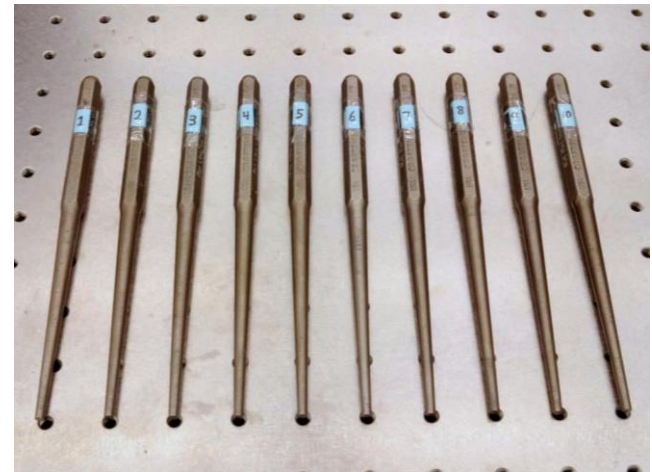# 2D/3D Topography Comparisons of 10 Consecutively Manufactured Chisels and Punches Through the Cross Correlation Function

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National Institute of Standards and Technology

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Forensics@NIST
2012

Disclaimer

Certain commercial equipment, instruments, or materials are identified in this report in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.
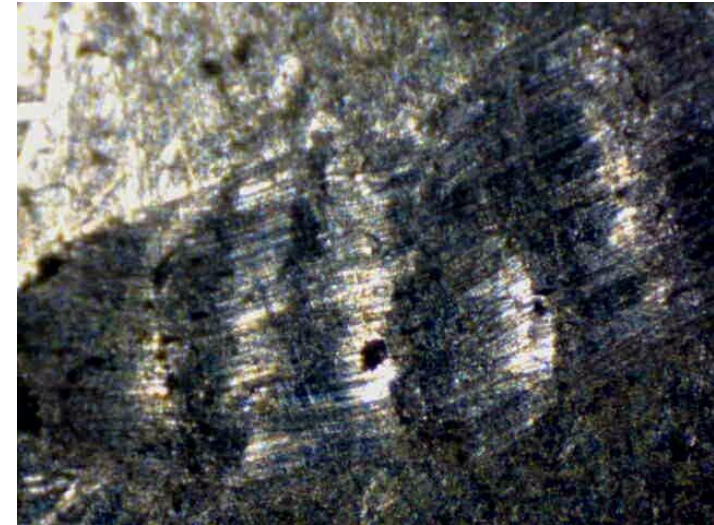
Contents

- Project Goal and Motivation

- Sample Preparation

- 10 Consecutively Manufactured Chisels

- Chisel – Striated Toolmark Creation

- Chisel – Measurement and Analysis

- 10 Consecutively Manufactured Punches

- Punch – Impression Toolmark Creation

- Punch – Measurement and Analysis

- Conclusions

What is a Toolmark?

WI Department of Justice

lockpickingforensics.com

- Almost anything can create a toolmark as long as the tool is harder than the surface it's being used on.

- The surface topography of the tool is imparted onto the surface. The resulting toolmark can be later used to identify the tool.

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Traditional Comparison Microscopy
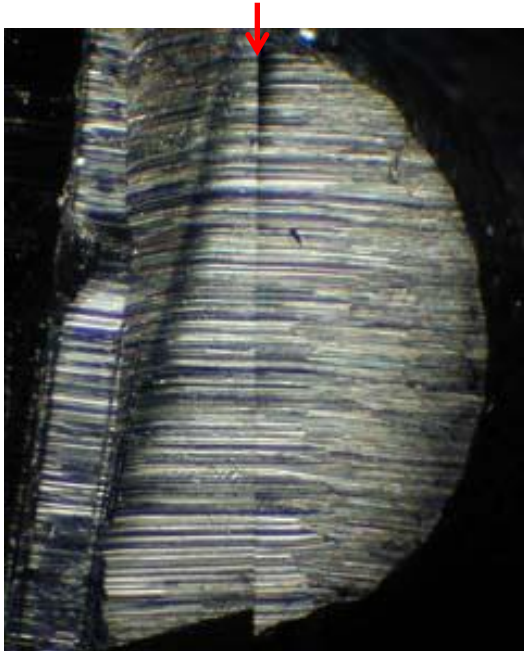

MO Dept. Of Public Safety

Leica Microsystems

Project Goal and Motivation

- Consecutively manufactured tools have a high likelihood of containing sub-class characteristics which can lead to false positives. It's considered the most difficult comparison.

- Our goal is to provide objective mathematical comparisons of toolmarks created by 10 consecutively manufactured chisels (striated toolmarks) and punches (impression toolmarks).

- Can consecutively manufactured tools still be uniquely identified from the toolmarks that they created?

Sample Preparation

- The surface that the tools will be marking is a soft copper plate. The copper plate has been sanded with 1000 grit sand paper and polished using a metal polish.

- The surface preparation ensures that there are no directional striations present on the surface that can be confused with the created toolmarks.

Ra ~ 70 nm

Ra ~ 20 nm

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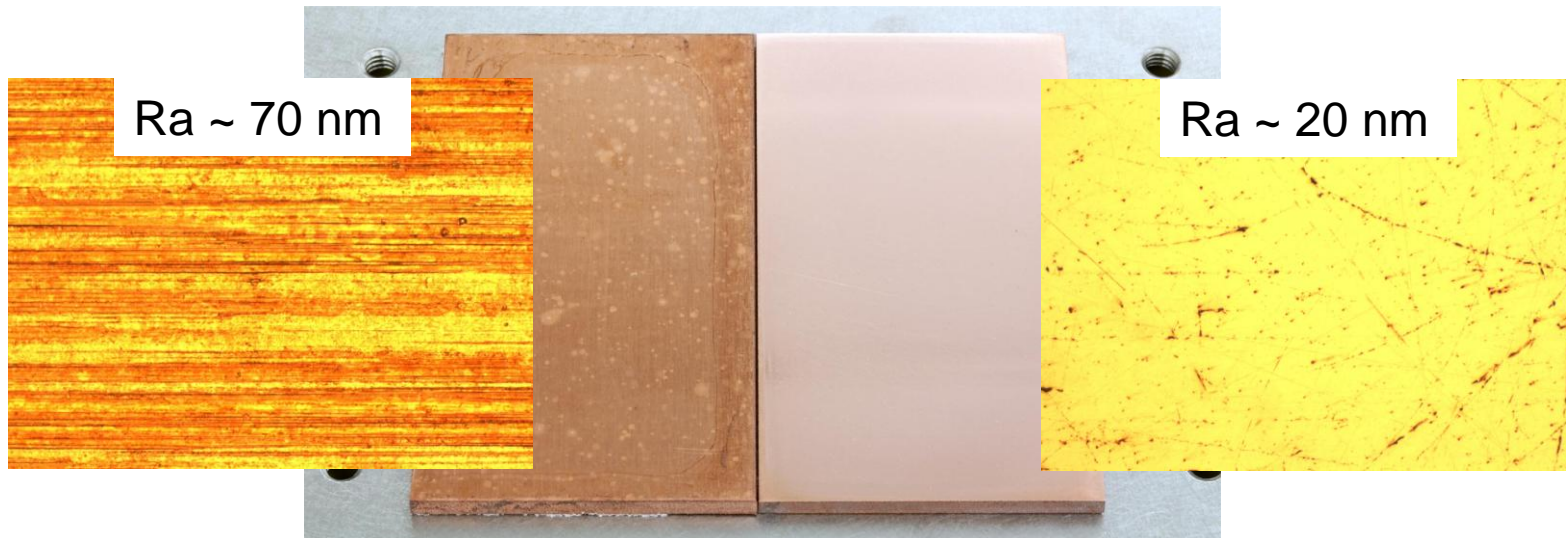
10 Consecutively Manufactured Chisels

