

EBSD – Identification of Bainite and Ferrite

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1 GENERAL OVERVIEW

To identify Bainite and Ferrite, a general overview of the microstructure is made in order to separate what are FCC and BCC (Figure 1). On green colours, the iron BCC phase of our interest – that contains both Bainite and Ferrite – is dominantly present as can be seen on the graph:

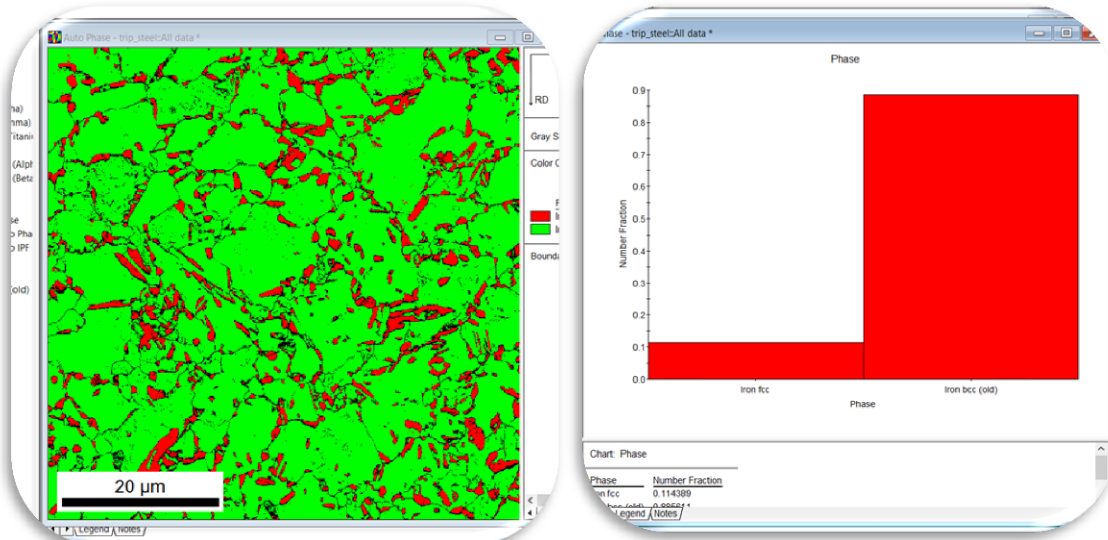


Figure 1: EBSD map of the Iron FCC phase in red, and Iron BCC phase in green. The chart indicates that the structure in BCC is dominantly present. Black regions account for non identified data and will be discarded.

A part of the material that is of our interest will be selected to avoid non identified material to be counted as well (Figure 2 a, b): adding fractions of BCC and FCC equals to 90, 7% of the material, and not 100%.

