

## Advances in High-Speed EBSD Orientation Mapping

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Since the advent of digital cameras, EBSD mapping speeds have broken the 30Hz barrier of TV rate (US) cameras and have continued to climb with advances in hardware and software. Fig. 1 shows the rise in quoted mapping speeds by year [1] [2]. In this context, mapping includes obtaining an electron backscatter pattern at every point within a map, and solving its orientation.

To achieve today's speeds (300Hz) requires a high speed digital camera capable of integrating and transferring the images within 3ms. The camera system (detector) must be sufficiently sensitive such that it can be illuminated to near its full bit depth by a typical scanning electron microscope (SEM) electron probe.

In addition, during this 3ms period, the analysis software must receive the transferred image, correct its background, create a Hough transform, detect several Kikuchi bands and solve the orientation correctly. The software not only needs to be efficient, but must also utilize a multi-threaded software architecture to take advantage of modern operating systems and PC hardware with multiple CPUs. Such software has been developed and tested on a four CPU PC.

To assess whether the data acquired during high speeds is of sufficient quality, two measures are used. *Hit Rate*, which is a simple measure of the total number of solved pixels versus the whole mapped area in pixels. This results in a simple percentage but does not alone determine the quality of the data since it does not consider the correctness of the result. Solving the orientation of a crystal under the beam from its Kikuchi pattern is termed *indexing*. Thus *misindexing* occurs when a solution shows an incorrect orientation, when compared to its neighbors on a sample of known microstructure. In a simple, fully recrystallized microstructure, misindexing shows up as a speckled effect as pixels change color within a grain of single orientation, which should be displayed in single color.

A fully recrystallized Ni sample was used for this test, since each grain had very little internal misorientation. In principle, a well-prepared sample such as this should index at near 100% and with no misindexing.

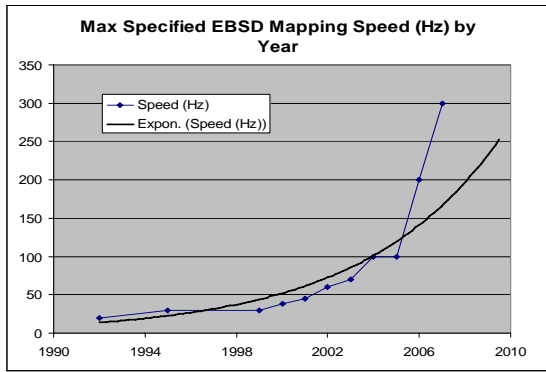
Results in Fig. 3 and Fig. 4 show that data can be acquired at rates of 272Hz and 409Hz without a compromise in quality.

Fig. 3 shows data at 99% hit rate with no misindexing and Fig. 4 shows data at 91% hit rate, again with no misindexing. Neither map has been processed with noise filters, so each hit rate can be considered *raw*. Indexed pixels in these maps are of high confidence since they have been indexed with five simultaneous Kikuchi bands, and thus the hit rate is not biased upward by the inclusion of low confidence points.

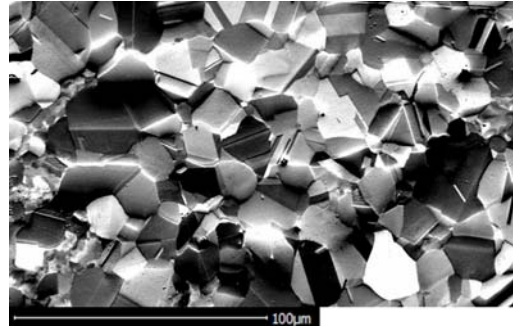
Detector limitations take the form of sensitivity since the on-chip integration times are very short. In practice this means that for the highest speeds, SEM probe current requirements are approximately 5nA versus 1nA for the 100Hz detector. Thus high brightness SEMs are desirable particularly if high spatial resolutions are required.

The pixel array used in the high speed camera is smaller than that of the 100Hz detector, and thus the ultimate angular resolution is lower. Further, when used at its maximum speed, pixel binning is used to increase sensitivity, thus angular resolutions are further reduced, see Fig. 5.

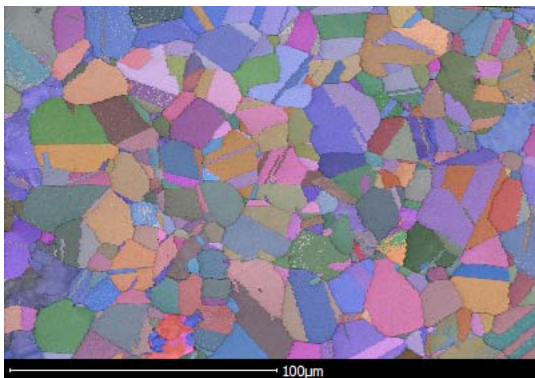
High quality, high speed mapping of at least 300Hz has been shown on a fully recrystallized Ni sample.



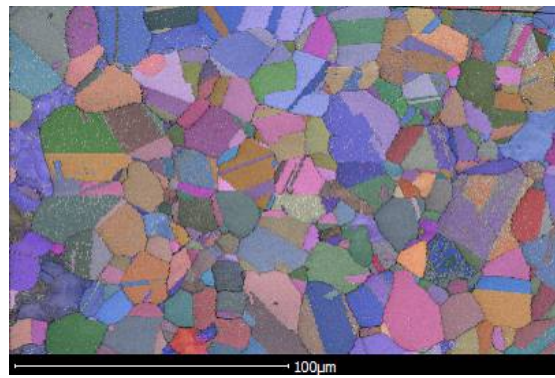
**Fig. 1** Maximum quoted EBSD mapping speed (Hz) by year



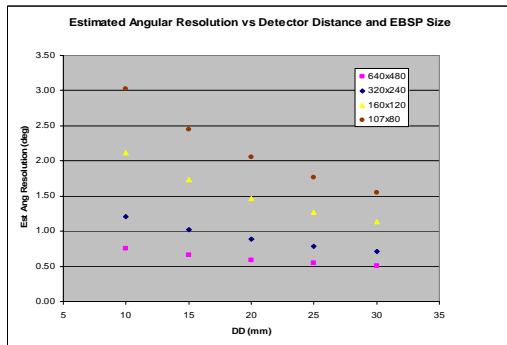
**Fig. 2** Forescatter image of fully recrystallized Ni test sample.



**Fig. 3** 272Hz orientation map of Ni sample - 99% hit rate, no misindexing



**Fig. 4** 409Hz orientation map of Ni sample - 90% hit rate, no misindexing



**Fig. 5** Estimated angular resolution versus detector distance (mm) and EBSD size (pixels)

**References**

[1] T.M. Maitland, *Microsc. Microanal.* (2004), 10: 936-937  
 [2] M.M. Nowell et al., *Microscopy Today*, Vol: 14 # 6 (2006)