Restoration of Firearm Serial Numbers with Electron Backscatter Diffraction (EBSD)

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MATERIAL MEASUREMENT LABORATORY

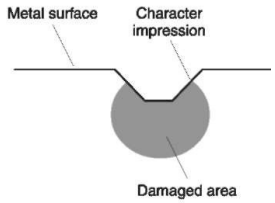
Firearm Serial Numbers

As the primary identifying mark on firearms, serial numbers are often removed by criminals.

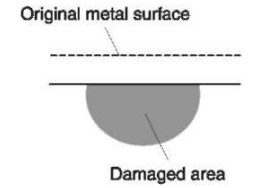
Image: MN State Police

In the case of a stamped serial number, deformation of the metallic crystal structure remains below the surface even when the imprint is no longer visible.

Stamped serial number:



Surface imprint removed:



A number of techniques (acid etching, heat treating, etc.) can partially or fully restore serial numbers. However, many of these methods can produce unsatisfactory and/or ambiguous results.

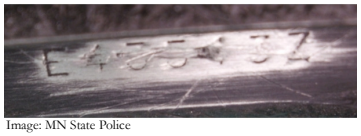


Image: MN State Police

Electron Backscatter Diffraction

Electron backscatter diffraction (EBSD) is a diffraction-based technique performed in the scanning electron microscope (SEM).

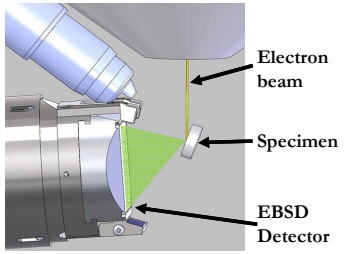
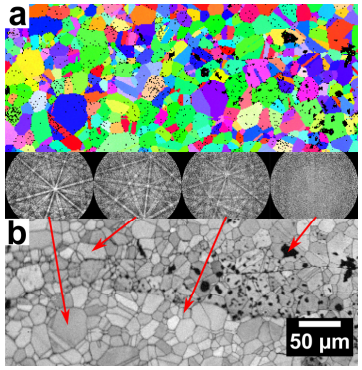


Image: Bruker

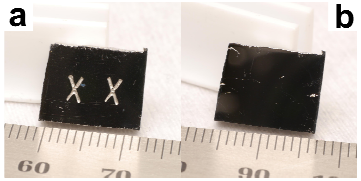
Diffraction patterns are collected from each pixel and indexed by commercial software. A map of the crystallographic orientation (below, top) is produced with resolutions reaching tens of nanometers.



The EBSD software also produces a map of a parameter called "pattern quality" (above, bottom) which is an assessment of the contrast in the diffraction pattern. Areas where the sample has undergone severe plastic deformation will tend have low pattern quality.

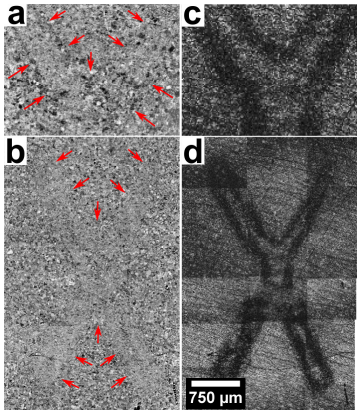
Reconstruction of Firearm Serial Numbers

A firearm serial number analog was produced by stamping (by hand/hammer) the letter X into a polished piece of 316 stainless steel. The depth of the imprint was measured to be about 170 µm



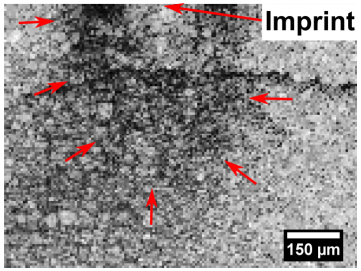
The imprint was then polished away, beginning with 120 grit SiC paper down to 0.05 µm colloidal silica, and finishing with electropolishing in a solution of 50% H_3PO_4 and 50% H_2SO_4

Forward scattered images (below left) and EBSD pattern quality maps (below right) were collected over the area of the now-removed imprint.

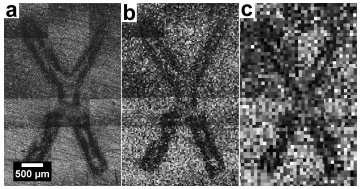


The imprint is faintly visible in the forward scattered image and very clearly visible in the EBSD pattern quality map. Low **pattern quality in areas with sub-surface damage reveal the image of the stamped letter X.**

A second sample was prepared by taking a cross-section of the stamped X and polishing it in the same manner.



The image quality map of the cross section (above) shows that the deformation is detected via EBSD pattern quality mapping to a depth of about 520 µm beneath the bottom of the imprint. **A criminal would therefore have to remove about 760 µm of material (140 µm imprint, 520 µm sub-surface damage) to render a serial number undetectable by EBSD.**



The original EBSD scan (above left) required 9 hours for a single letter due to a (software limited) maximum pixel size of 6.72 µm. Undersampling the collected data by 5x (above center, 33.6 µm pixels) and 10x (above right, 67.2 µm pixels) still shows unambiguous reconstruction of the stamped letter.

At a 67.2 µm pixel size, scanning a single letter would take about 5.4 minutes and a full 8 character serial number would take under an hour to reconstruct.

Additional Applications

Laser engraved serial numbers are difficult to restore. EBSD can detect changes in the material structure induced by the laser.

Vehicle identification numbers (VINs) are often defaced on stolen vehicles. EBSD restoration may be possible in this case.

Images: Wikipeida

EBSD may also be used in the restoration of artifacts, such as coins where dates or other imagery may have been worn away.

Next Steps

- Perform the same reconstruction method on real firearm serial numbers defaced in an uncontrolled manner.
- Compare the EBSD restoration technique to acid etching and other restoration techniques
- Attempt EBSD technique on laser engraved serial numbers.
- Determine if EBSD technique can identify serial number which has been destroyed by other methods (heating, overstamping, etc.)
- Collaborate with law enforcement to apply EBSD serial number restoration to an active investigation.

Acknowledgements

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