CLEMEX

Image Analysis Report

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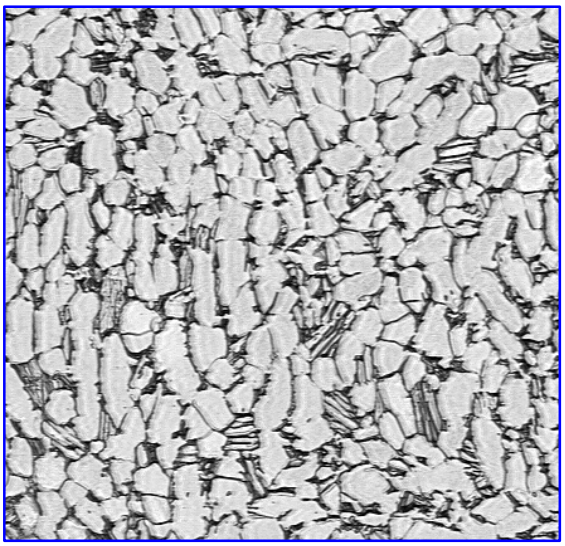

Alpha Grain Characterization in Titanium

Sample Description

Two samples of titanium (Ti-6-4) electro-polished and etched.

Purpose of Analysis

Demonstrate the ability of the image analyzer to discriminate and measure alpha grains, transformed beta phase (acicular alpha grains) and colonies (grouped acicular alpha grains). Requested measurements are volume fraction, grain size, aspect ratio and orientation.

Equipment Used

Image Analysis System:	Clemex Vision Software (640 or 1024 and possibly an Impak)
Microscope:	Nikon Epiphot 200 with a 20x objective
Stage:	Motorized Marzhauser EK8B-S1 with auto focus drive
Camera:	Sony XC-77CE (768X574) B&W

Procedures

Procedures described here were performed at a magnification of 200X for a calibration factor of 0.524 µm/pixel. Thirty-six fields were analyzed on each sample. The total analysis area was 1 958 154.09 μm^2.

An *Average Grab* and a *Gray Sharpen* improved the original image (cover page). Figure 1a shows the blue binarization by *Gray Thresholding* of the grain boundaries. In figure 1b, Alpha grains were discriminated from the matrix using binary instructions like *Closing, Reconstruct, Disconnect* and *Zone*. An *Object Transfer* based on *Area Ratio* removed artifacts.

Figure 2 shows the resulting alpha grain boundary network overlaid against the original image.

Colonies were isolated from the matrix using an *Object Transfer* based on *Child Count*, the child bitplane representing the acicular alpha grains. *Boolean, Pruning, Zone* and *Chord Size* were also necessary performing this task. Figure 3 shows the matrix outline. The pink outline represents colonies.

Field Measurements were then performed to obtain area percentage of each

phases and alpha grain size. Figure 4 shows the area percentage of transformed beta phase and primary alpha phase compared to field. Using a binary *Square Grid*, grains that were sectioned by the field were eliminated prior to *Object Measurements*. *Length*, *ASTM E 112* grain size, *Aspect Ratio* and *Orientation* measurements were then performed on each object.

The most significant image modifications and final results are as follows:

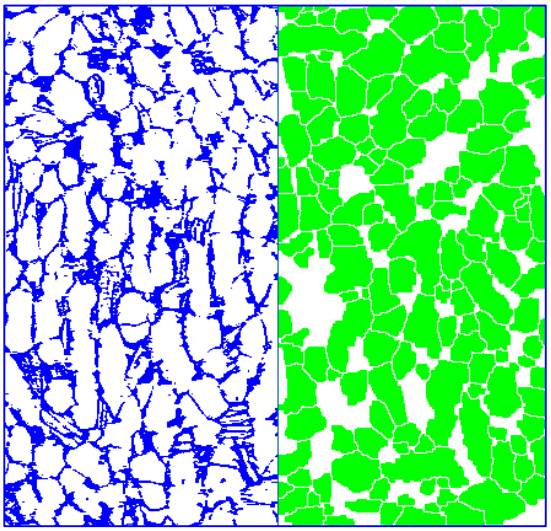

Figure 1a: *Blue binarization by Gray Thresholding of the grain boundaries.*

Figure 1b: *Alpha grains isolated from the matrix.*

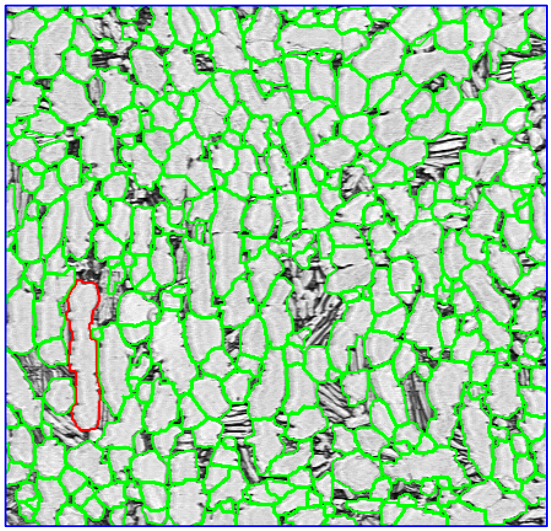

Figure 2: *Alpha grain boundaries overlaid against the original image (cover page). The red outline object was the longest alpha grain the system found through the analyzed fields.*