- 10 consecutively manufactured chisels from Western Forge (supplier to Craftsman Tools)
- 2 known marks per chisel to establish known match/non-match distributions
- Hide chisel identities, 2 more marks per chisel (Unknown set)
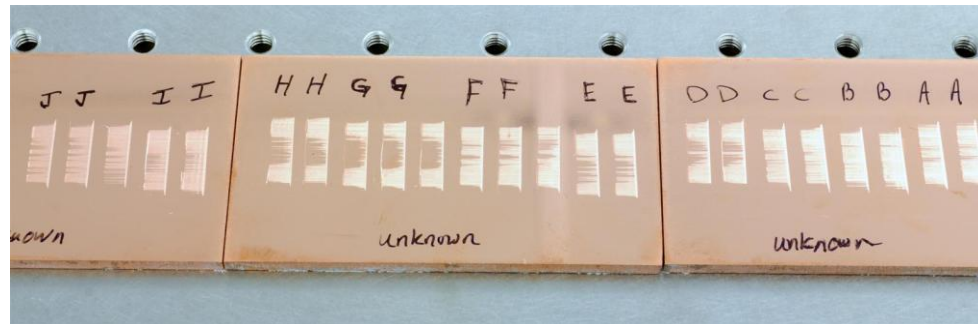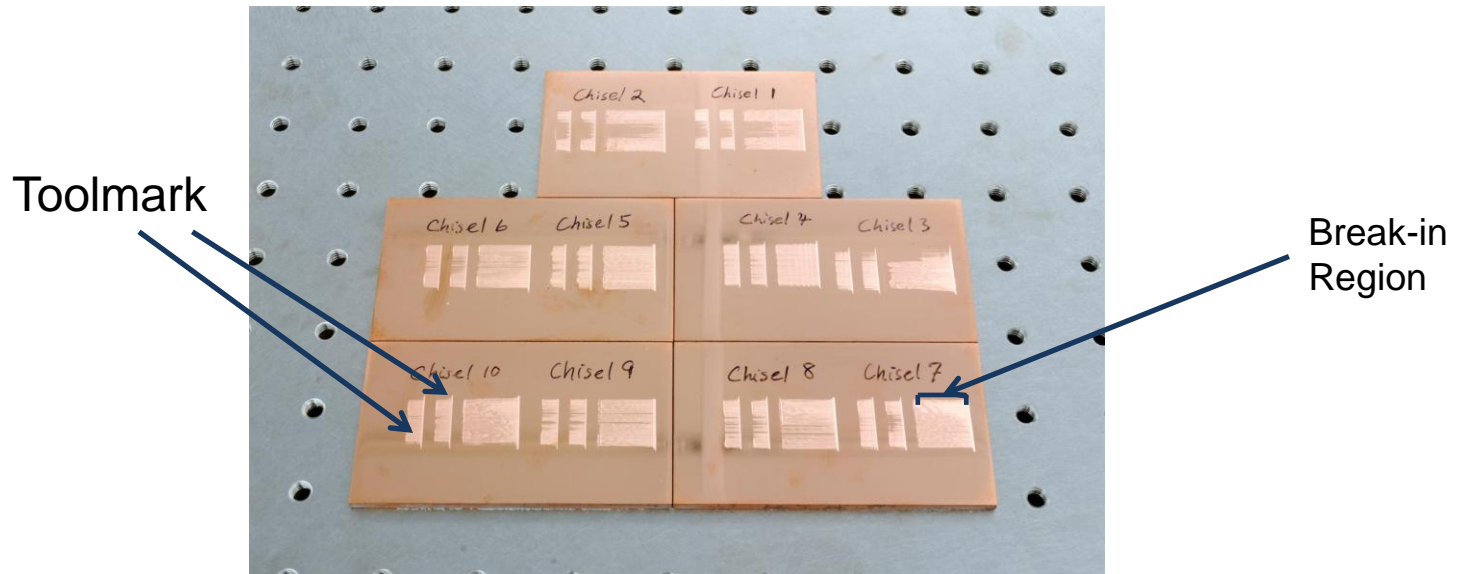- Identify unknown toolmarks using CCF_{max}

Chisel – Striated Toolmark Creation
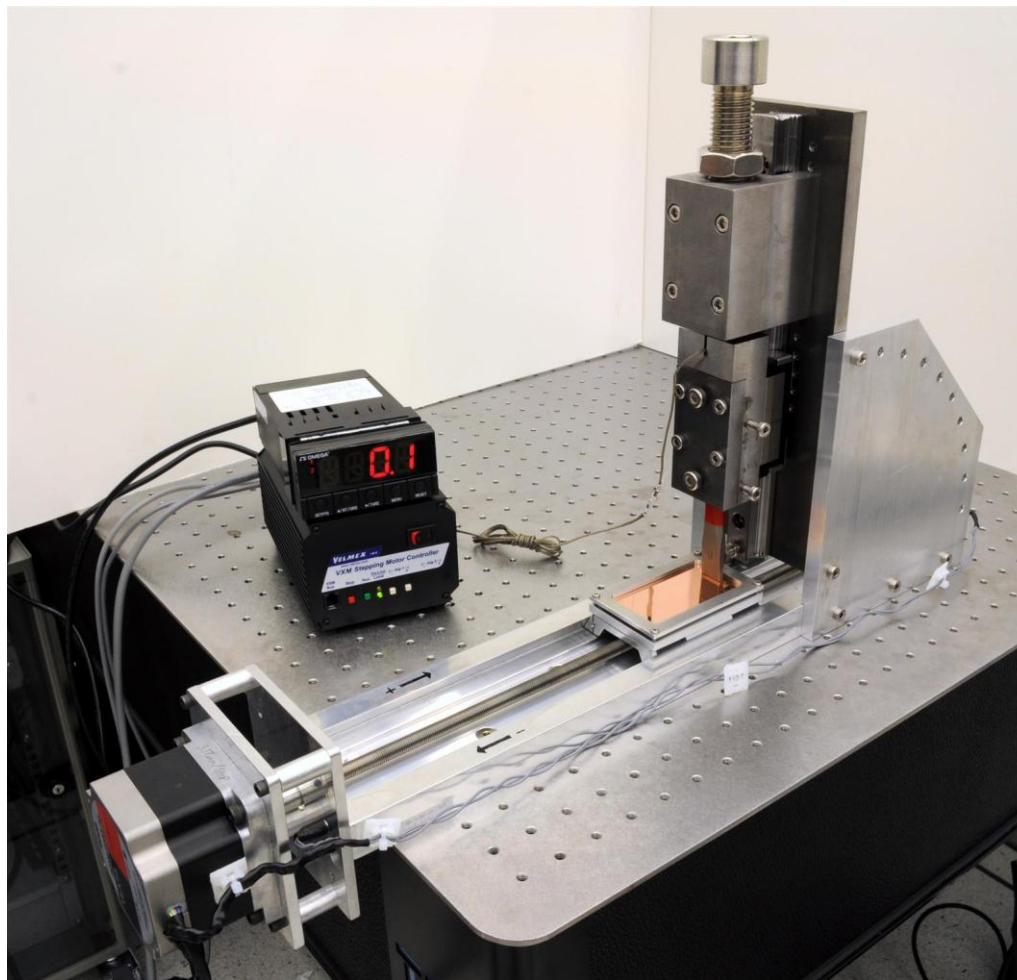
Chisel – Striated Toolmark Creation

