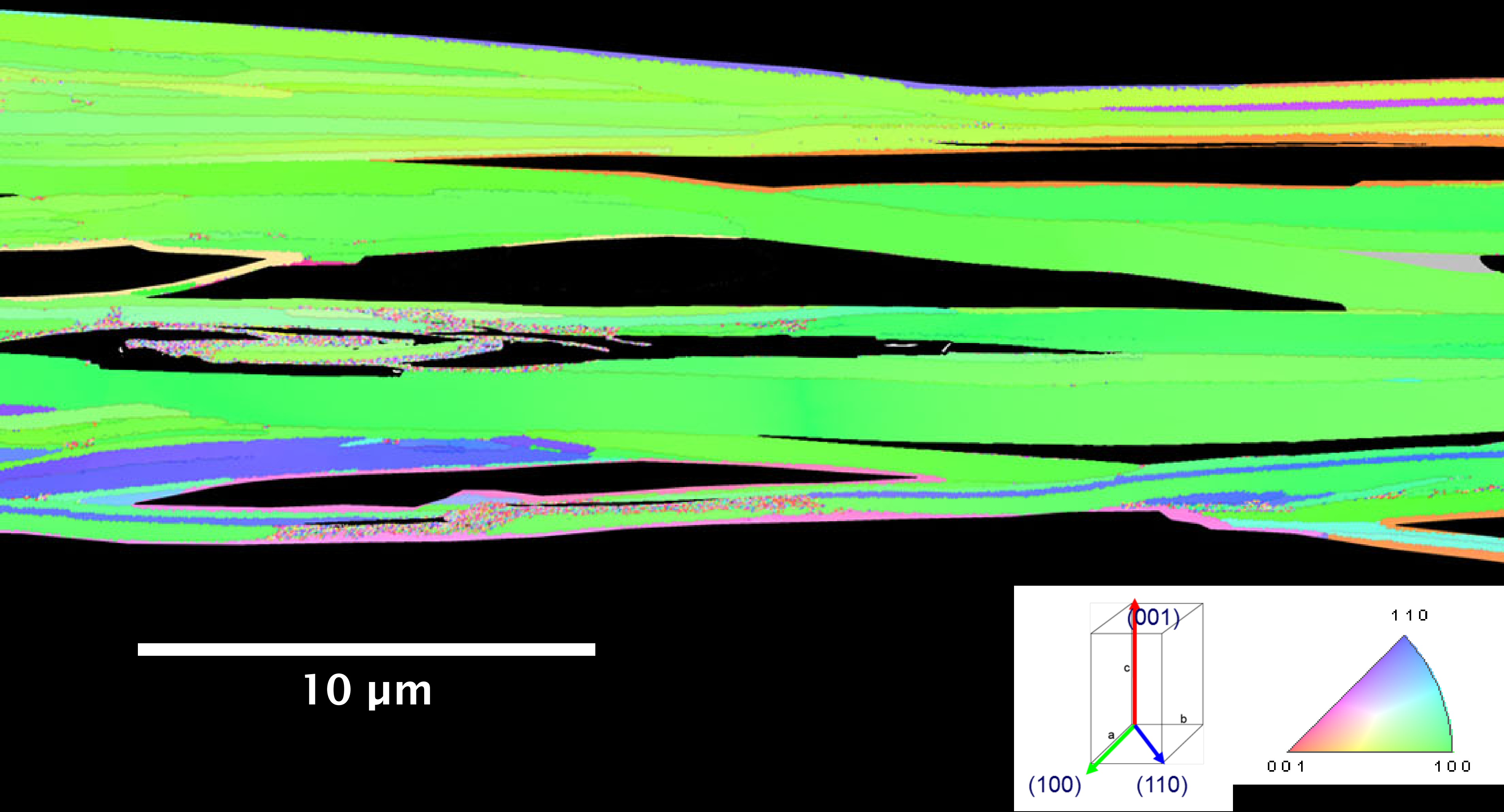
Presentation given at ICEC25 – ICMC2014, Enschede, July 2014

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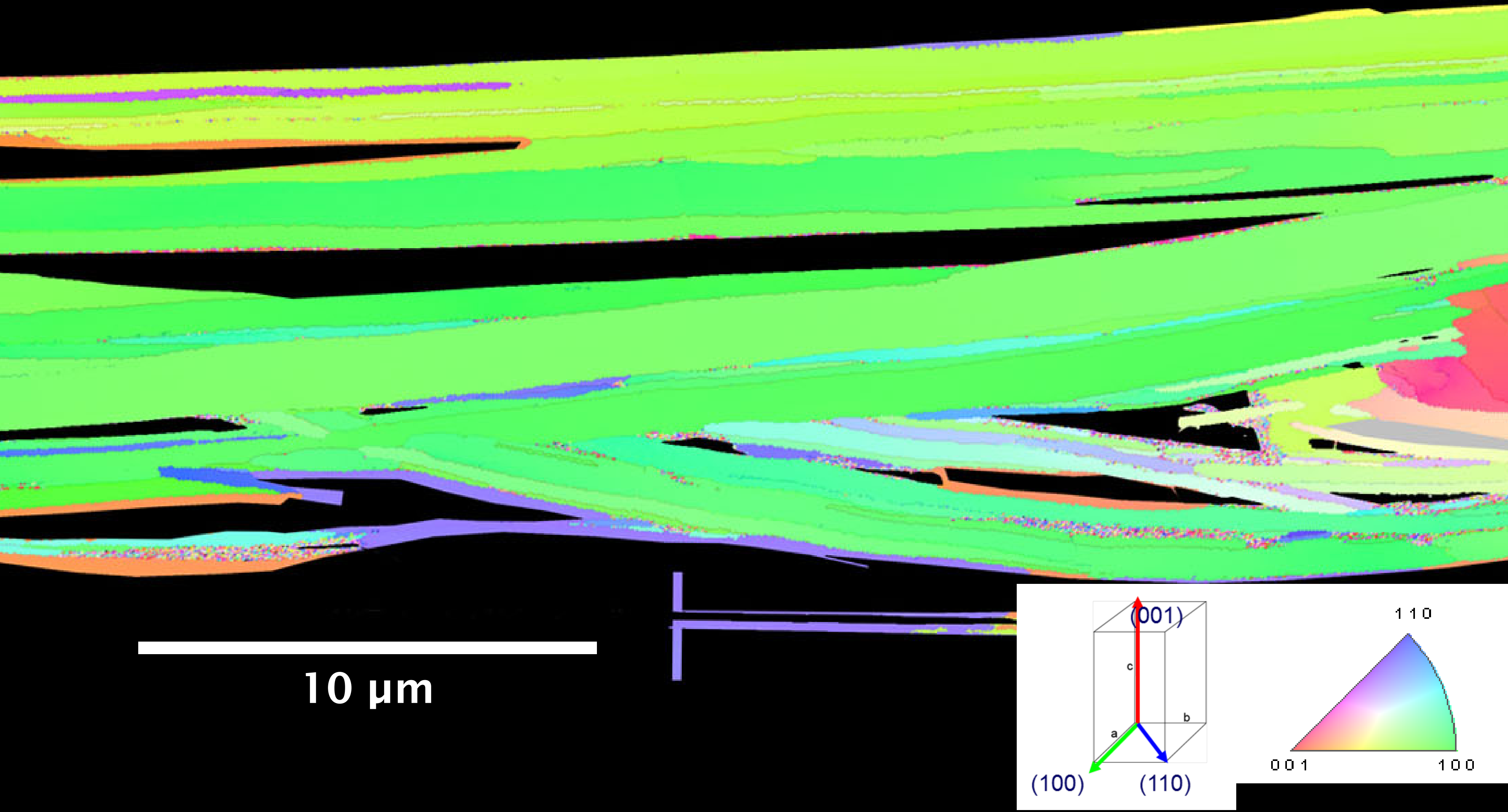
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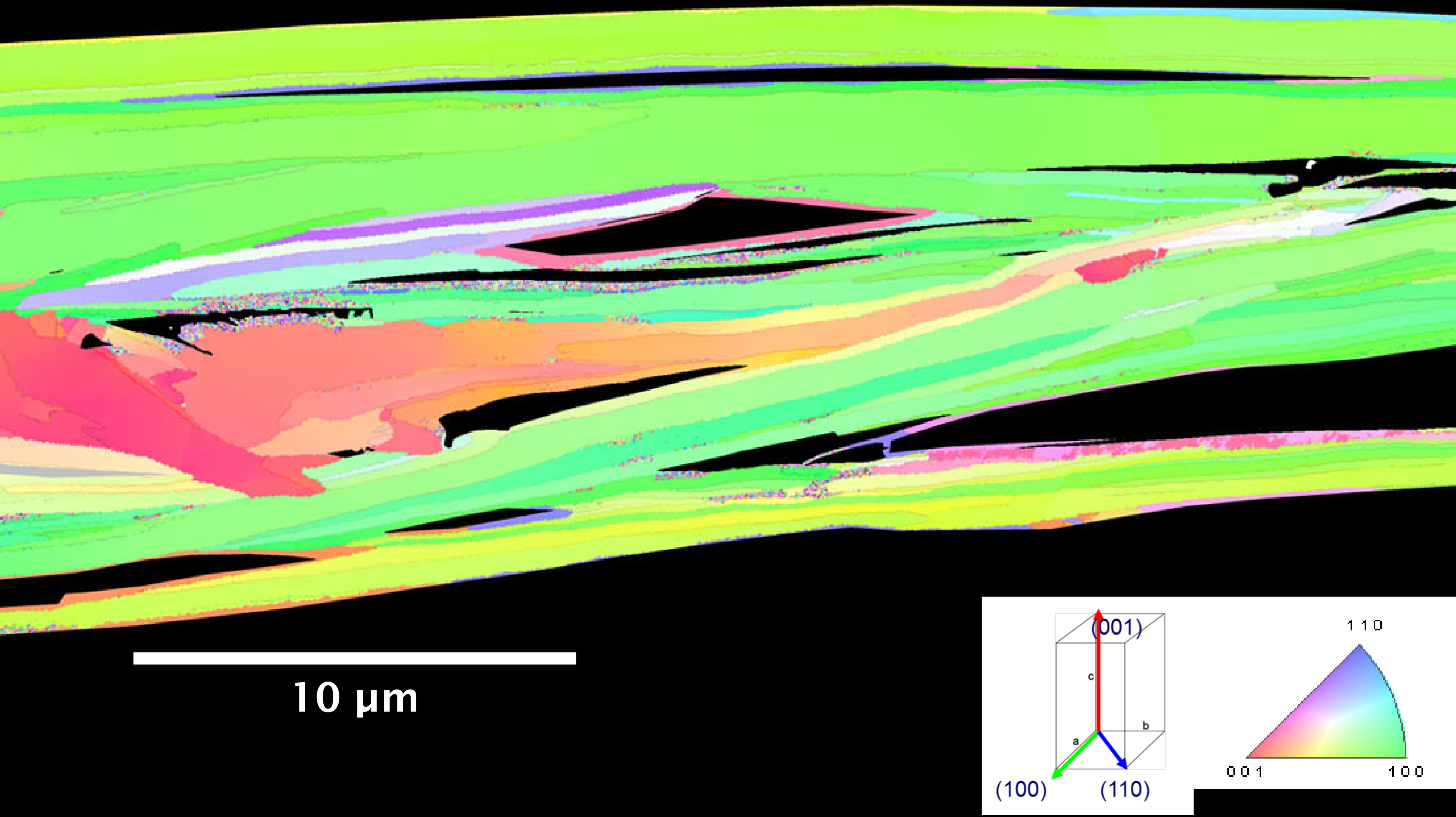