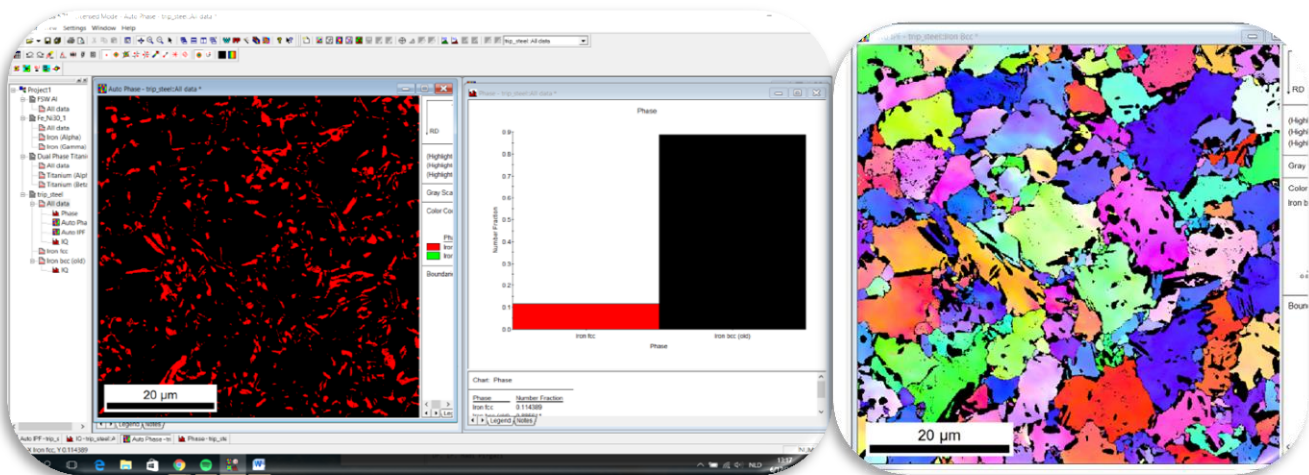


Figure 2: a) To avoid using all data file for the threshold and partitioning and risking that some of the not identified material would be counted as one of the phases of interest, only bcc data is used. b) Inverse pole figure of the BCC phase.

2 Image Quality Maps

In order to determine the amount of dislocations in the material, an image quality map is created. It is known that a material with many defects and dislocations have lower image quality, and Bainite has a larger dislocation density, thus the image quality of Bainite will be lower than Ferrite.

2.1 Average Image quality

The preference for this map is to avoid that Ferrite pixels with lower image quality are perceived as Bainite, and also to avoid that grain boundaries with low image quality are summed.

It can be seen on the charts that the grain average image quality varies between 60 and 170, having an average value of 115 (Figure 3). On the literature provided it is shown that this chart is an overlap of the distribution curve for Bainite and Ferrite. Thus, to separate both phases, image qualities lower than 110 will be denoted to be Bainitic material.

When applying the chosen threshold, the corresponding highlighting will appear on the map. These highlighted zones should be Bainite (Figure 4).

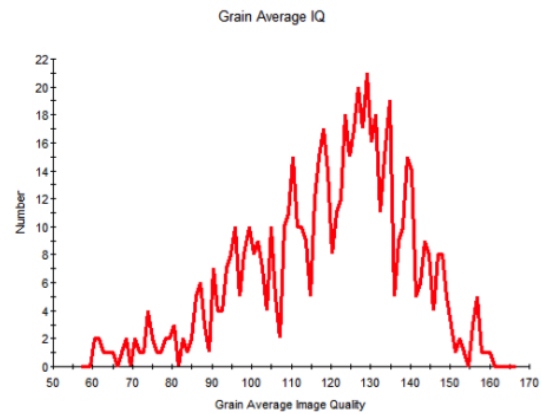
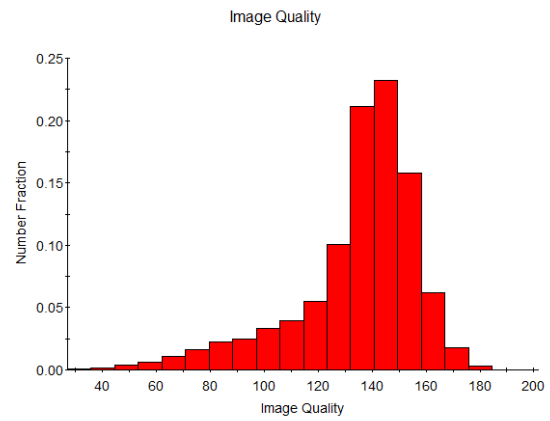


Chart: Grain Average IQ

Average IQ	Number
57.2203	0

Figure 3: Charts for Image Quality and Grain Average Image Quality of the phase.