Chisel – Striated Toolmark Creation

Toolmark

Break-in Region

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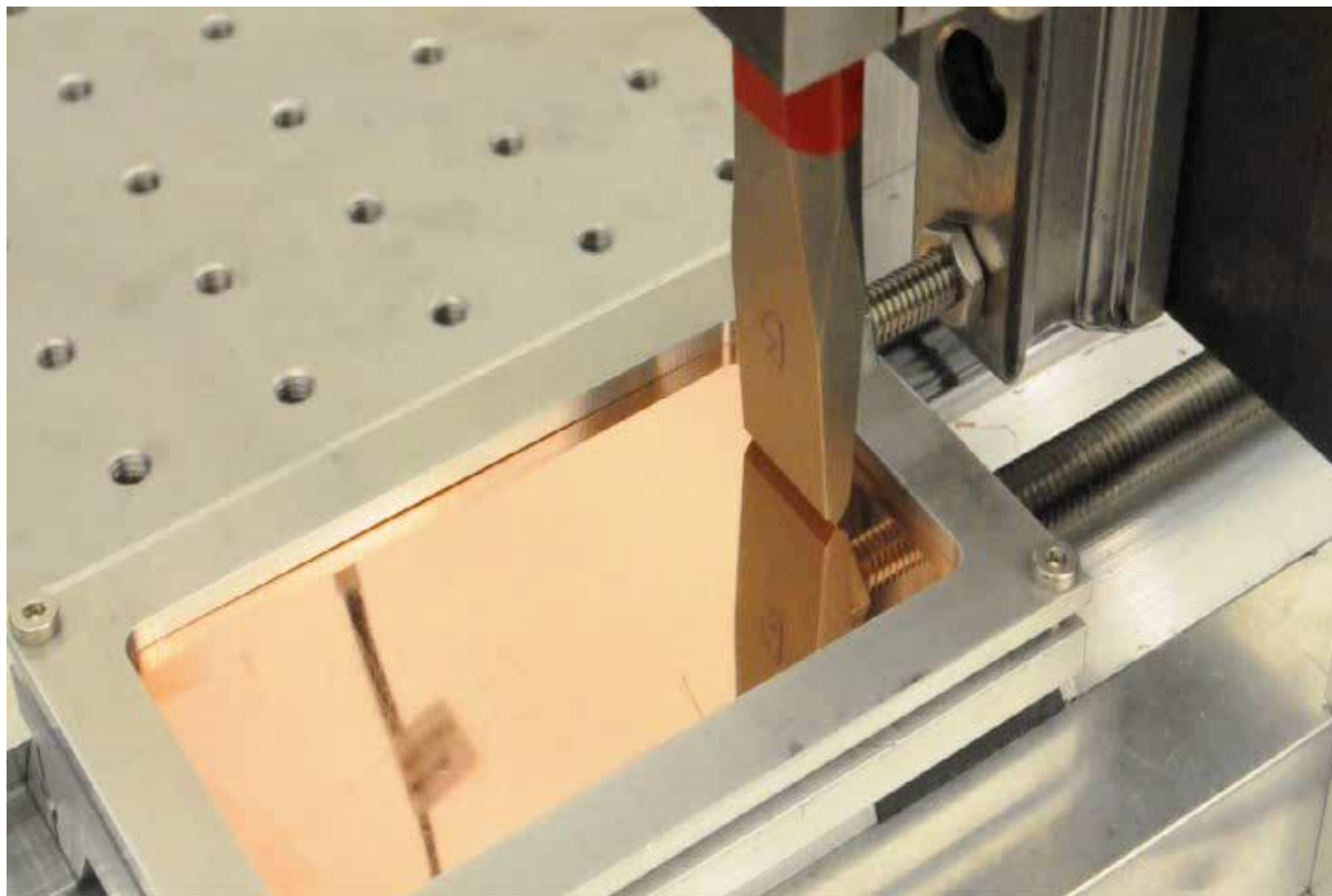
Chisel – Measurement and Analysis

Taylor Hobson Ltd

- Z-resolution: 0.8 nm
- X-Point spacing: 0.25 μm

- Nominal Stylus Tip Radius: 2 μm
- Trace Length: 25 mm
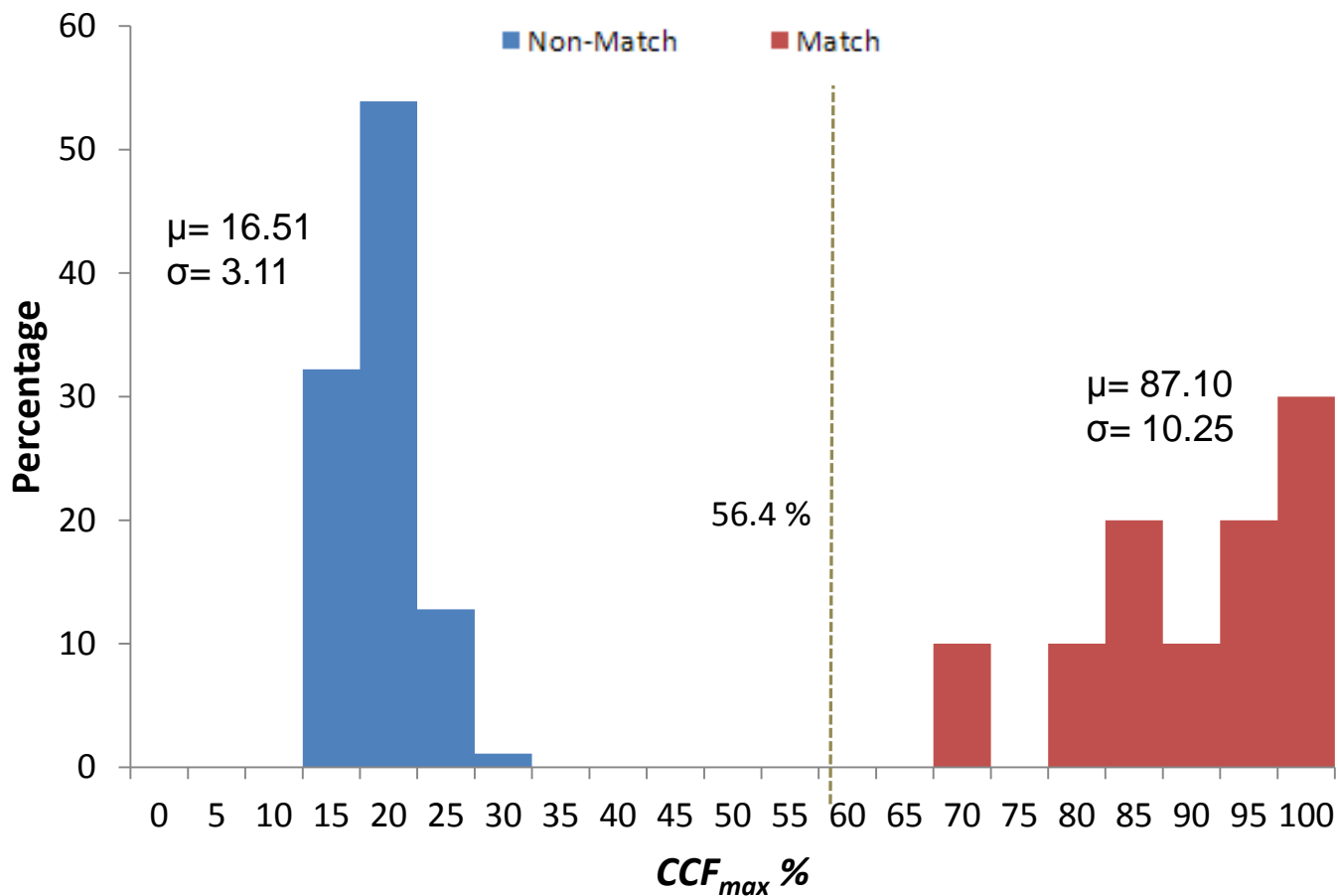
Chisel – Measurement and Analysis

