

Conversion of substrate dislocations to stacking faults and investigation of Frank stacking fault subtypes

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Motivation

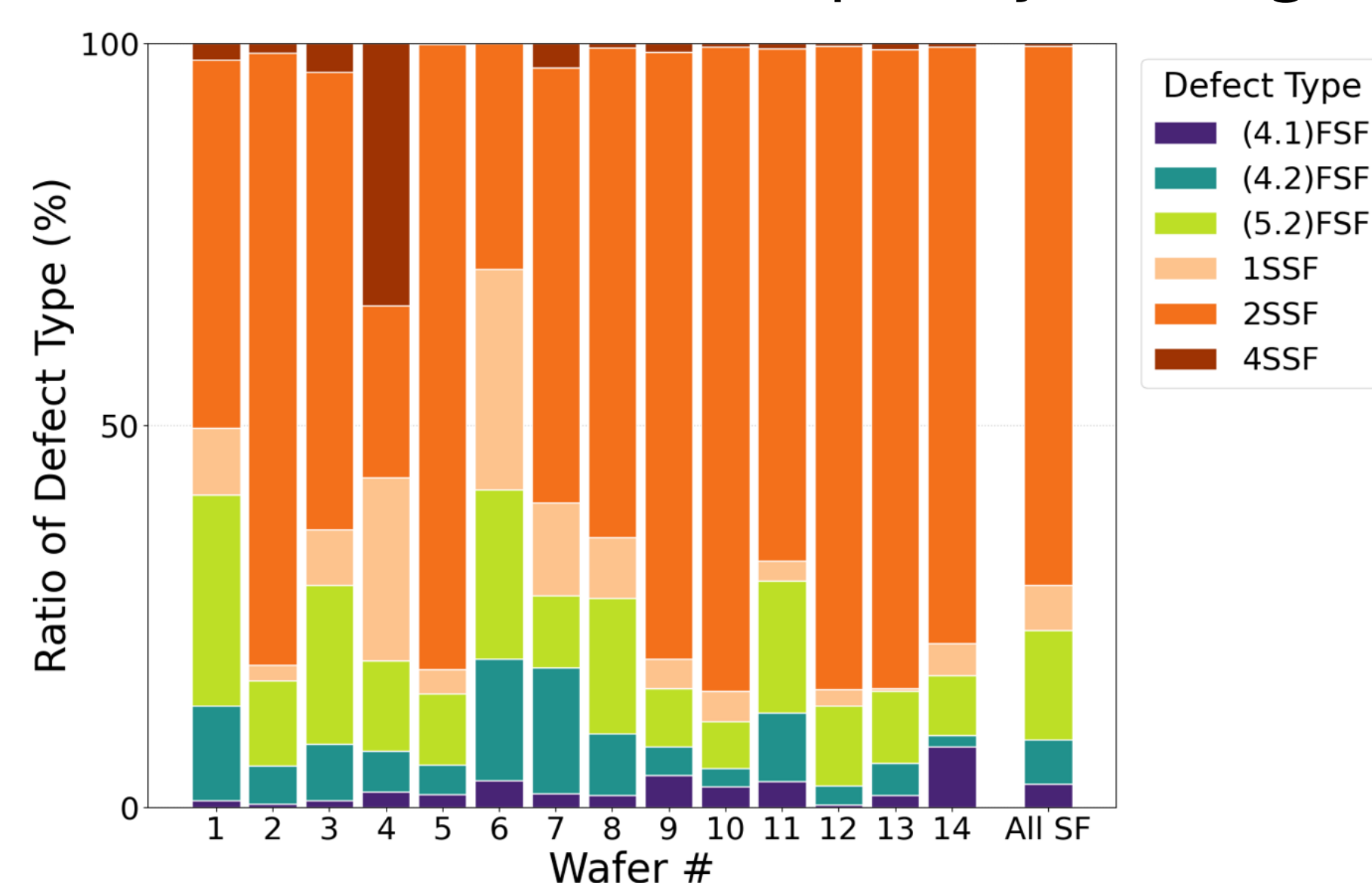
- Stacking faults (SFs) are typical defects in SiC substrates and epilayers
- Former studies show a kill rate for devices of around 60% for SFs, despite being classified as killer defects, indicating a lack of subclassification [1]
- The MiPLATO-SiC tool from Horiba can identify SF subtype via spectral analysis of photoluminescence (PL) [2]
 - This enables additional differentiation and investigation of the properties of the SF subtypes