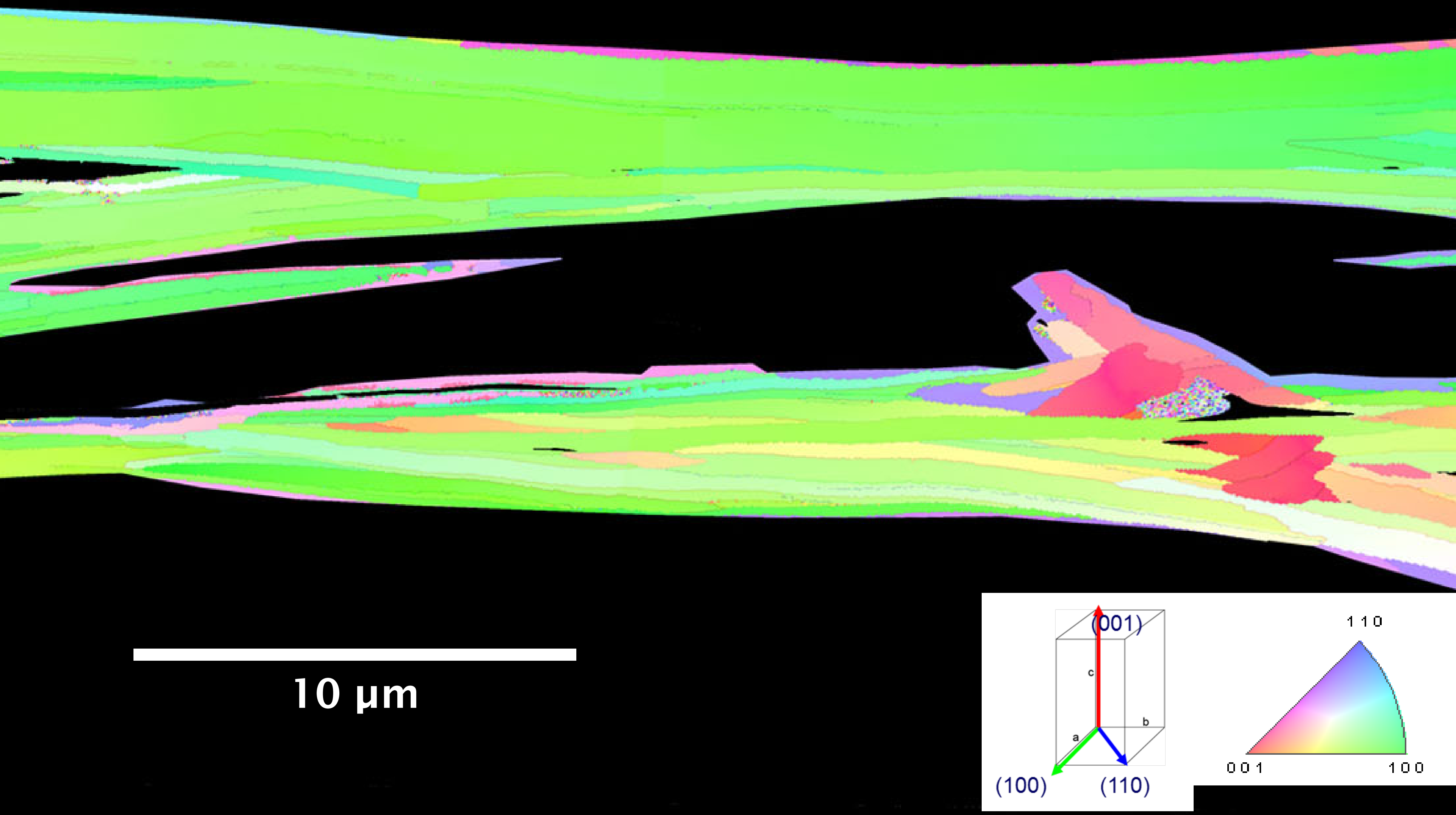
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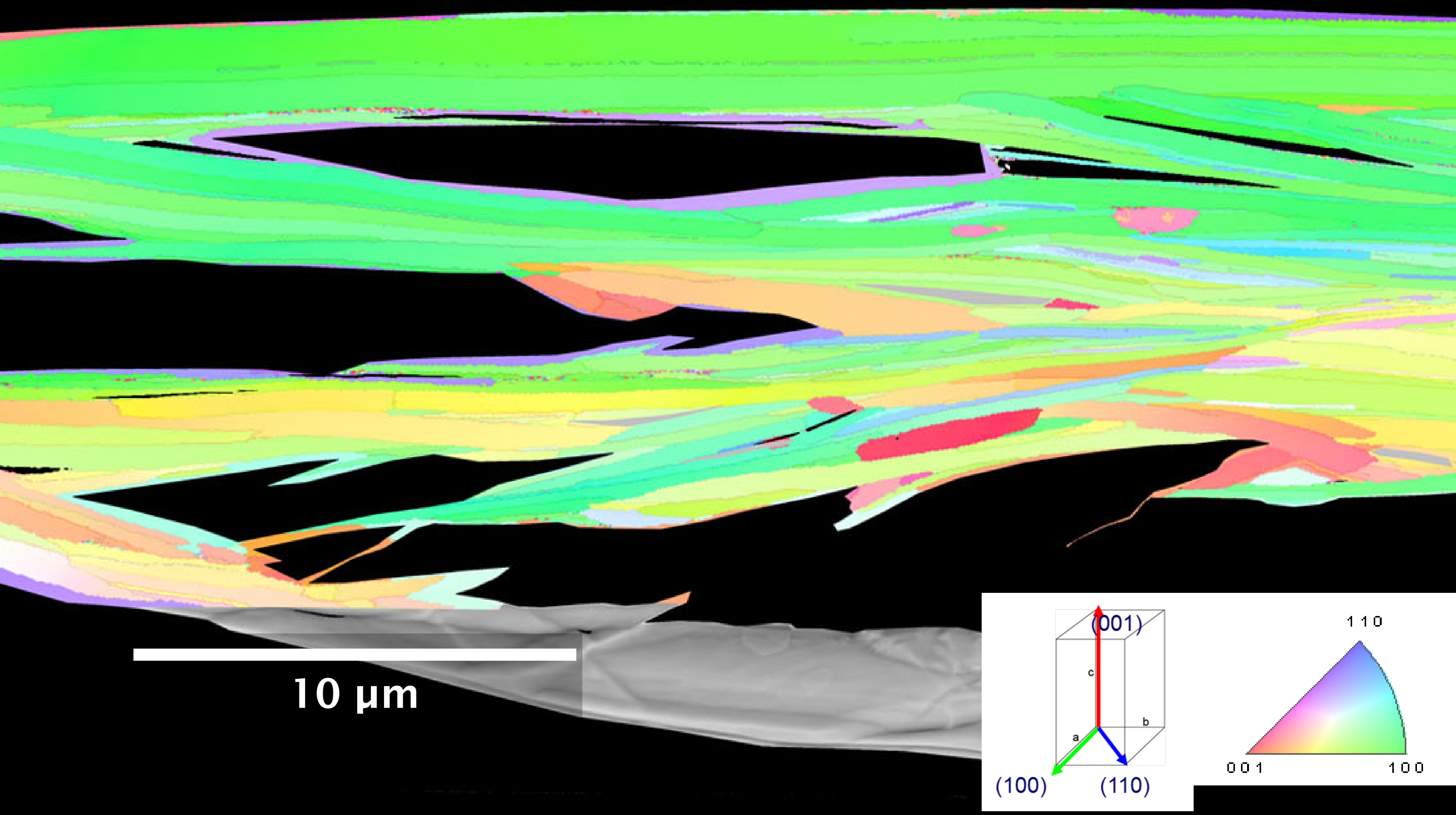
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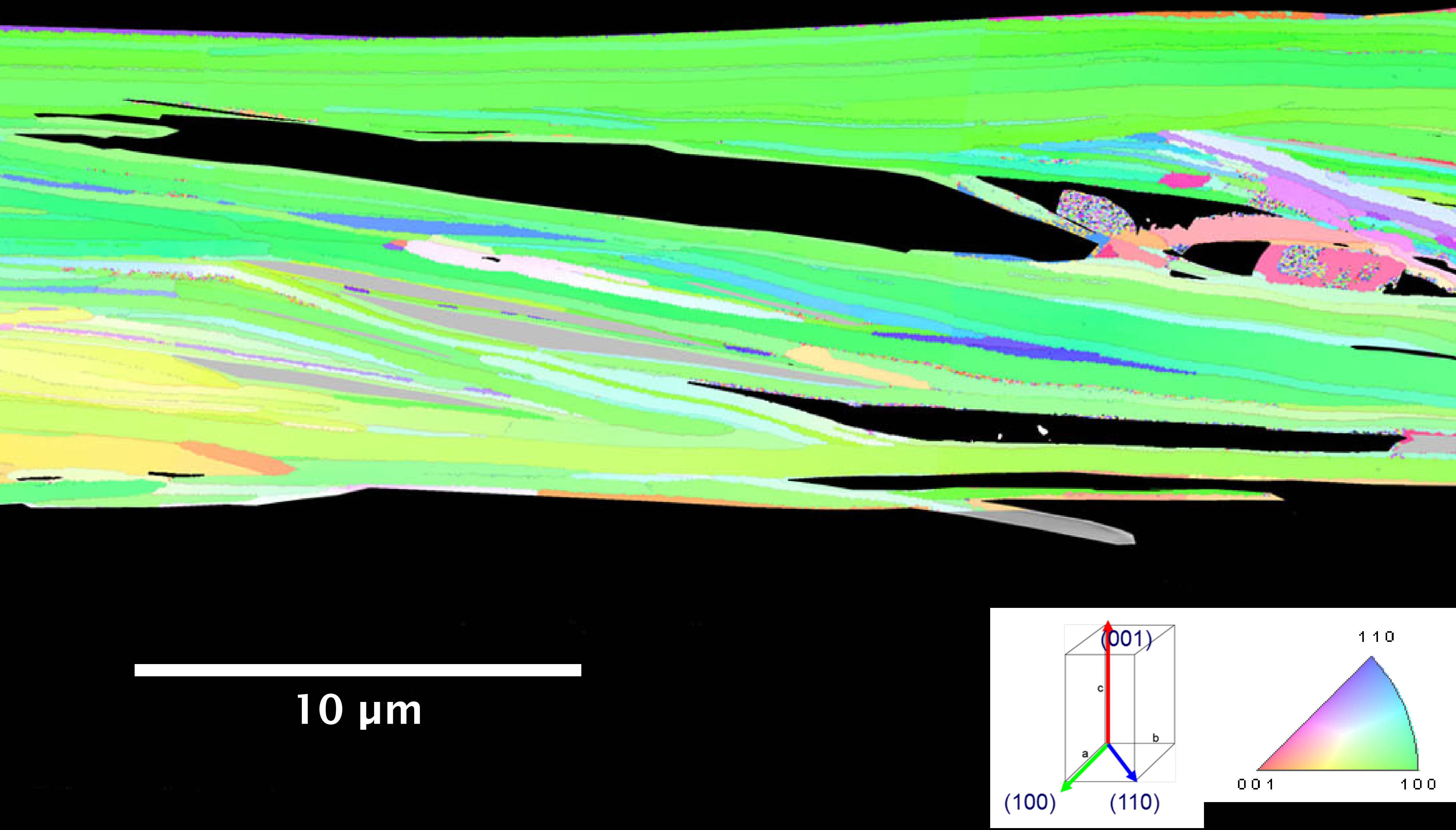
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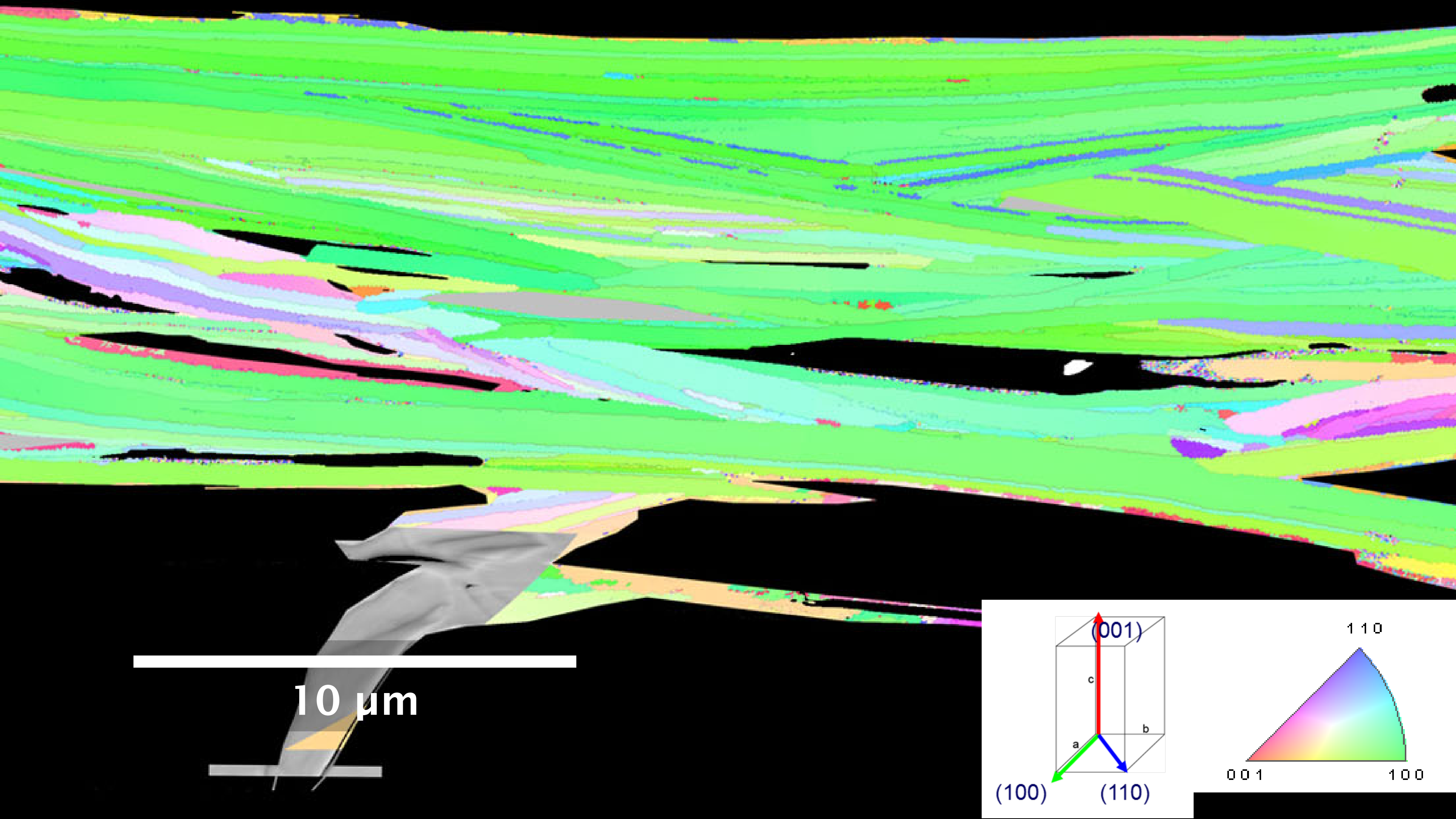