Chisel 6-1

Chisel 6-2

Two Dimensional Cross Correlation Function
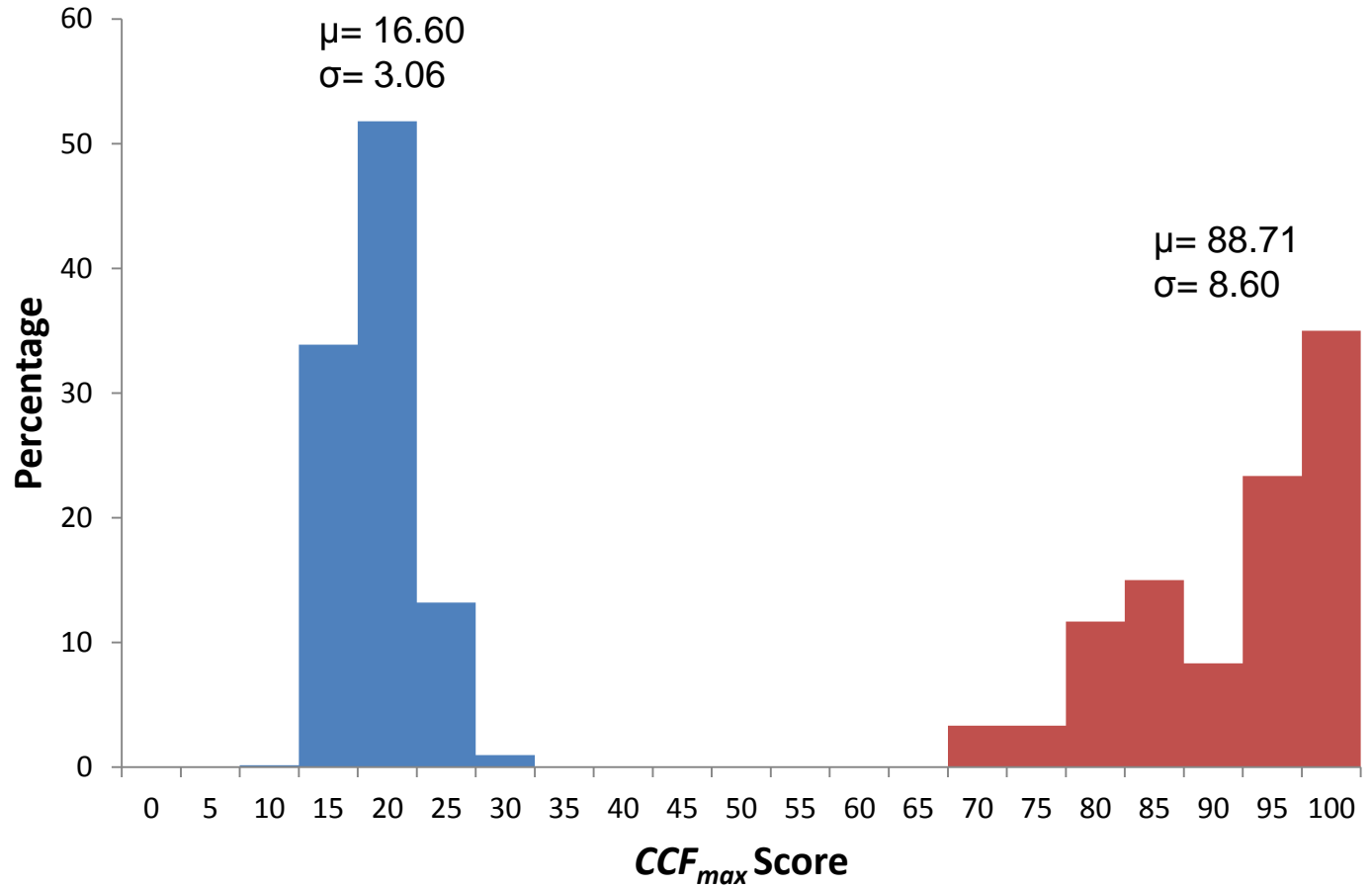
$$CCF(A, B, \tau) = \frac{CCV(A, B, \tau)}{Rq(A)Rq(B)}$$

$$Rq = \left[\frac{1}{L} \int_0^L Z^2(x)\,dx \right]^{\frac{1}{2}} \approx \left[\frac{1}{N} \sum_{i=1}^N Z_i^2 \right]^{\frac{1}{2}}$$

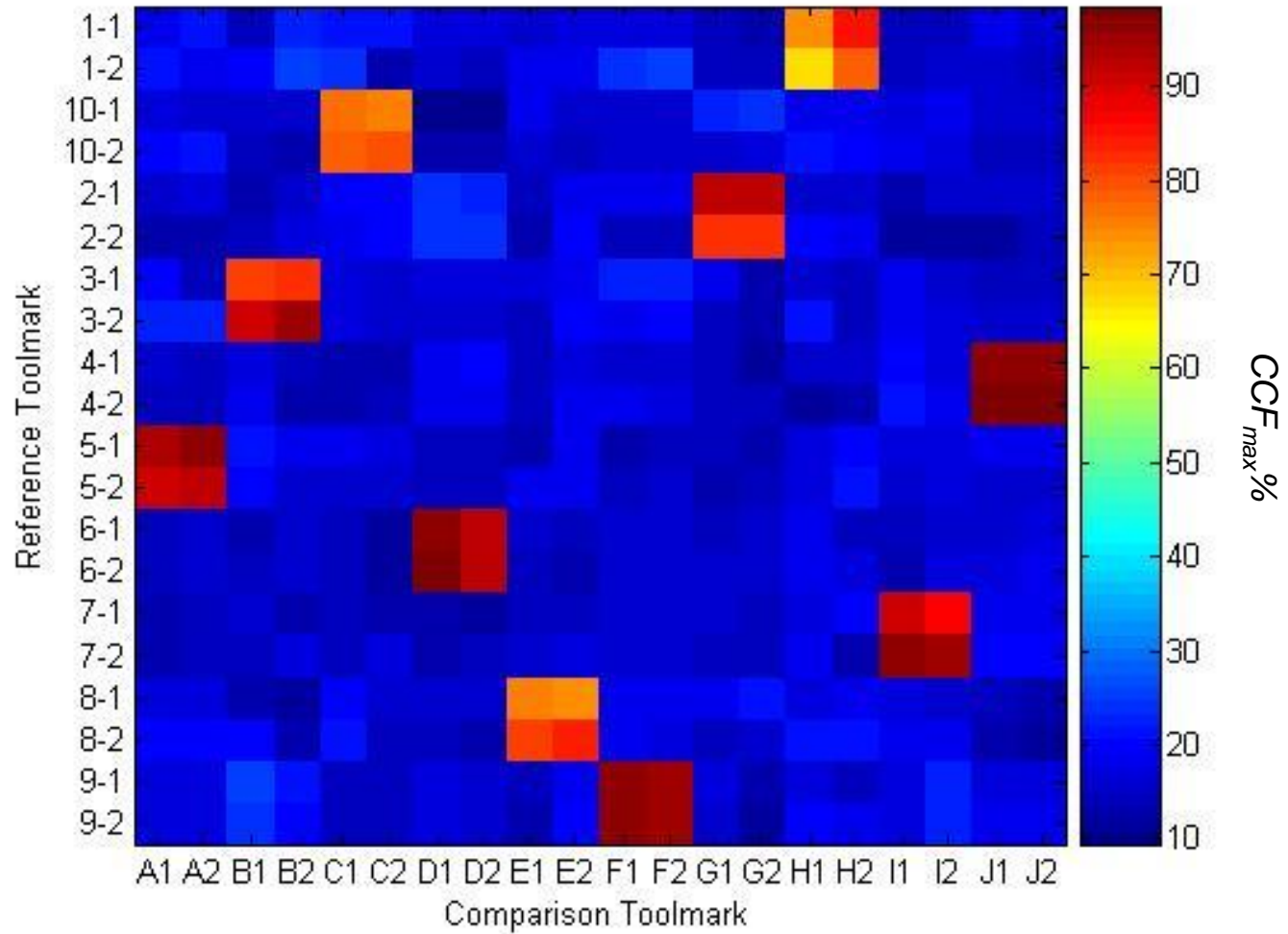$$CCV(A, B, \tau) = \lim_{L \to \infty} \left(\frac{1}{L} \int_{-L/2}^{L/2} Z_A(x) Z_B(x + \tau)\,dx \right)$$