Experiments

- 14 4H-SiC wafers (200 mm) with n-type epitaxial layer with a thickness of 14 μm and doping $1 \cdot 10^{16} \text{ cm}^{-3}$
- Photoluminescence and surface differential interference contrast (DIC) scans using the Lasertec SICA 88 and the Horiba MiPLATO-SiC
- Spectral PL scans and identification of SF subtypes using the MiPLATO-SiC
- X-ray topography (XRT) with Rigaku XRT micron for substrate dislocation mapping

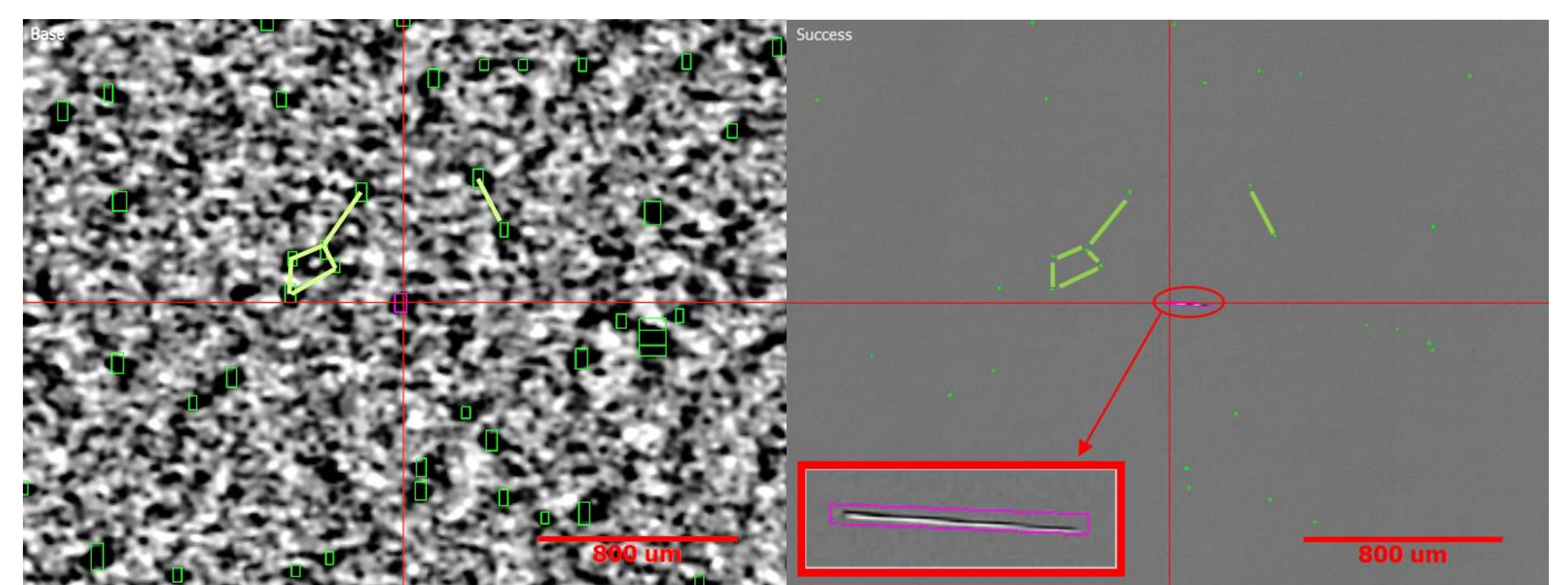
SF subtypes distribution

- Fractions of different SF subtypes determined with spectral PL in 14 epiwafers with 9862 SF in total
- Shockley-type SFs (SSFs) significantly outnumber Frank-type SFs (FSFs), with 2SSF being the most frequently observed subtype
- Around a quarter of all SFs are FSFs; their frequency ranking: $5.2 > 4.2 > 4.1 \text{ FSF}$