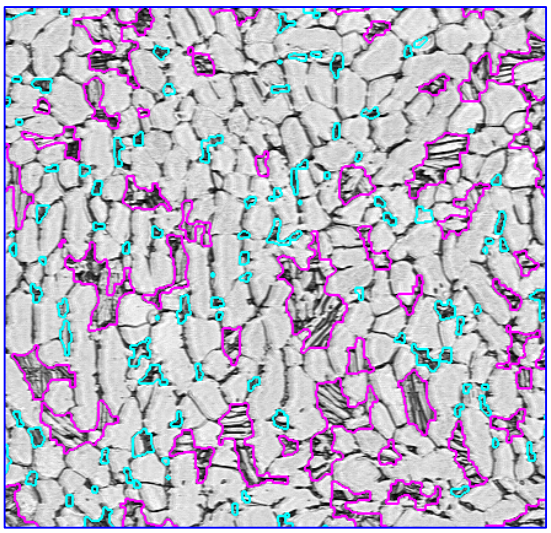

Figure 3: *Pink outline represents colonies and cyan outline represents transformed beta phase containing less than 2 acicular alpha grains.*

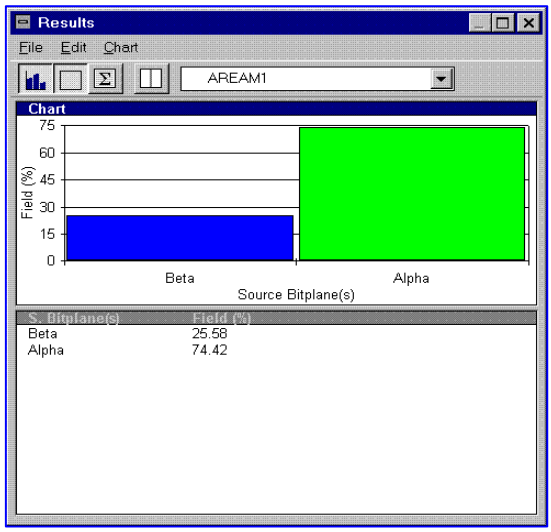

Figure 4: *Area percentage of transformed beta phase (acicular alpha) and primary alpha phase compared to field.*

Results Summary

Transversal Sample:

Field Measurement	*Alpha Grain Size (log) ASTM E 112*	*Alpha Area (% on field)*	*Transf. Beta Area (% on field)*	*Colonies Area (% on field)*
Minimum	9.65	69.09	25.26	14.98
Maximum	9.97	74.74	30.91	21.51
Mean	9.79	72.90	27.10	17.80
Standard Deviation	---	1.24	1.24	1.68

Object Measurement	*Alpha Grain Size ASTM E 112 (log)*	*Alpha Grain Length (mm)*	*Alpha Grain Aspect Ratio*
Minimum	6.51	3.7	1.07
Maximum	13.42	85.6	3.89
Mean	9.95	15.8	1.52
Standard Deviation	---	7.2	0.30

Longitudinal Sample:

Field Measurement	*Alpha Grain Size (log) ASTM E 112*	*Alpha Area (% on field)*	*Transf. Beta Area (% on field)*	*Colonies Area (% on matrix)*
Minimum	9.36	70.28	23.62	14.18
Maximum	9.78	76.38	29.72	22.47
Mean	9.58	72.71	27.29	19.09
Standard Deviation	---	1.29	1.29	1.71

Object Measurement	*Alpha Grain Size ASTM E 112 (log)*	*Alpha Grain Length (mm)*	*Alpha Grain Aspect Ratio*
Minimum	6.33	4.0	1.06
Maximum	13.25	96.2	4.14
Mean	9.87	16.3	1.53
Standard Deviation	---	8.6	0.30

Discussion

The Clemex Vision image analysis system can discriminate all phases and, produce the requested measurements.

The *Gray Binarization* was strait forward since frontiers were black on an evenly white background. No difficulties were encountered through the image analysis process. Nevertheless, the samples were not even and we had to decrease the field surface to fit only the portion of the sample that was in focus. Because of the elongated shape of the samples, we had to stabilize them with modeling clay instead of usual stabilizer (a metallic arm) that is more efficient during auto focussing.

Some alpha grains were completely isolated, some were touching one to another by a small link, and some others were just elongated grains. Of course several grains were somewhere between the two last categories. To separate grains, one cycle of *Reconstruct* was applied on the corresponding bitplane. This operation separates grains accordingly to their kernels. Insufficient cycles of *Reconstruct* would not separate grains that had an important overlapping percentage and too many cycles would subdivide grains that were elongated. Both phenomena were existent so we had to use a quantity of cycles that produce equilibrium between both effects. Final results were not significantly influenced by occasional improper detection.

Transformed beta phase was classified as a colony if containing at least 2 acicular alpha grains. That criterion was set arbitrary and it could be set differently.

Aspect Ratio was not summarized into “Results Summary” because of the two distinctive bumps obtained into the histogram. The mean represents the middle between both curves and has nothing to do with the most frequently occurring values.

Results are reproducible.