Known Toolmark Distribution

Unknown Toolmark Distribution

μ= 16.60
σ= 3.06

μ= 88.71
σ= 8.60

Percentage

CCF_{max} Score

Unknown Toolmark Identification

10 Consecutively Manufactured Punches

- 10 consecutively manufactured punches from Western Forge (supplier to Craftsman Tools)

- 2 known marks per punch to establish known match/non-match distributions

- Hide punch identities, 2 more marks per punch (Unknown set)

- Identify unknown toolmarks using CCF_{max}

Punch – Impression Toolmark Creation

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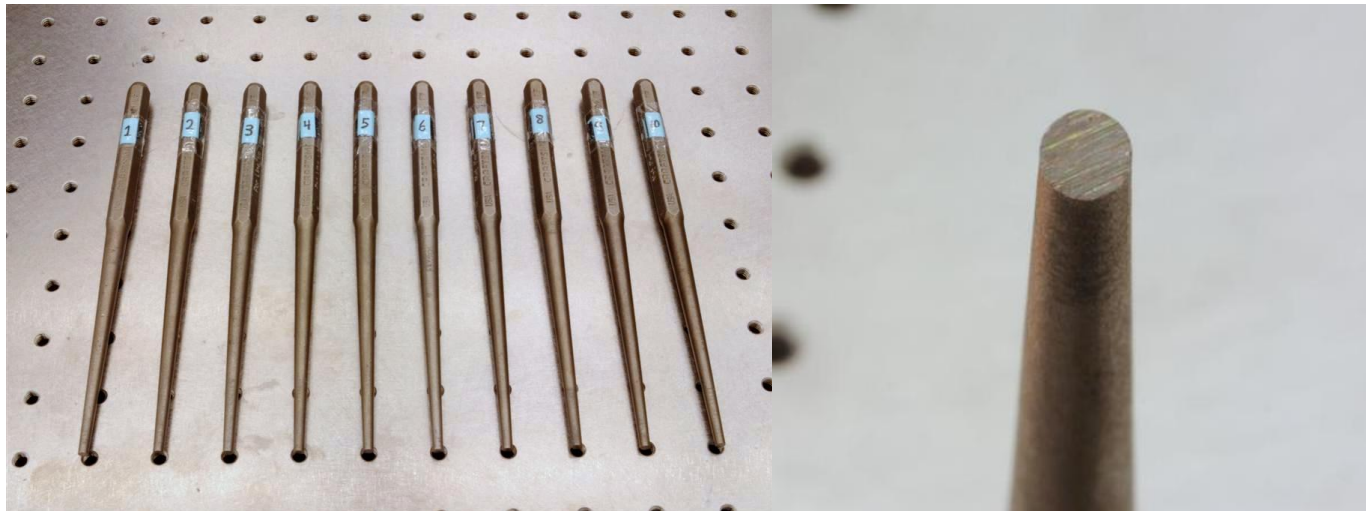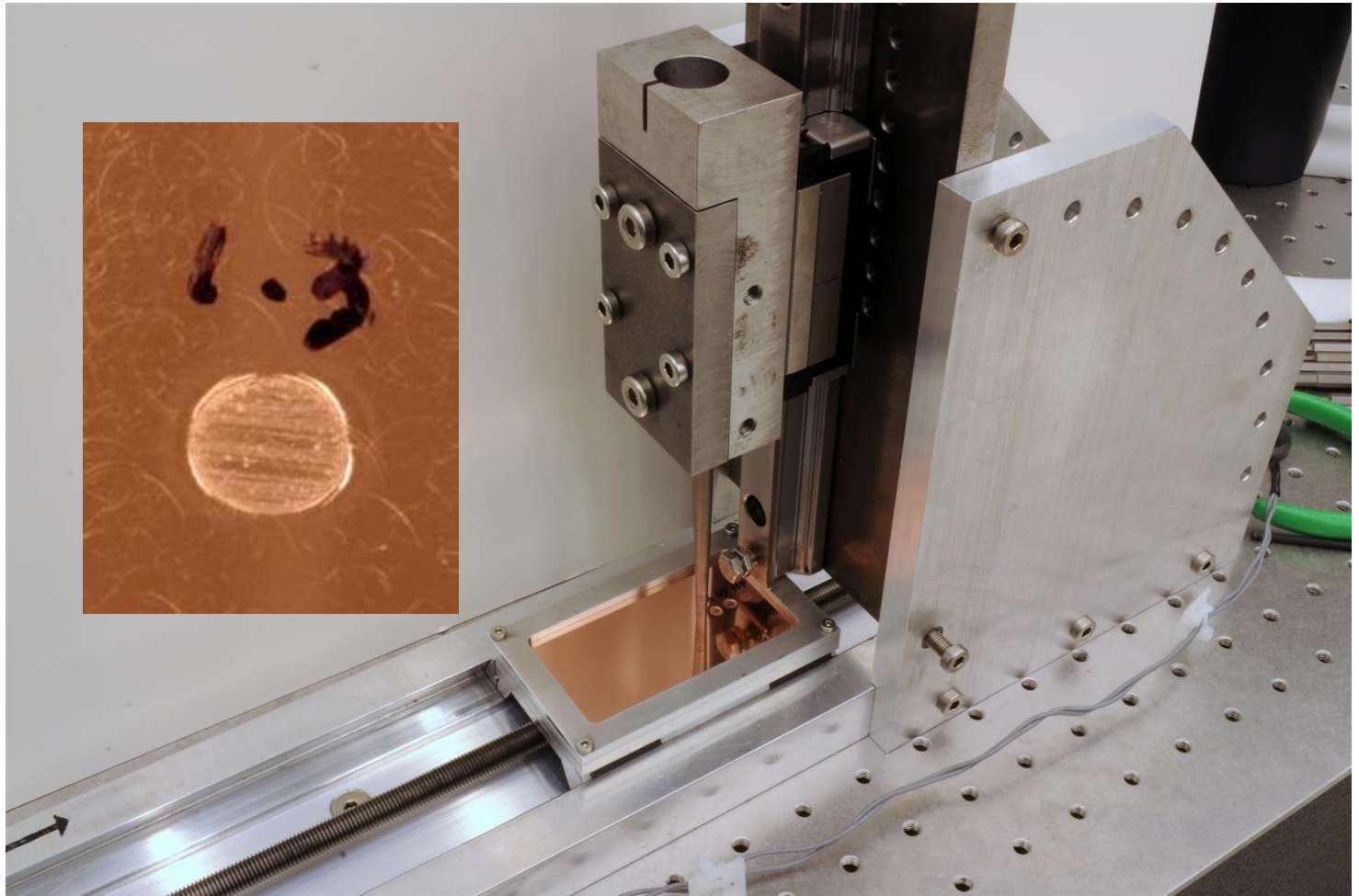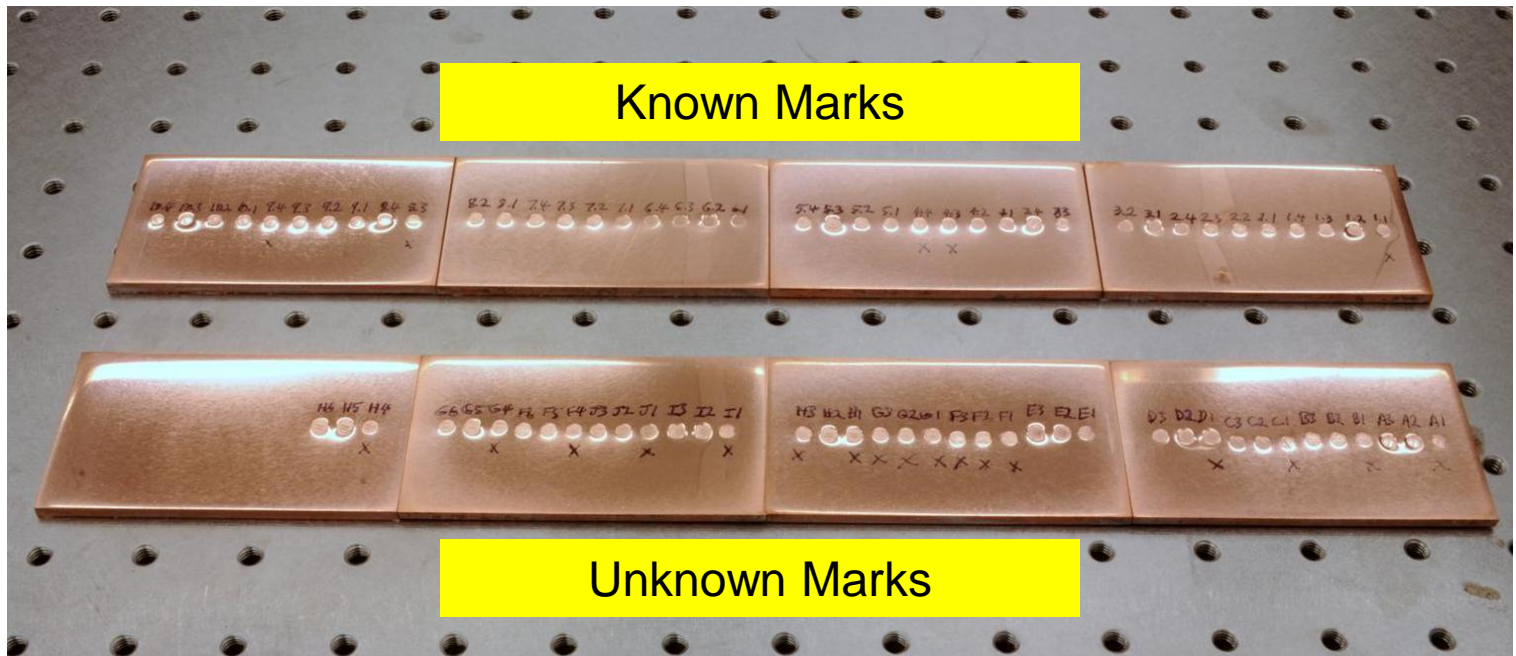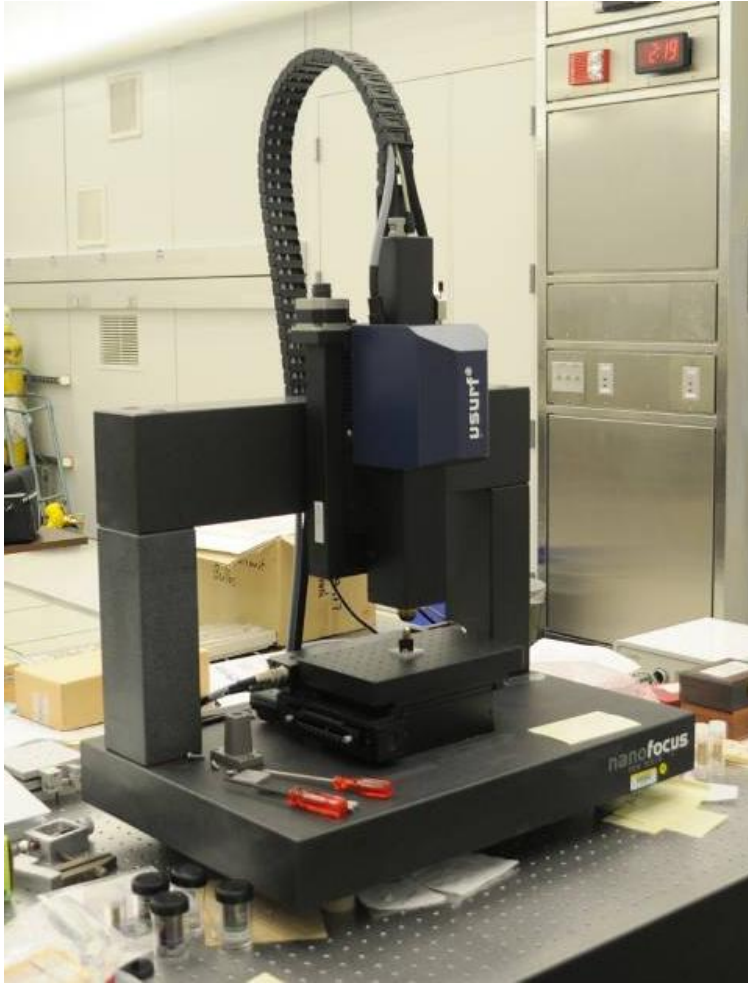
Punch – Impression Toolmark Creation

