Contamination of µCMM stylus tips: on-machine inspection

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Abstract: Contamination adhered to the surface of a µCMM stylus tip significantly impairs the dimensional accuracy of a µCMM system. Regular cleaning of the stylus is essential to minimising the dimensional error but little data exists for determining appropriate cleaning intervals. This study investigates the build-up of contamination on the µCMM stylus tip during probing procedures. Experiments were conducted on surfaces with controlled contamination for 18 different conditions to study the impact of surface morphology and contact pressure. Contamination rate was observed to vary significantly, suggesting a probabilistic mechanism for contamination adhesion. As such, predictive methods may not offer a reliable threshold for determining cleaning intervals. To that end, a technique for on-machine imaging has been proposed to work in-line with the µCMM and inspect surface contamination as it builds. Debris of less than 300 nm in size was detectable.

Sample preparation

The samples involved in the study were precision surface references (Rubert & Co, Microsurf) representing surfaces made with various machining processes and calibrated surface roughness.

To reproduce consistence amount of contamination, each sample has undergone the following steps:

1. cleaned with isopropanol in an ultrasonic bath for 5 minutes;
2. immersed in used cutting fluid for 5 minutes;
3. left to dry in the air for 5 minutes,
4. cleaned again with isopropanol in an ultrasonic bath for 5 minutes.

Experiment setup

Equipment:
- Mitutoyo CMM Euro-C-A121210
- Renishaw probe head PH10M
- Renishaw modules TP200SF/LF
- Renishaw styli, ruby sphere

Experiments:
- Set 1: low contact pressure
- Set 2: high contact pressure

Contamination detection:
- Hitachi H-2600N ESEM

Fig 3. Probing setup in (a) experiment set 1 with parallel orientation and (b) set 2 with perpendicular orientation

Table 1. List of variables involved in the study.

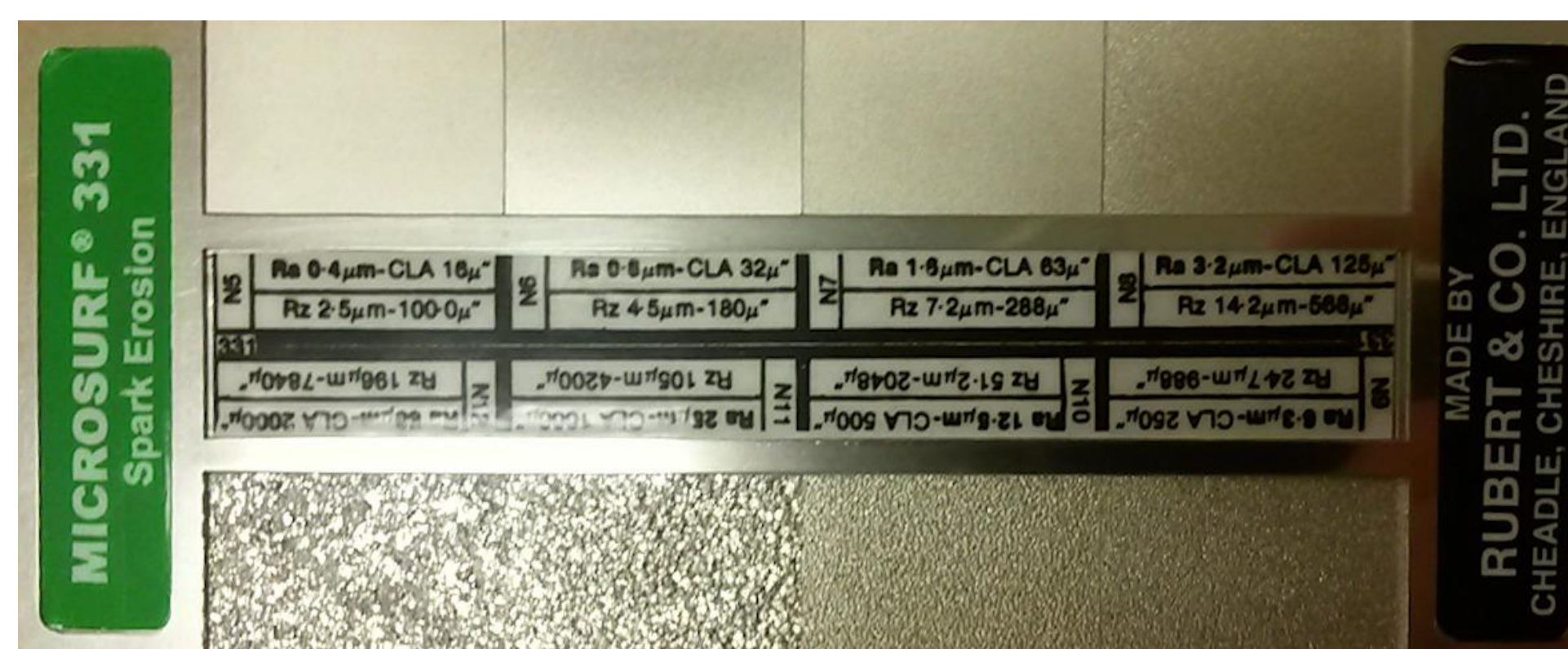| Variables	Values
Machining process	grinding, EDM, milling
Surface roughness/µm	0.4, 0.8, 1.6, 3.2
Stylus tip diameter/mm	0.3, 1.0
Contact pressure level	low, high