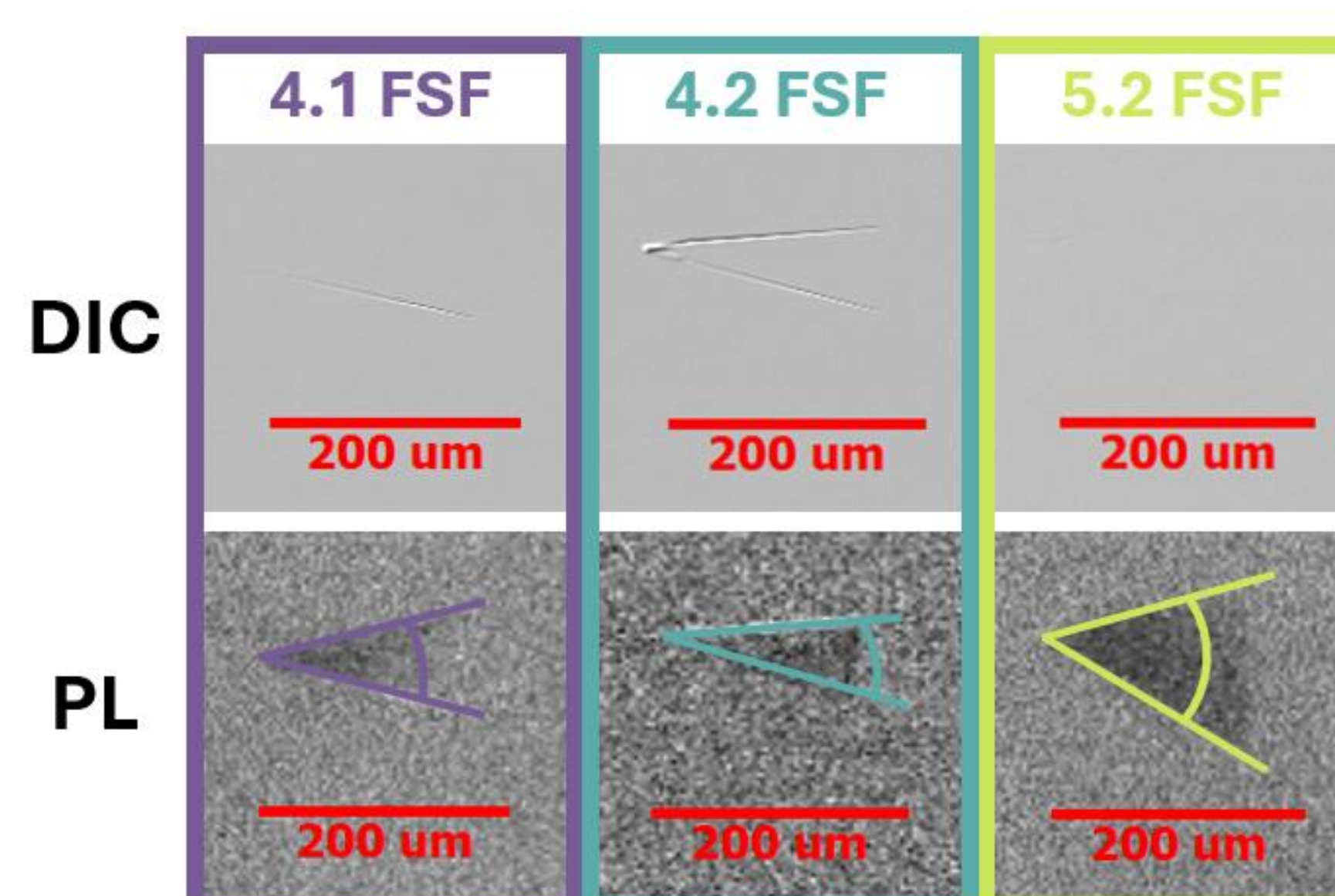
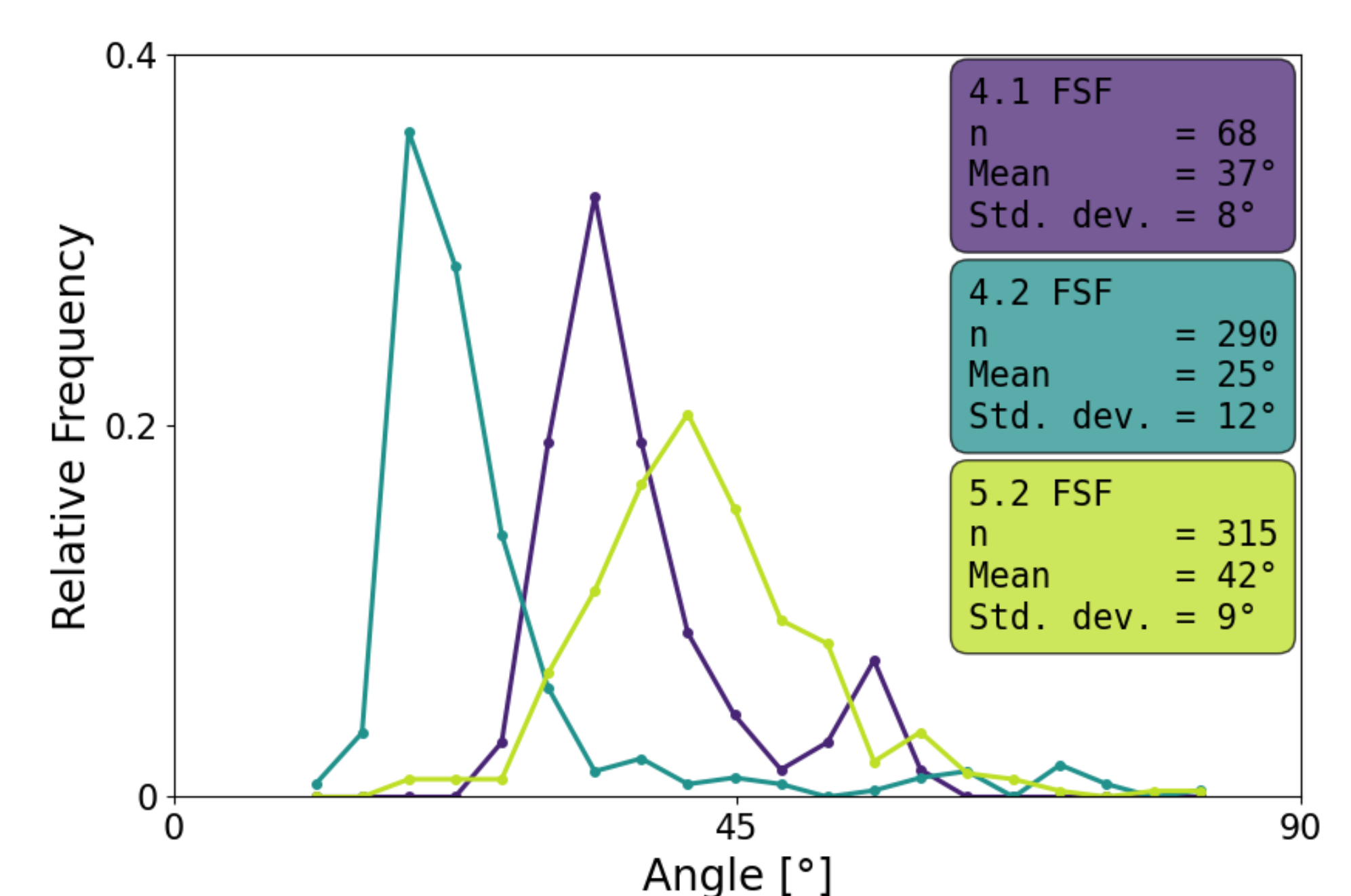
Substrate dislocation conversation