Punch – Impression Toolmark Creation
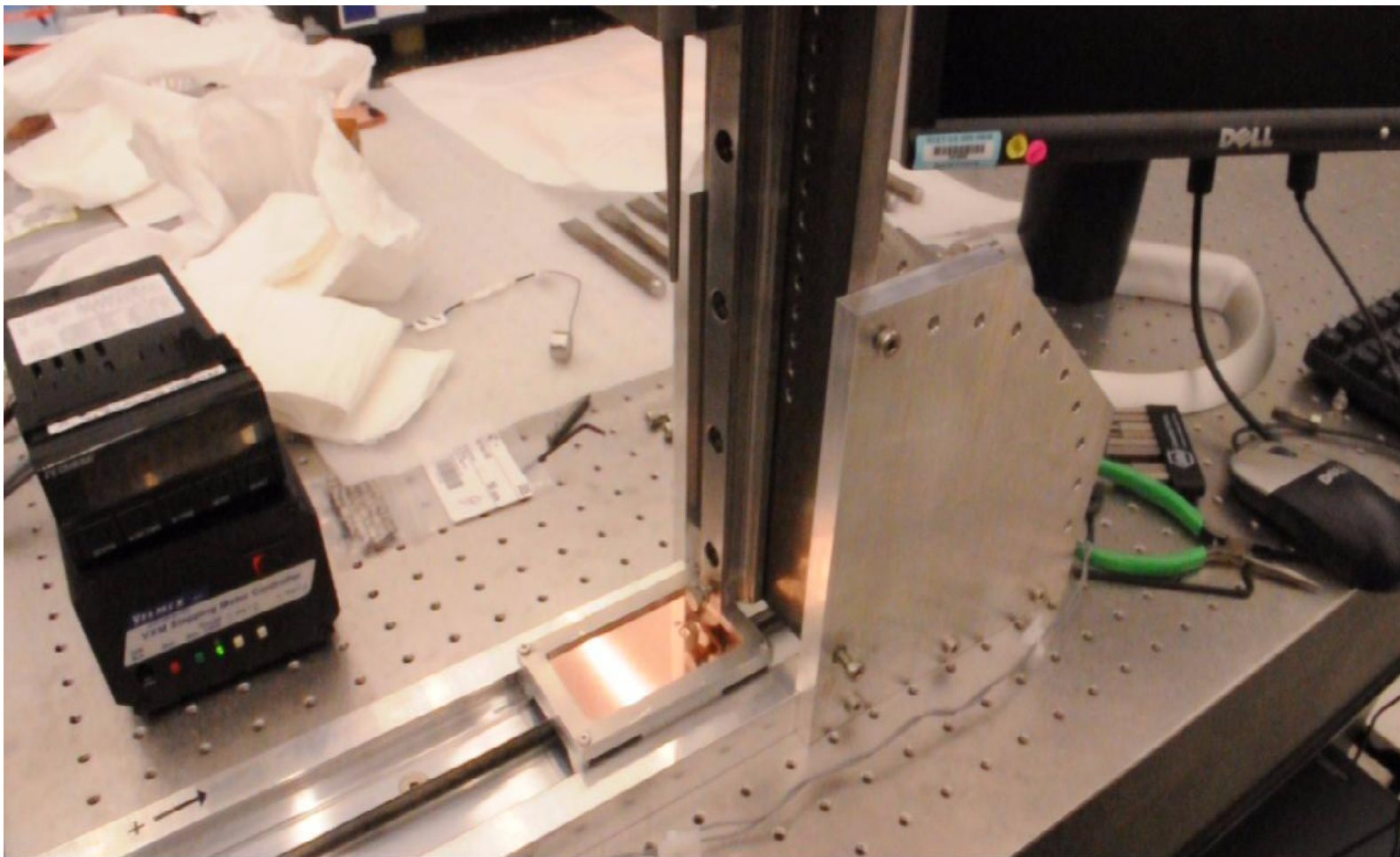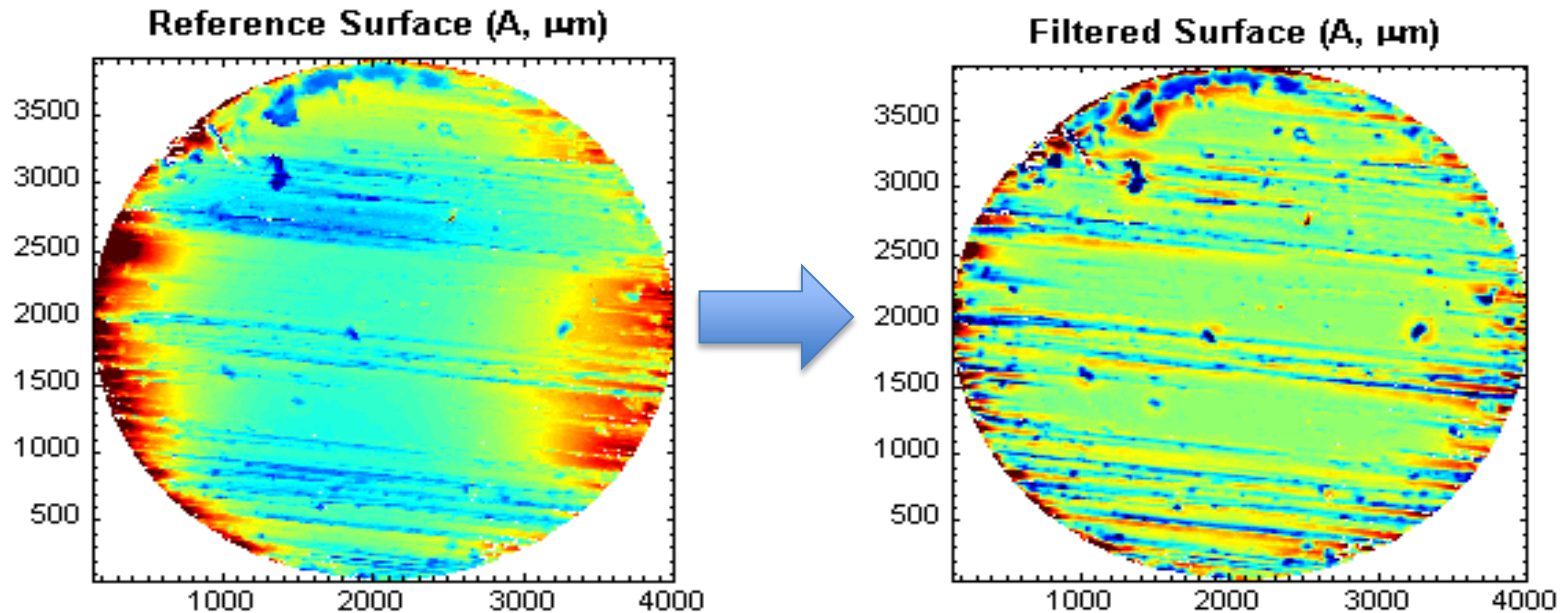
Punch – Measurement and Analysis