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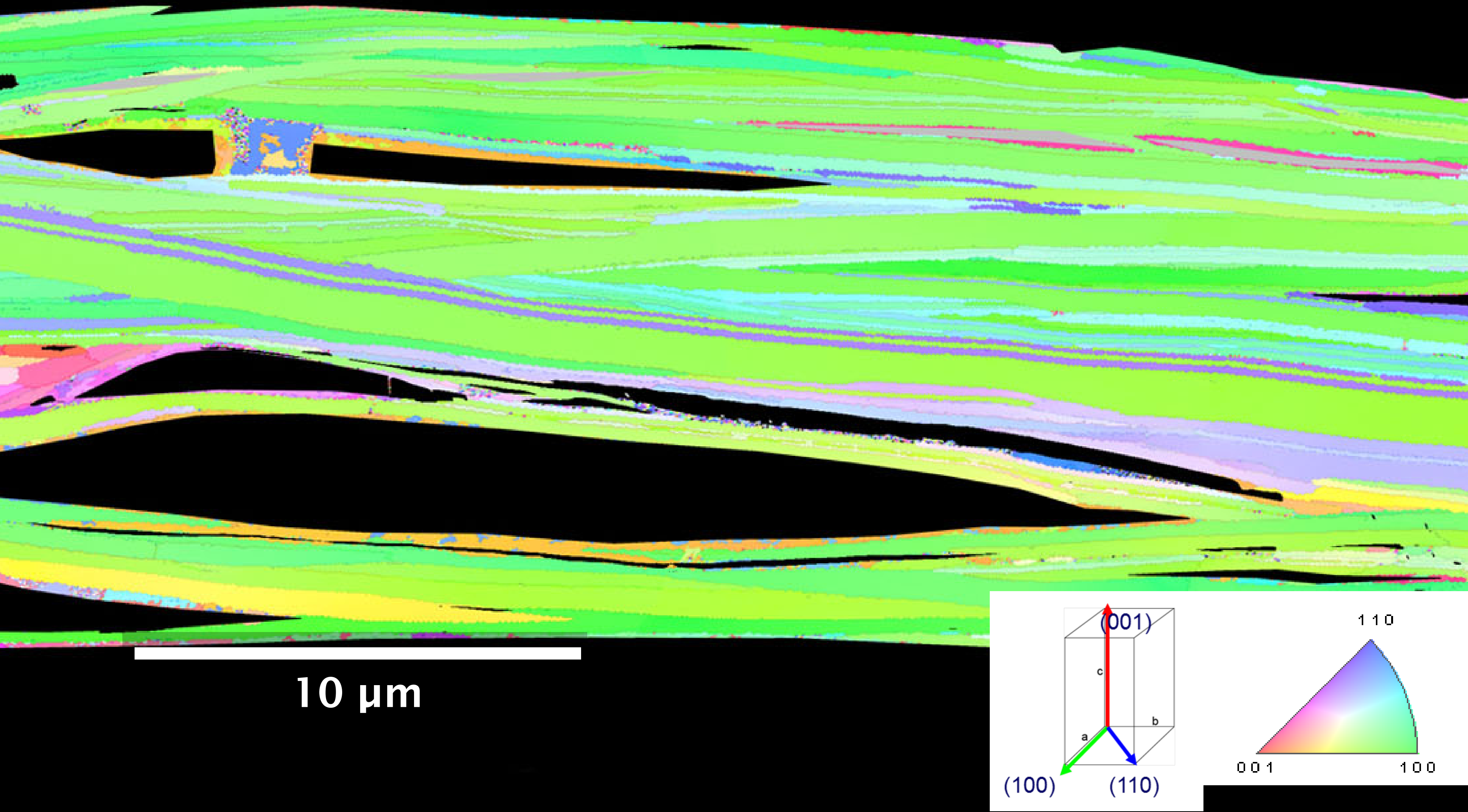
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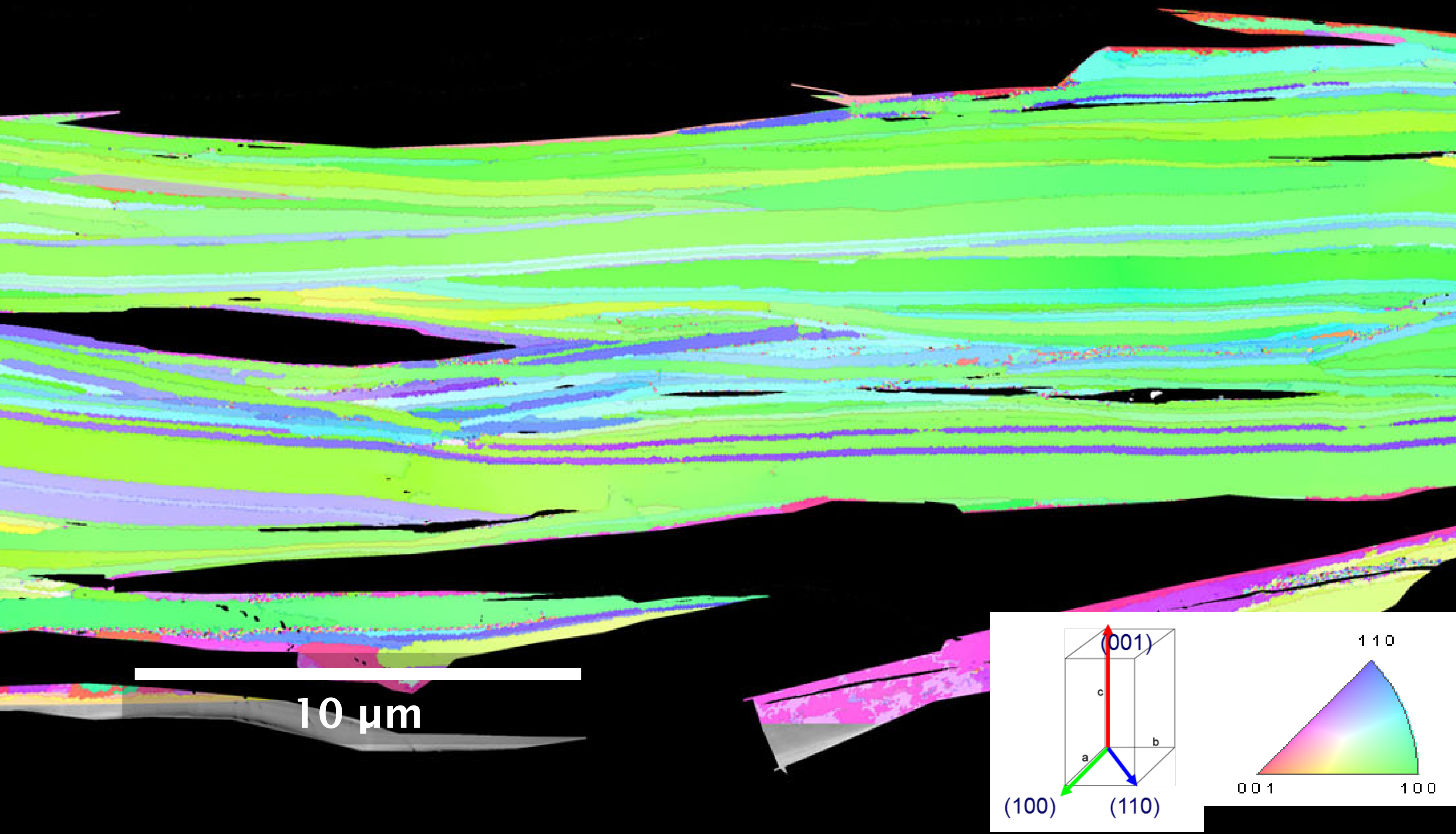
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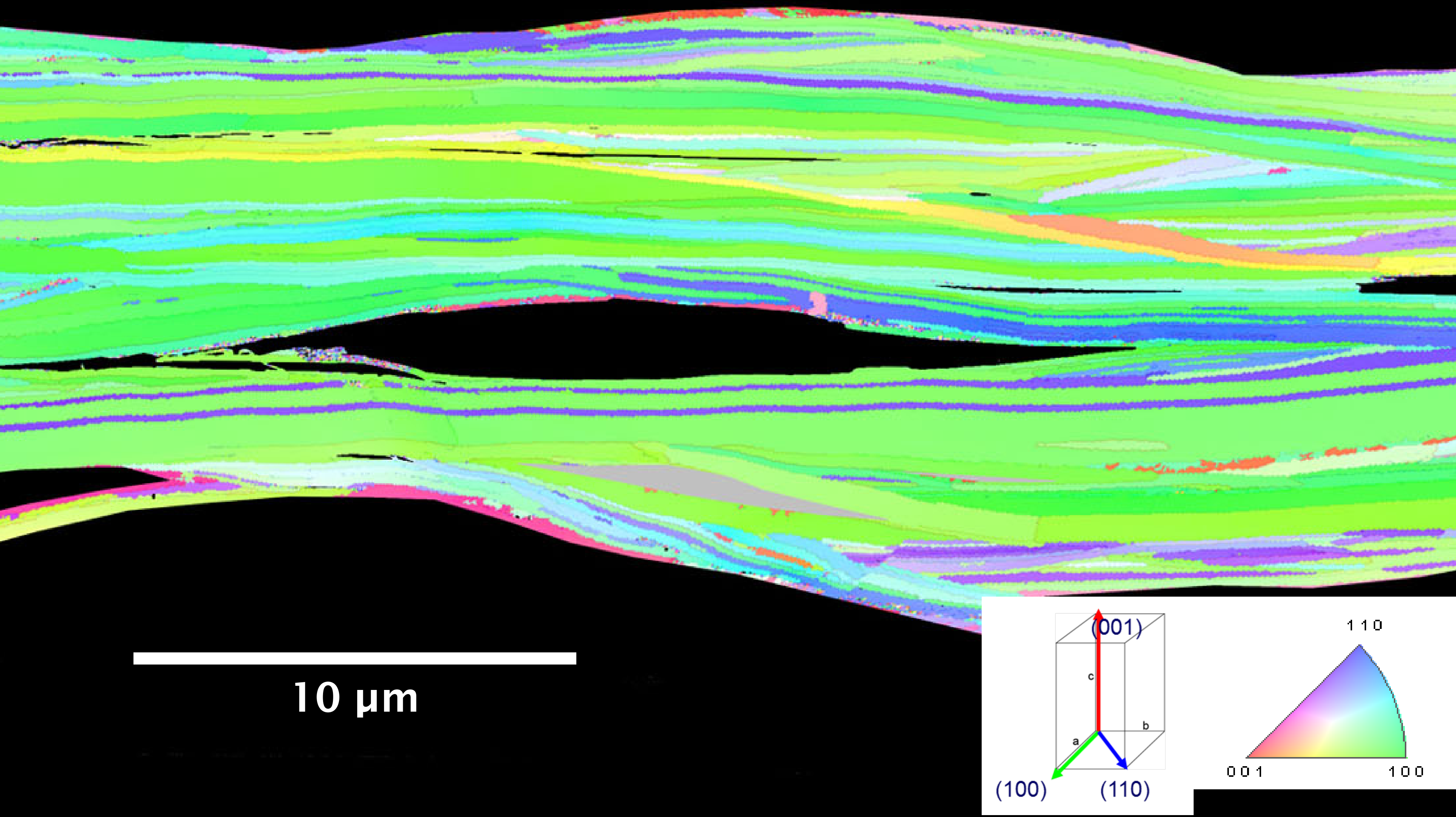
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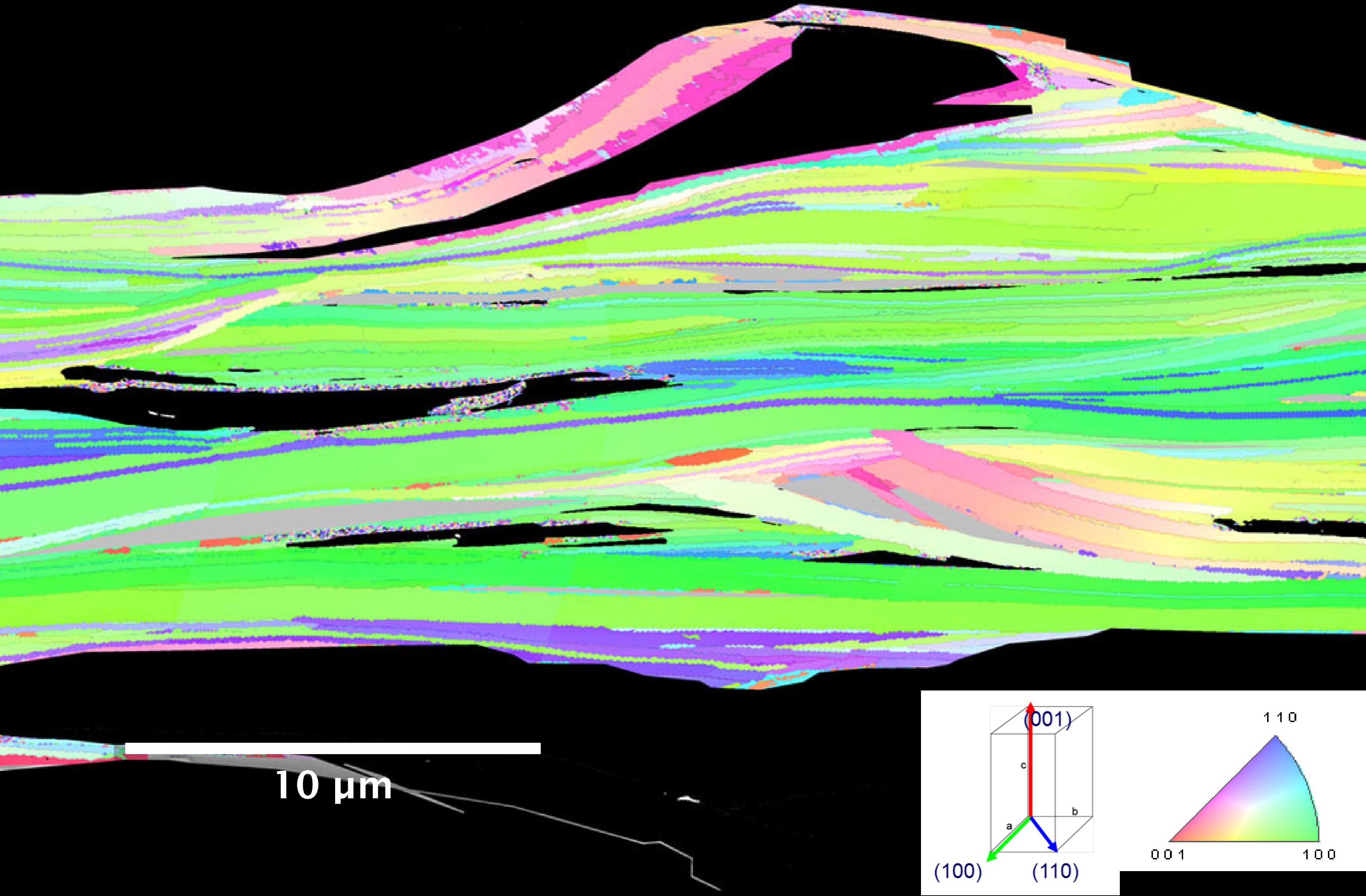