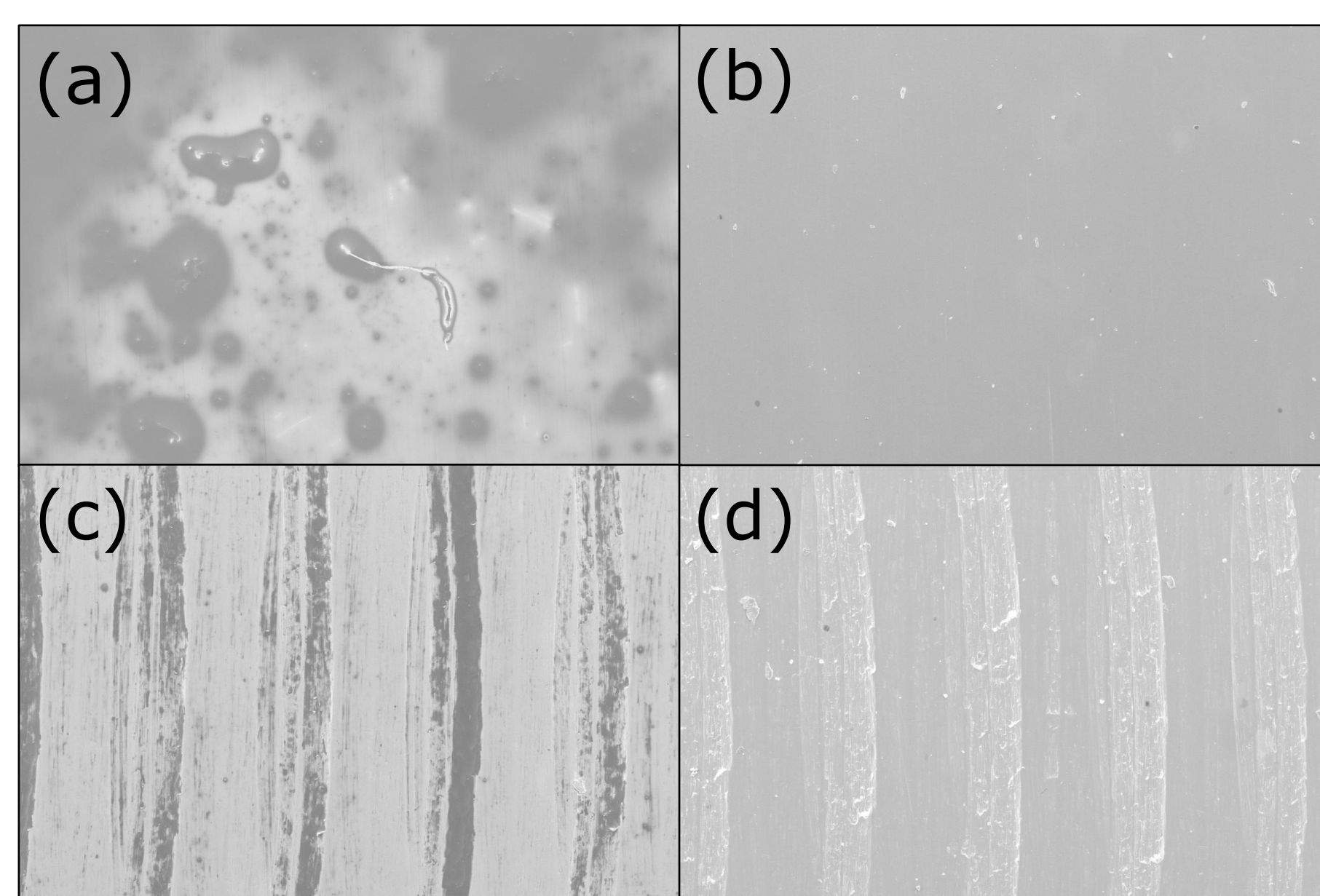Fig1. EDM samples with calibrated surface roughness values.