- It was observed, that 1SSF can originate from threading mixed dislocations (TMDs) from the substrate [3]
- X-ray topography images were compared with UVPL maps of 73 stacking faults to find the root dislocation in the substrate
- 71 out of 73 stacking faults were directly correlated to threading dislocation in substrate



Opening angle of FSF

- While the angle is not a definitive indicator of the SF subtype [4] certain FSF subtypes exhibit the same angle
- SF subtype identified by PL emission
- Measuring opening angle of each SF types were measured and statistical evaluated
- While the angle is not a definitive indicator of the SF subtype [4] each FSF subtypes shows a specific opening angle



Conclusion and outlook

- Spectral analysis of SF enables a subclassification of SFs for large datasets
- Properties of the different subtypes like shape and morphology can be examined further
- FSF of the same subtype show a similar triangular shape and opening angle in the PL channel
- Further studies on the influence of process steps like implantation or the properties of the subtypes and influence on electrical devices are possible with the help of spectral PL based measurements and will be conducted in the future

We gratefully acknowledge the HORIBA team for demo measurements.

[1] Baierhofer D, Thomas B, Staiger F, et al (2023) Correlation of Extended Defects with Electrical Yield of SiC MOSFET Devices. DDF 426:11–16. <https://doi.org/10.4028/p-182158>

[2] Na M, Bahng W, Jung H, et al (2024) Revisiting stacking fault identification based on the characteristic photoluminescence emission wavelengths of silicon carbide epitaxial wafers. Mater Sci Semicond Process 175:108247

[3] Ota C, Nishio J, Iijima R, et al (2026) Release of basal plane dislocations from a helical threading mixed dislocation in 4H-SiC. Scr Mater 281:117317. <https://doi.org/10.1016/j.scriptamat.2026.117317>

[4] Na M, Bahng W, Jung H, et al (2024) Observation of broad triangular Frank-type stacking faults and characterization of stacking faults with emission wavelengths below 430 nm in 4H-SiC epitaxial layers. Appl Phys Lett 124:111101. <https://doi.org/10.1063/5.0198216>