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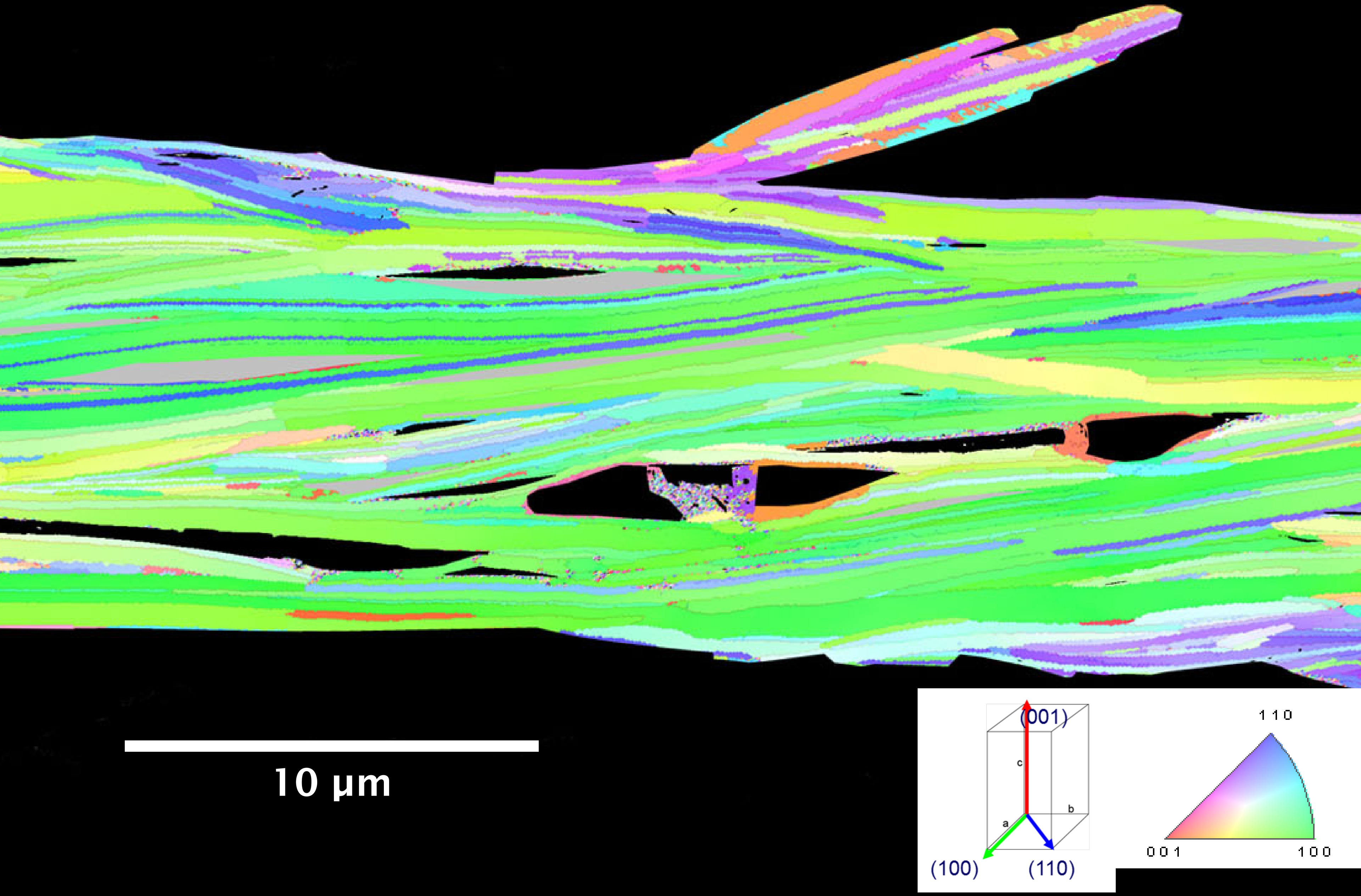
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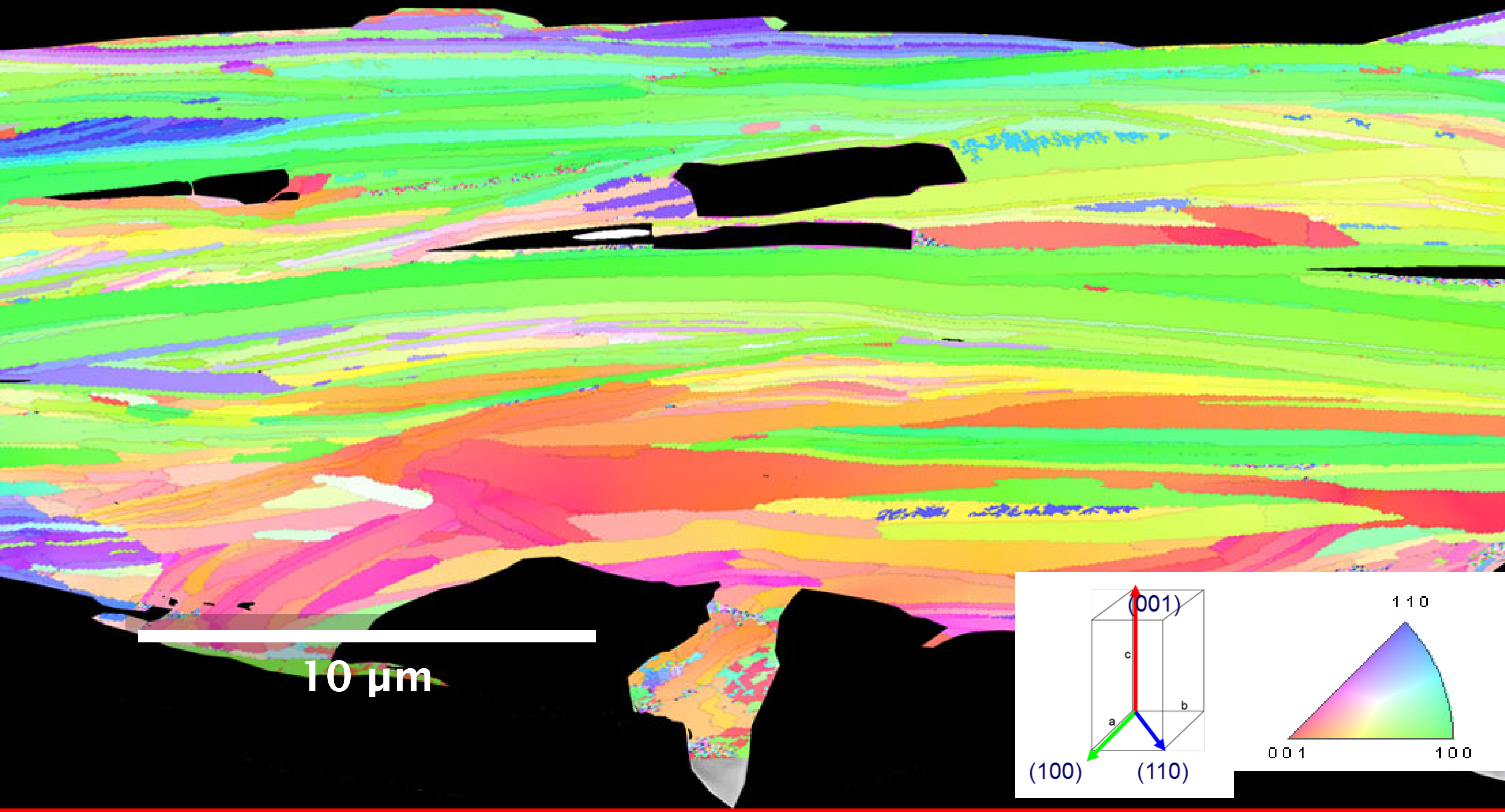
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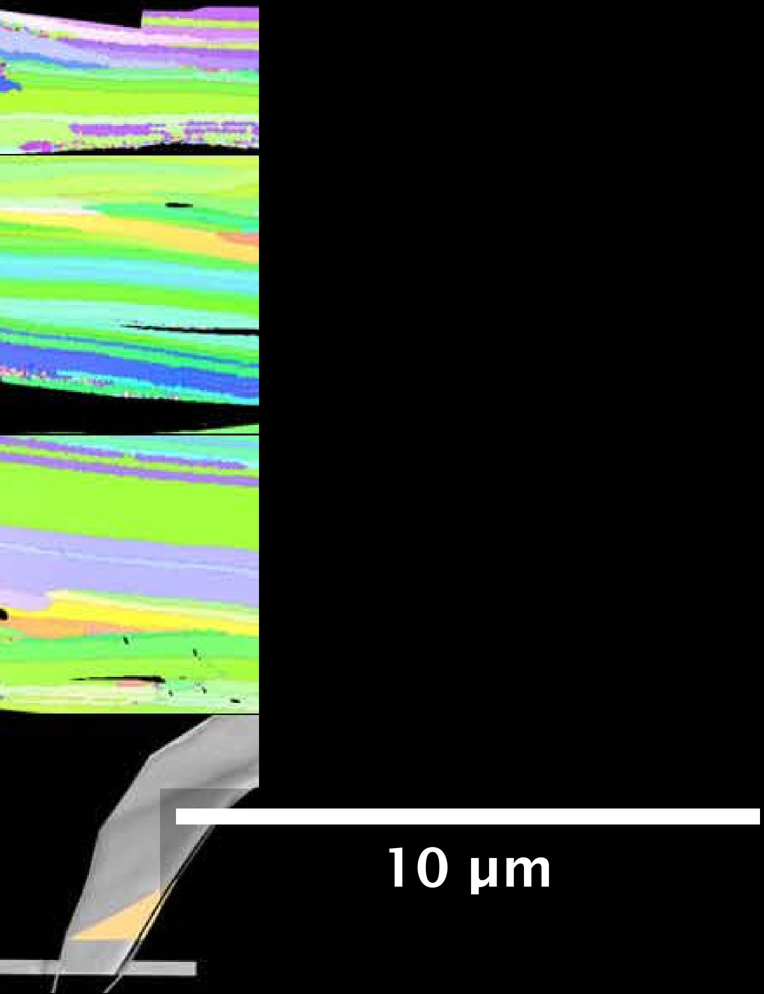
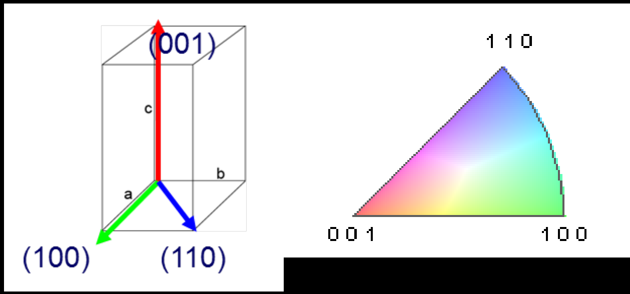