Parameters for data collection:

- 10 x objective
- Z direction step size: 0.2 µm
- Lateral Resolution: 3.125 µm
- Measured Dimension: 4.8 mm x 4.8 mm

Punch – Measurement and Analysis Filter Parameters

Reference Surface (A, µm)

Filtered Surface (A, µm)

Apply Gaussian filter with:
$\lambda_L = 400$ µm
$\lambda_S = 40$ µm
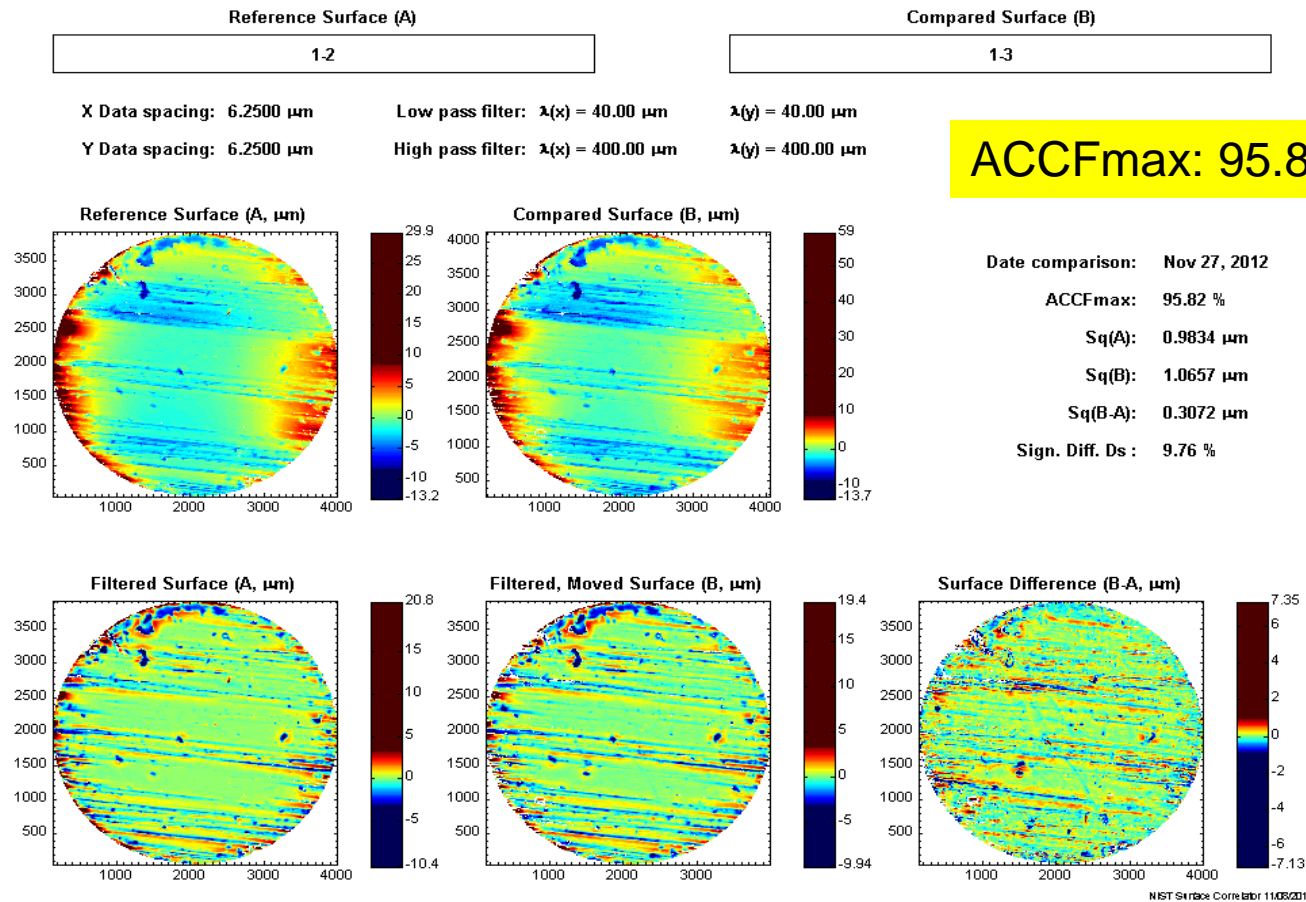
Three Dimensional Cross Correlation Function