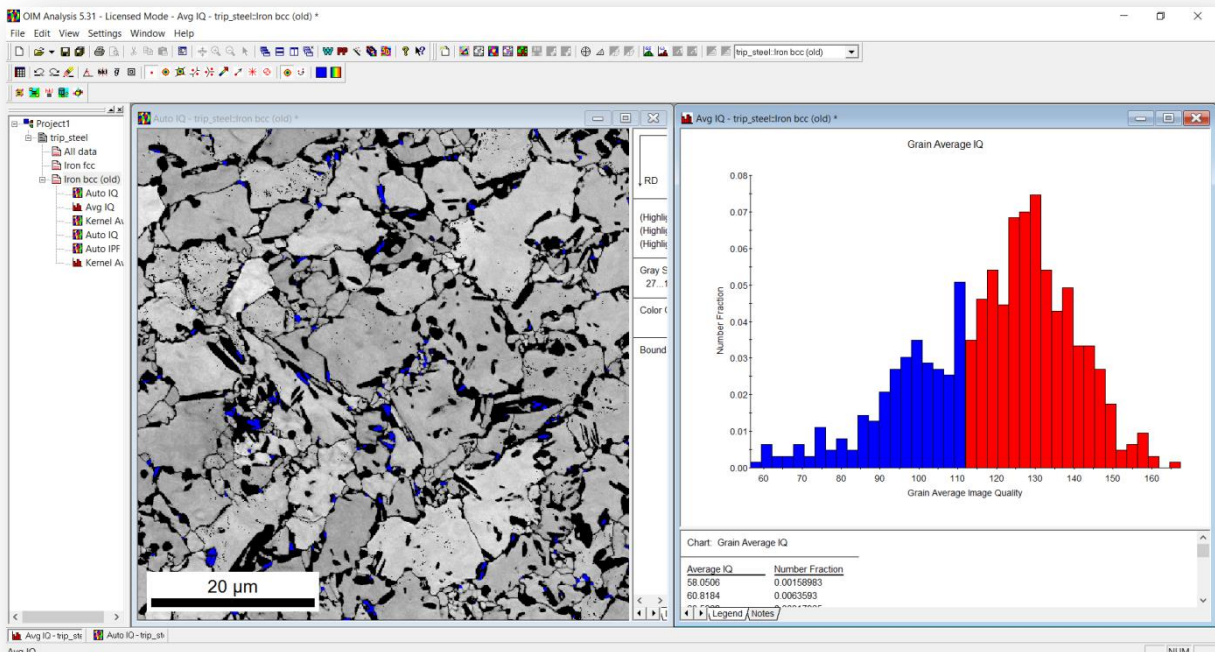


Figure 4: Applied threshold in blue on the chart and highlighted zones of the map.

3 Kernel Average Misorientation (KAM)

The Kernel Average Misorientation map is a standard method that indicates differences in crystallographic orientation between neighbouring points located in the specimen. This method takes the orientation of a pixel and calculates the average of misorientation within its six neighbours, being more local than the measurement of average image quality.

On Petrov *et al.* one can find the parameters necessary to extract information through this method: the nearest neighbour should be the 3rd and the maximum grain misorientation is 5 degrees in the calculation (Figure 5).

In order to define the threshold for the KAM value that differentiates ferrite and Bainitic ferrite, an empirical analysis is carried. The zones which contain Bainite should be visible for a value higher than the threshold. On figure 6 a KAM map of BCC phase is shown with different threshold applied. The red and purple zones should be Bainite if the threshold is lower than 2; highlighting values lower than 1.7 degrees display scattered pixels inside the microstructure which makes the value of 1.7 to be chosen.

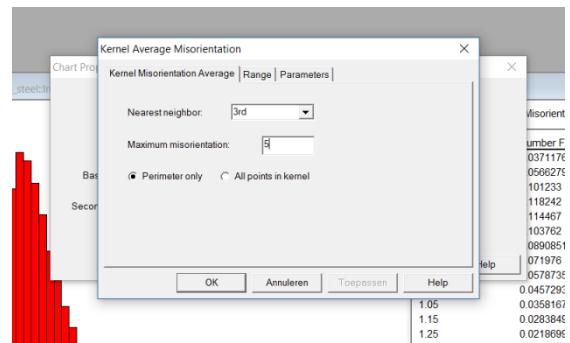


Figure 5: Input settings for the calculation of KAM.