10 μm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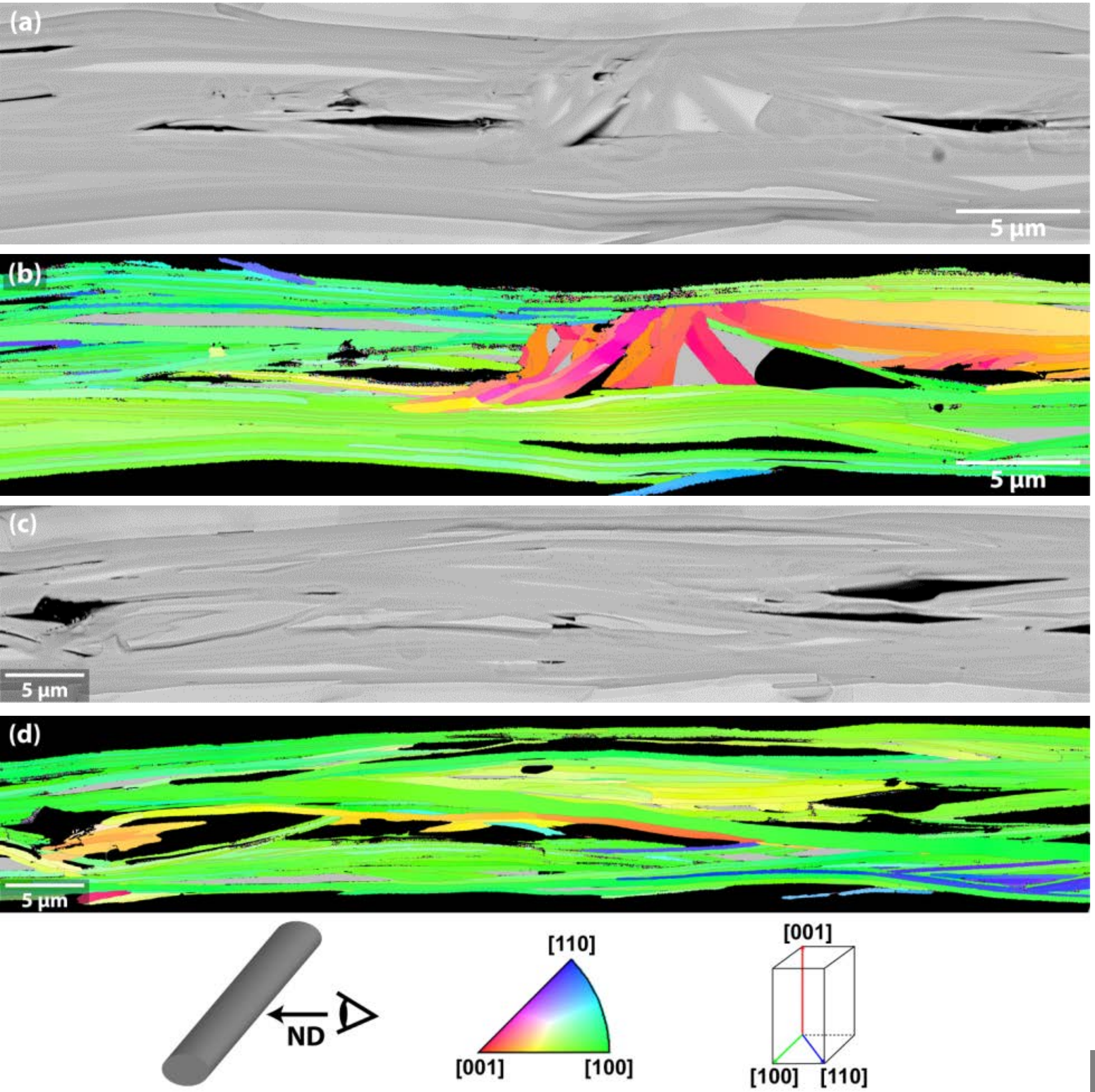
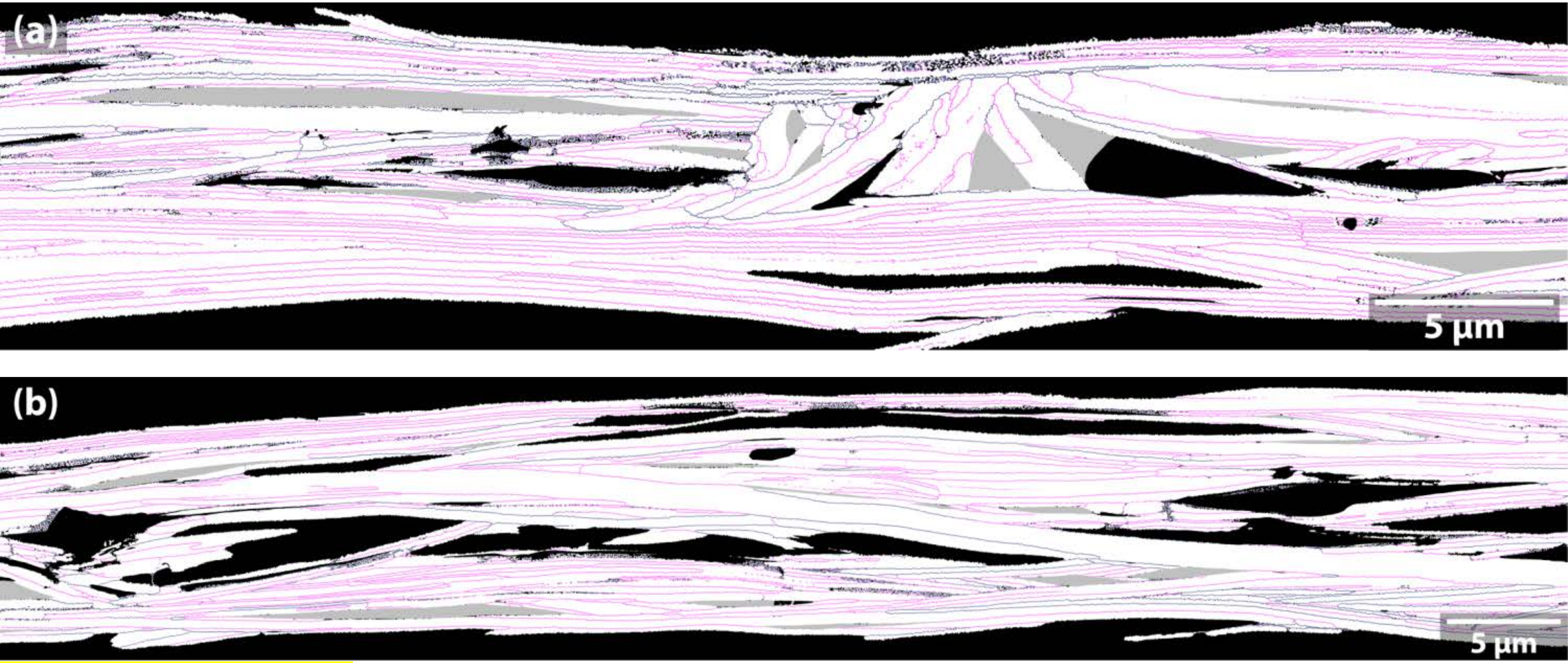
Typical grain structure in a Bi2212 RW