$$\mathrm{ACCF}(A, B, \tau_x, \tau_y) = \frac{\mathrm{ACCV}(A, B, \tau_x, \tau_y)}{\mathrm{Sq}(A)\mathrm{Sq}(B)}$$

$$Sq = \left[\frac{1}{L_x L_y} \int_{-L_x/2}^{L_x/2} \int_{-L_y/2}^{L_y/2} Z^2(x, y) dx dy \right]^{\frac{1}{2}} \approx \left[\frac{1}{MN} \sum_{k=1}^{M} \sum_{j=1}^{N} Z^2(j,k) \right]^{\frac{1}{2}}$$

$$\mathrm{ACCV}(A, B, \tau_x, \tau_y) = \lim_{L_x L_y \to \infty} \left(\frac{1}{L_x L_y} \int_{-L_y/2}^{L_y/2} \int_{-L_x/2}^{L_x/2} Z_A(x, y) Z_B(x + \tau_x, y + \tau_y) dx dy \right)$$

Punch – Measurement and Analysis

- Final results of this study will be published in 2013.
- Below is an example of a matching correlation.

ACCFmax: 95.82%

Example of a non-matching correlation.

Reference Surface (A)

B2

Compared Surface (B)

2-3

X Data spacing: 6.2500 μm   Low pass filter: λ(x) = 40.00 μm   λ(y) = 40.00 μm

Y Data spacing: 6.2500 μm   High pass filter: λ(x) = 400.00 μm   λ(y) = 400.00 μm

ACCFmax: 13.38%

Date comparison: Nov 27, 2012
ACCFmax: 13.38 %
Sq(A): 1.0617 μm
Sq(B): 1.0823 μm
Sq(B-A): 1.4111 μm
Sign. Diff. Ds : 176.65 %

Reference Surface (A, μm)
Compared Surface (B, μm)
Filtered Surface (A, μm)
Filtered, Moved Surface (B, μm)
Surface Difference (B-A, μm)

NIST Surface Correlator 11/08/2012
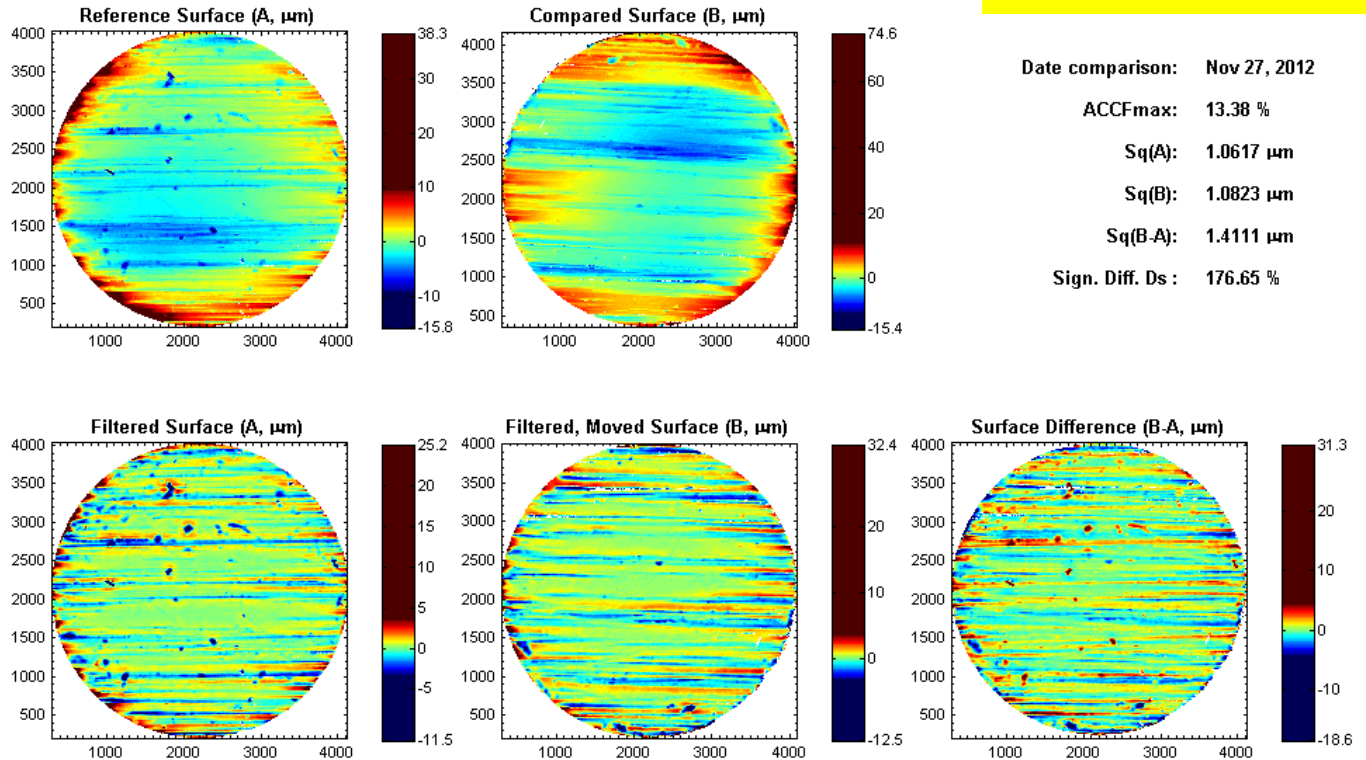
Conclusions

- 10 Consecutively Manufactured Chisels
  - The statistical distribution between the known matching and known non-matching are clearly separated with no overlap.
  - All 20 unknown striated toolmarks were correctly identified back to the chisel that created them.

- 10 Consecutively Manufactured Punches
  - To be determined

Thanks for your attention!

Questions?

alan.zheng@nist.gov

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