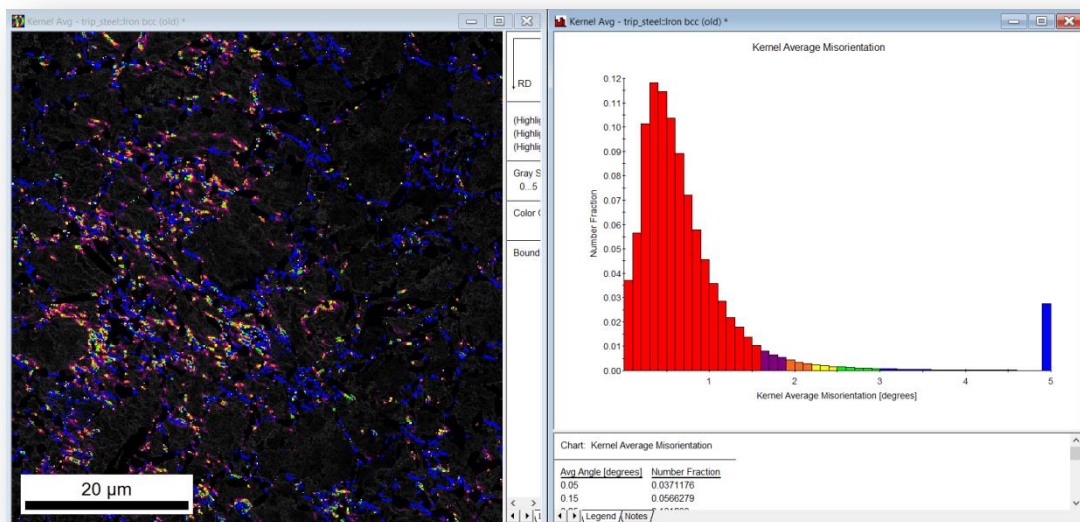


Figure 6: Several thresholds are empirically analysed to determine the adequate one. The corresponding highlighting can be seen on the phase map.

4 Comparison of Image Quality and Kernel Average Misorientation Map

When comparing both maps, one can see that the results are significantly different although in both cases the results can be found close to grain boundaries.

On figure 7 both thresholds were plotted, blue being the zones highlighted by Image Quality method and red zones being Kernel Average Misorientation method.

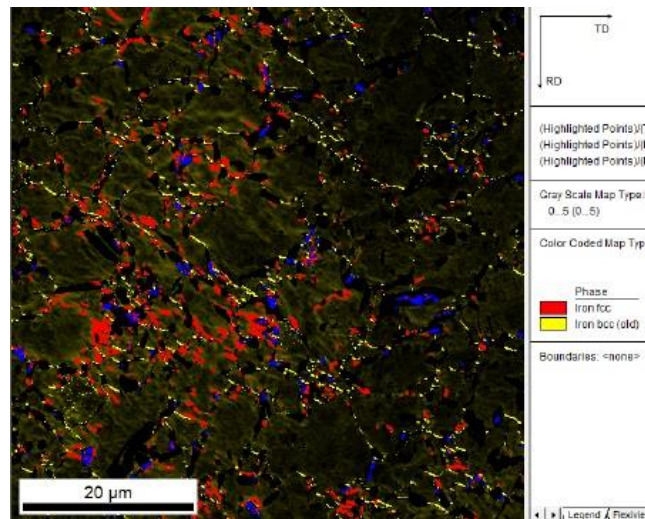


Figure 7: Comparisson between methods with both thresholds superimposed display different results.

A possibility for such disparity is the way both methods are calculated. The Image Quality method will be comparing grains as either Bainite or Ferrite according to its image quality, resulting in concrete regions that are identified as grains. The KAM method may however use abstract non identified zones as grains, increasing the chance of error.

5 References

- i. S. Zaefferer, P. Romano, and F. Friedel, "EBSD as a tool to identify and quantify bainite and ferrite in low-alloyed Al-TRIP steels" *J. Microsc.*, vol. 230, no. 3, pp. 499–508, 2008.
- ii. R. Petrov, L. Kestens, A. Wasilkowska, and Y. Houbaert, "Microstructure and texture of a lightly deformed TRIP-assisted steel characterized by means of the EBSD technique", *Mater. Sci. Eng. A*, vol. 447, no. 1–2, pp. 285–297, 2007.
- iii. K. Zhu et al., "Characterization and quantification methods of complex BCC matrix microstructures in advanced high strength steels", *J. Mater. Sci.*, vol. 48, pp. 413–423, 2013.
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