- Grain dimensions (ab vs c-axis) are more anisotropic
- Larger area of GBs//ab-plane due to the more anisotropic grain shape
- There are regions close to [001] (**red**), forming the colony structure

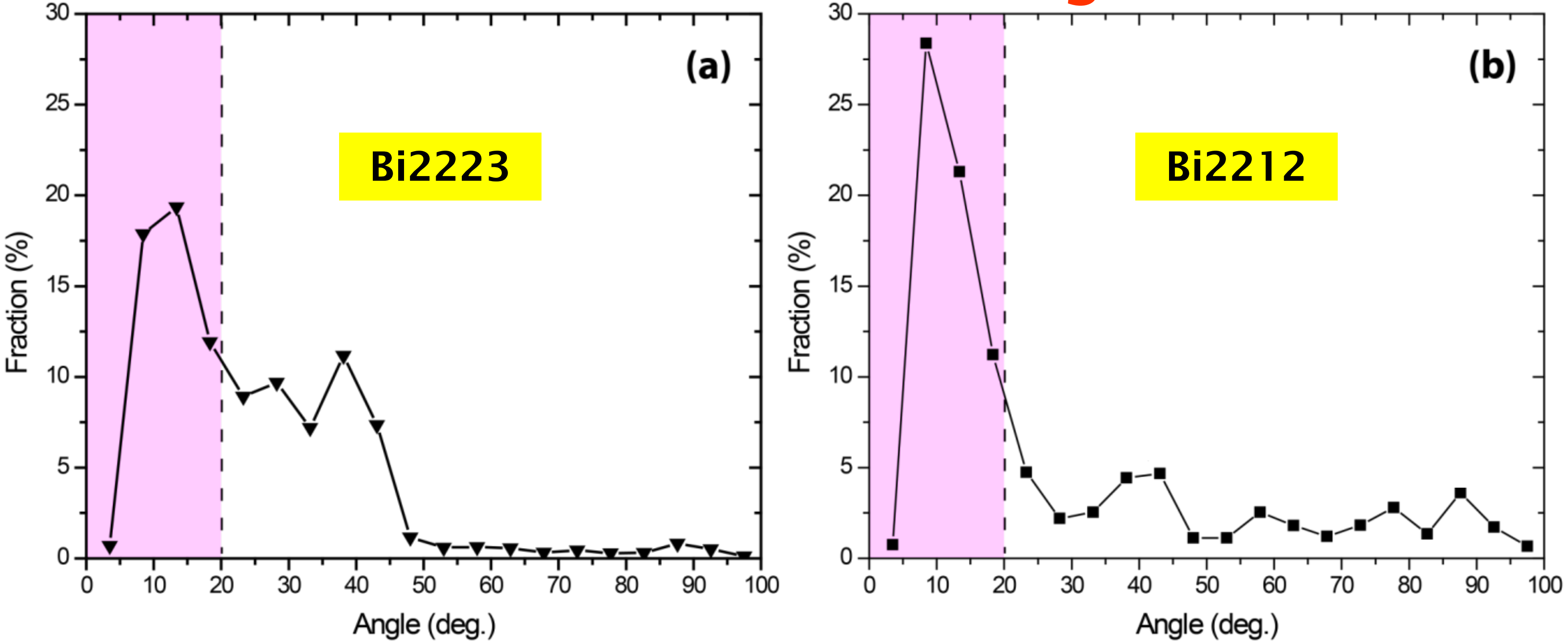
Typical GB structure in Bi2212



Magenta: <20˚
Dark Blue: >20˚

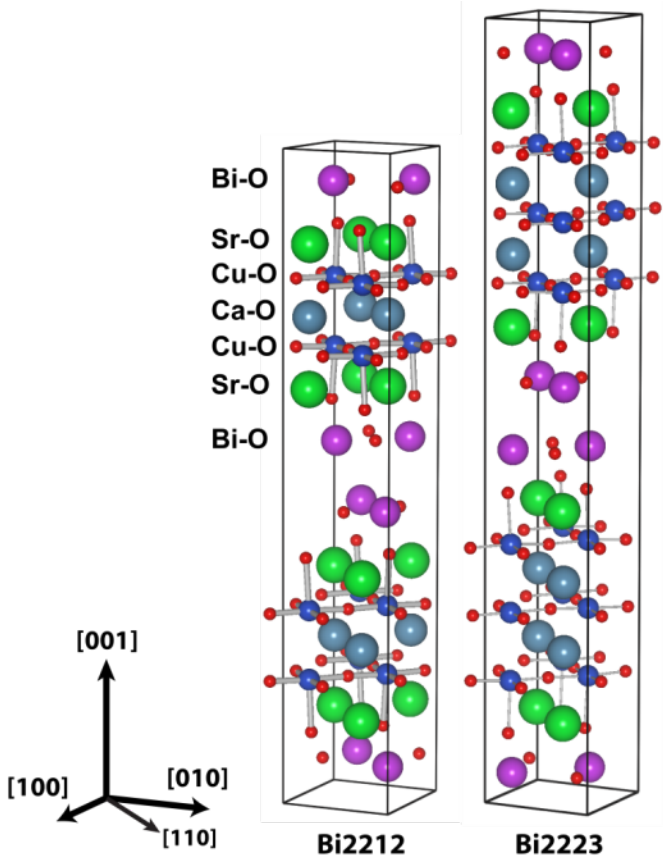
- Most of GBs appeared here have <20˚ misorientation
- There are more current paths that consists of just <20˚ GBs.

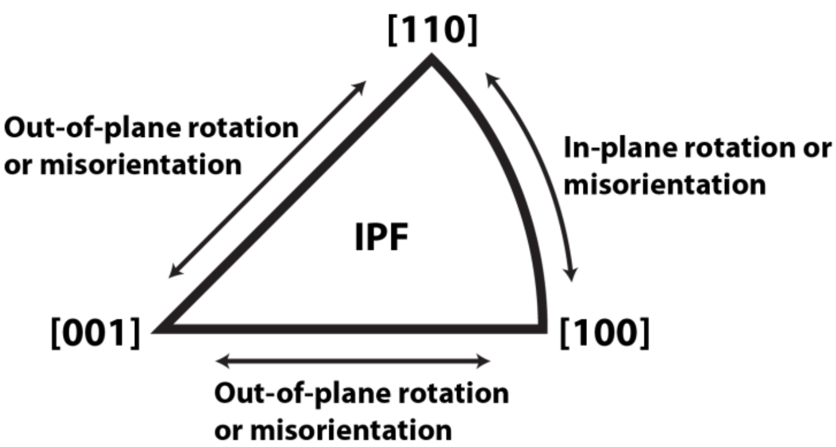
GB fraction as a function of misorientation angle

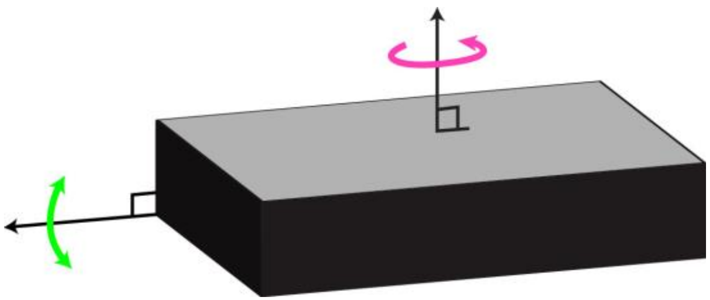


- In the Bi2223 flat filament, the GB misorientation angles are broadly distributed from <5˚ to 45˚
- The distribution of Bi2212 misorientation angles shows a sharp peak around 10-15˚

Anisotropic BSCCO crystal defines in-plane and out-of-plane misorientation

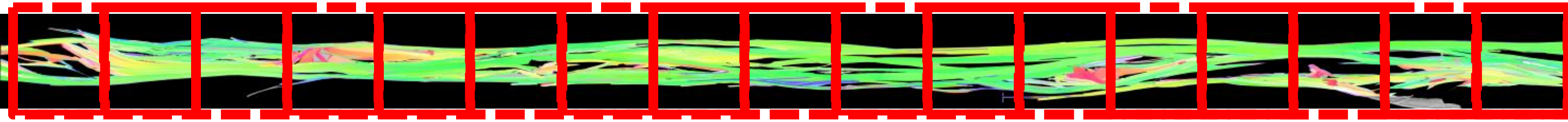




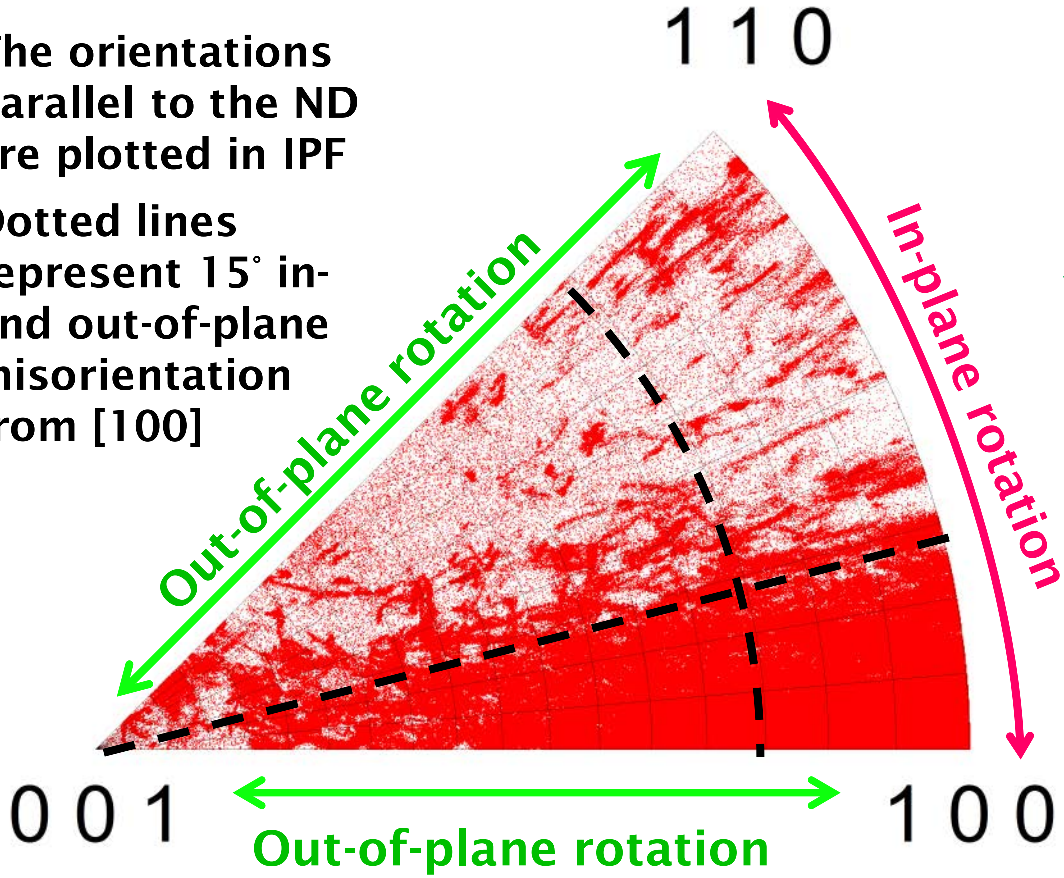


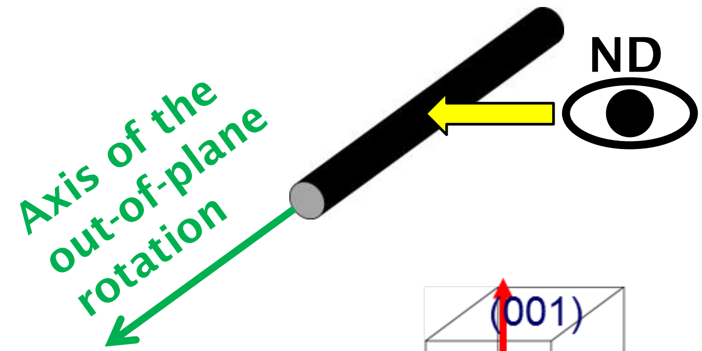
- In-plane rotation: rotation axis // c-axis
- Out-of-plane: rotation axis // ab-plane

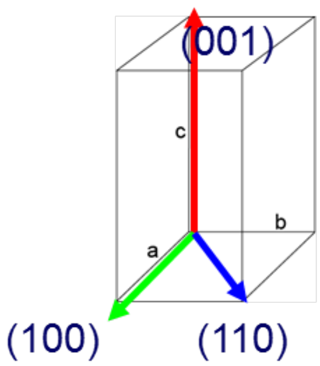
Bi2212 grain orientations in the filament



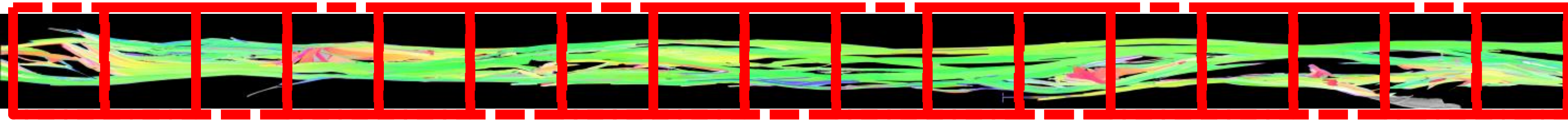
- The orientations parallel to the ND are plotted in IPF
- Dotted lines represent 15˚ in- and out-of-plane misorientation from [100]



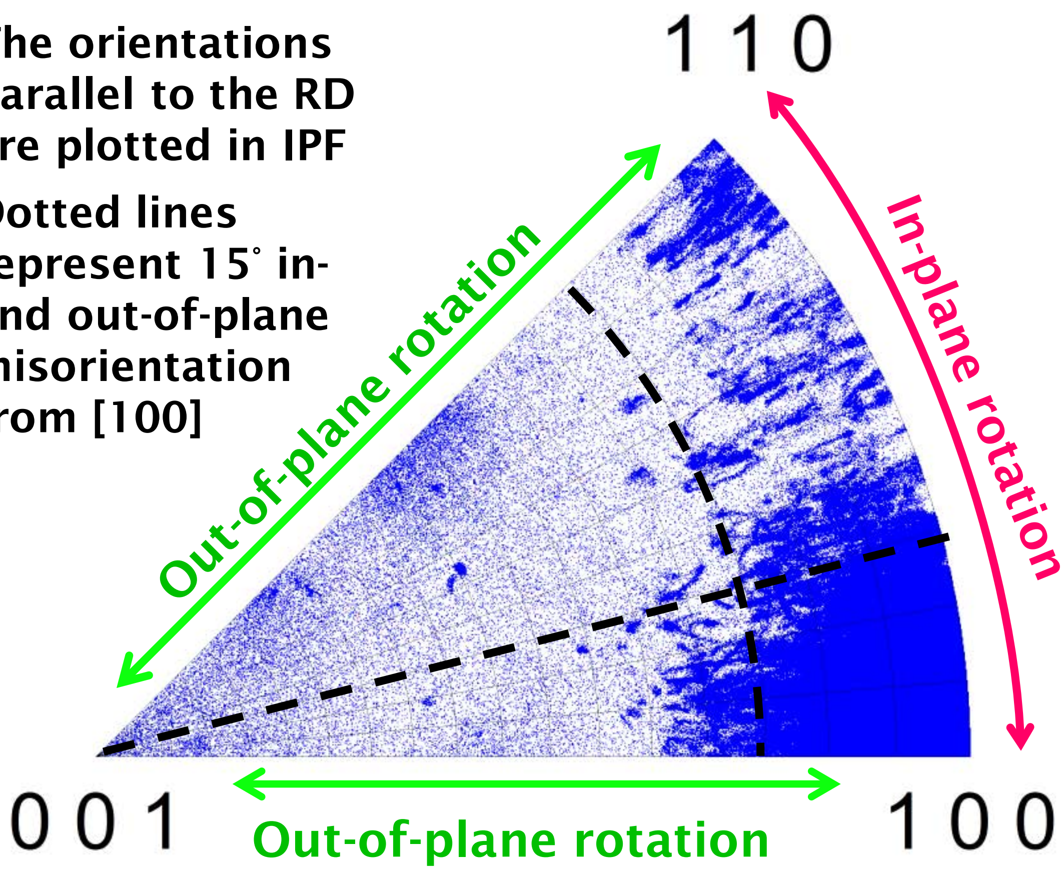


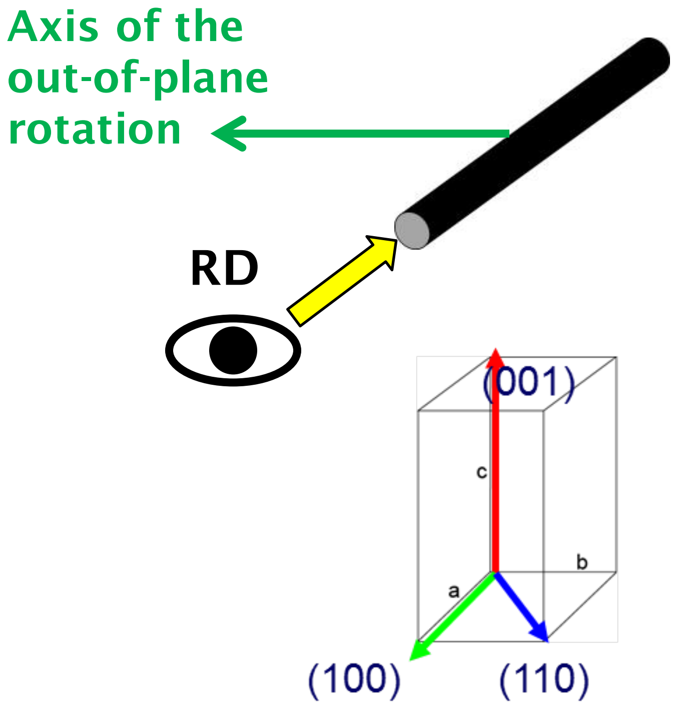


Bi2212 grain orientations in the filament



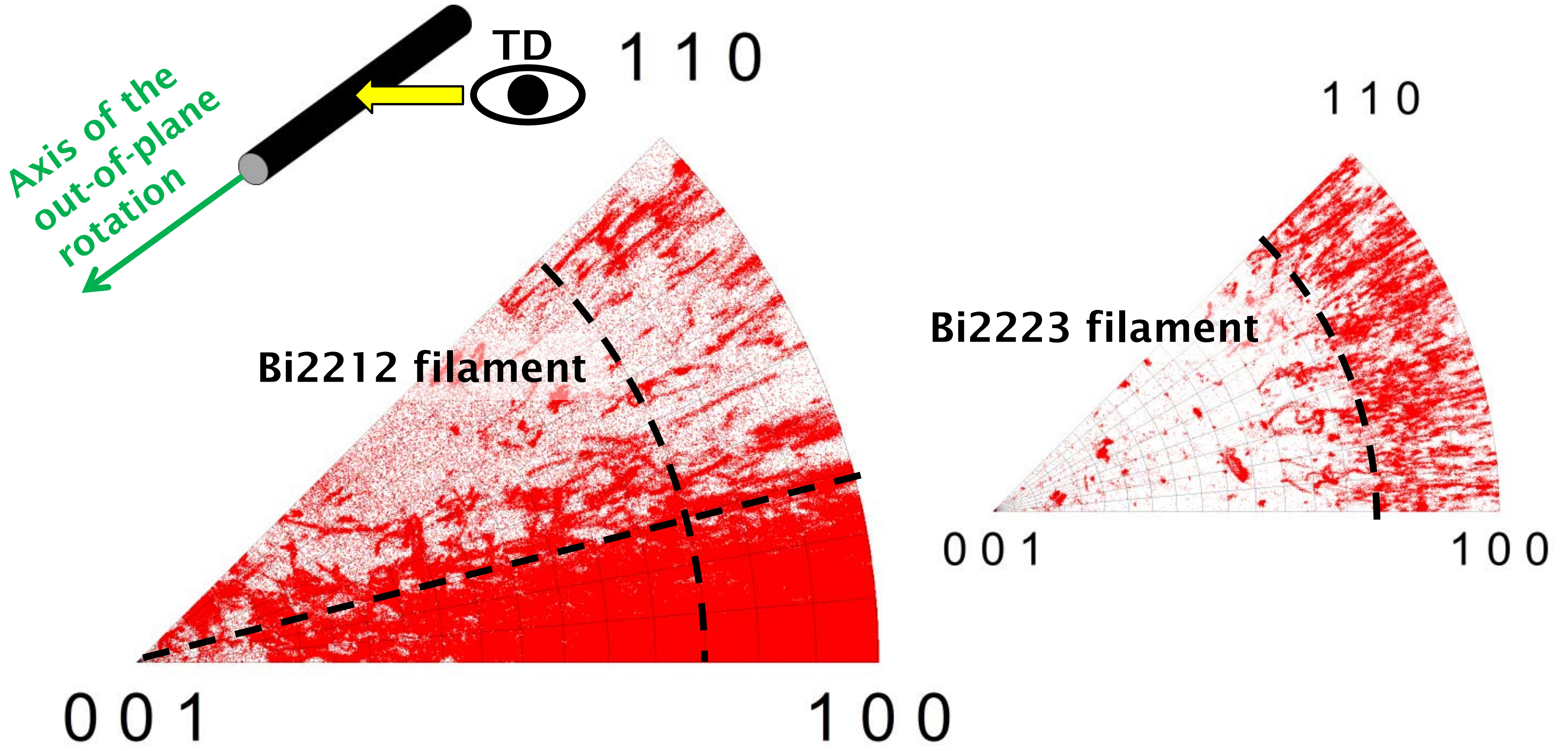
- The orientations parallel to the RD are plotted in IPF
- Dotted lines represent 15° in- and out-of-plane misorientation from [100]



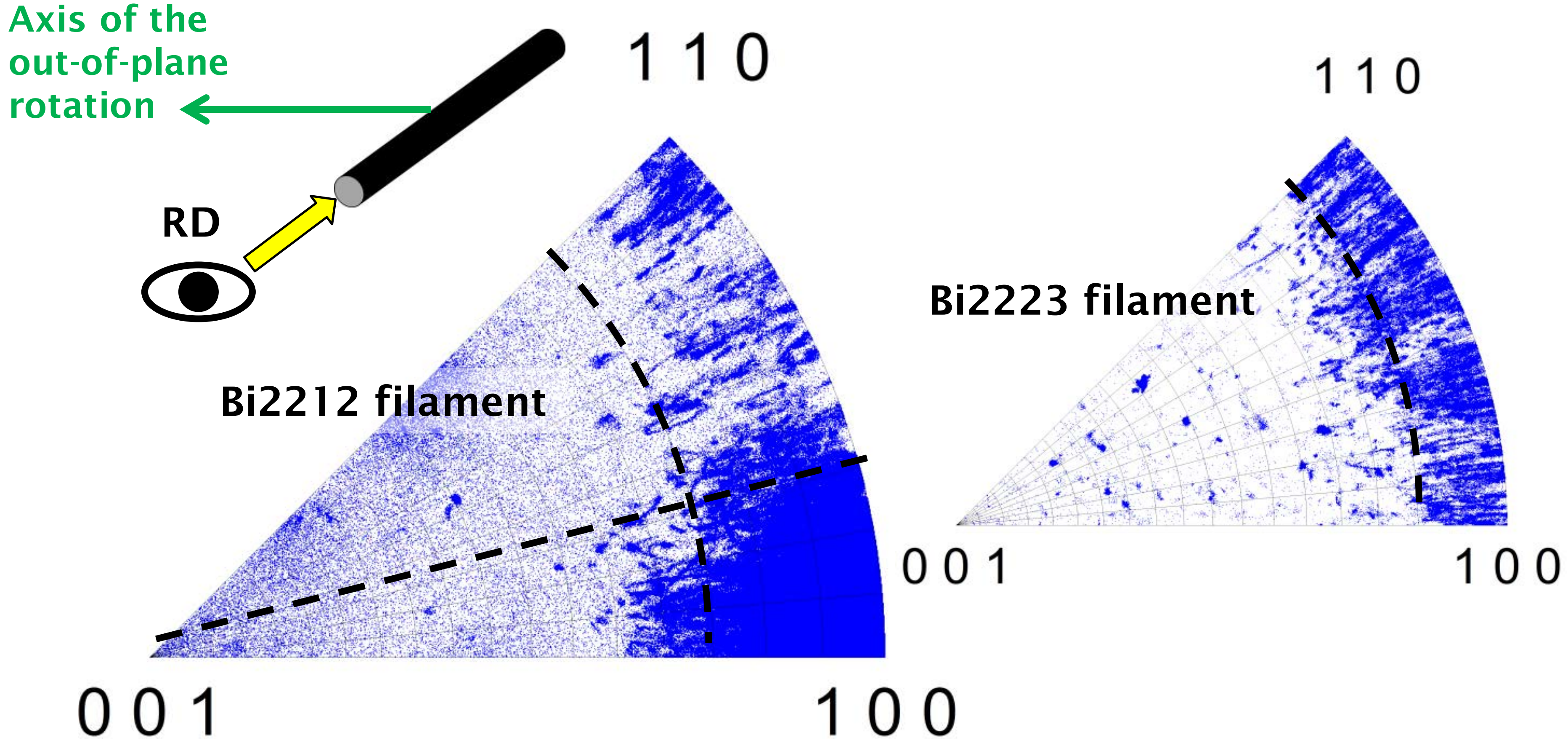


- Along the filament direction, both in- and out-of-plane misorientation is ~15° or less

The Bi2212 filament has greater out-of-plane misorientation along the radial direction



The Bi2212 has fewer in-plane misorientation



- The in-plane misorientation in Bi2212 is almost ~±15° or less
- Meanwhile, almost random in-plane orientation in Bi2223

Conclusion

- Two BSCCO sibling materials require two different architectures for high J_c wires
  - Bi2223 needs high uniaxial texture
  - Bi2212 does not need macroscopic texture
- The Bi2212 RWs show no Jc(H) hysteresis
  - Strong indication that the Bi2212 grains are strongly coupled
  - There must be HAGBs, but they don't dominate transport J_c
- Bi2212 has the unique grain structure
  - There is a huge amount of local texture, although prior deformation (wire drawing) can play no role in the grain growth
  - The out-of-plane misorientation along the filament direction is ~15°
  - Surprisingly in-plane misorientation is ~15° too