Fig 2. SEM images of ground finish (a) after step 2, (b) after step 4 and milled finish (c) after step 2, (d) after step 4.
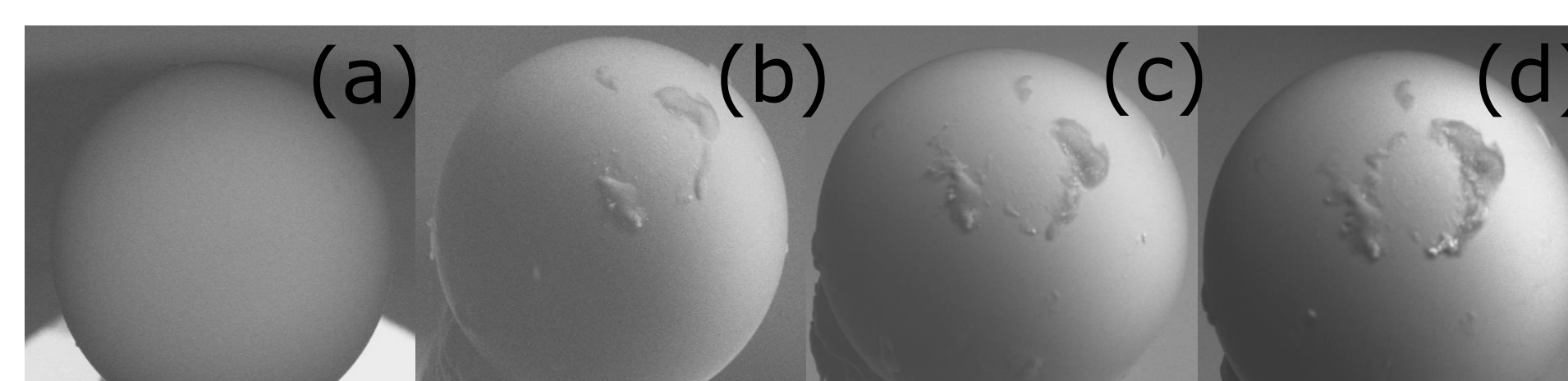

Fig 4. Stylus tip of 0.3 mm diameter (a) before probing, (b) after 3rd probing round, (c) after 8th probing round and (d) after 1st probing round on a new location.
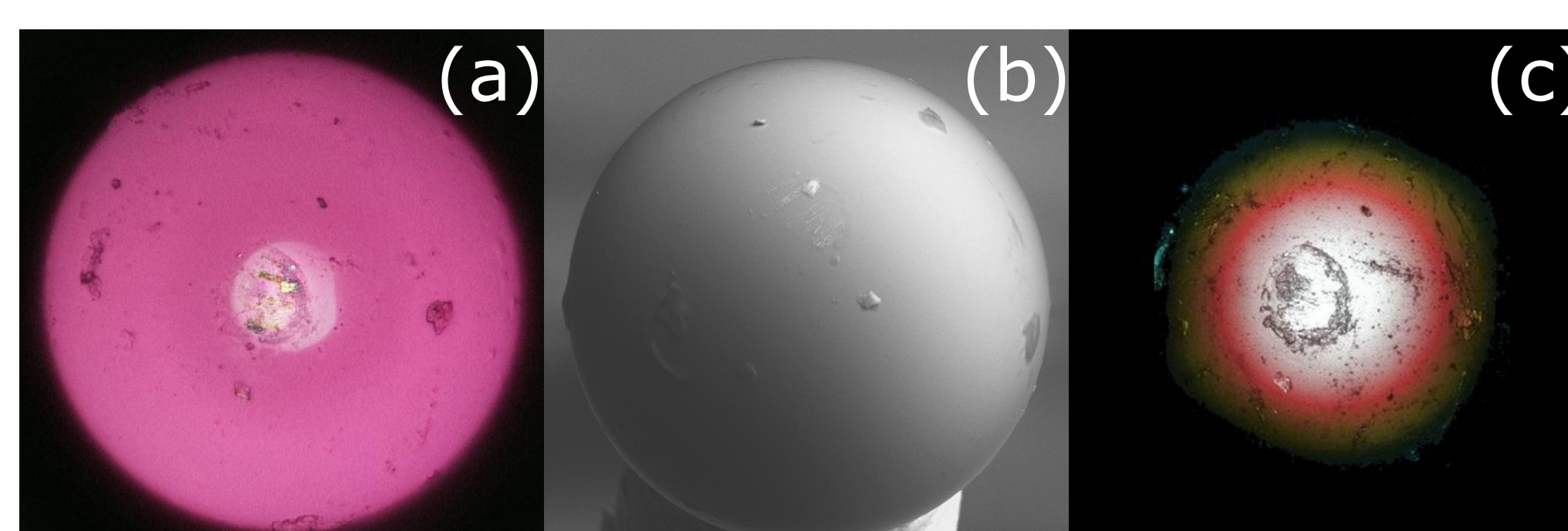

Fig 6. Images of a 0.3 mm diameter stylus tip obtained using (a) proposed solution at 20X, (b) SEM and (c) confocal microscope at 50X.

Contamination rate

Progression of contamination

Contamination was observed to build up over multiple contacts of the same location, plateauing after 3-5 contacts

Statistic influence of machining process & surface roughness

- Large variance between & within experimental conditions.
- Stochastic nature in debris adhesion.
- Variance in build-up rate more strongly affected than average rate.
- Higher contact pressure correlated with higher contamination rate.
- Sometimes 5% of stylus tip was contaminated after only 50 contacts.

On-machine stylus inspection

Principle:

Epi-illumination microscope
Focus stacking algorithm

Capability:
- Imaging of full hemisphere
- On-machine inspection
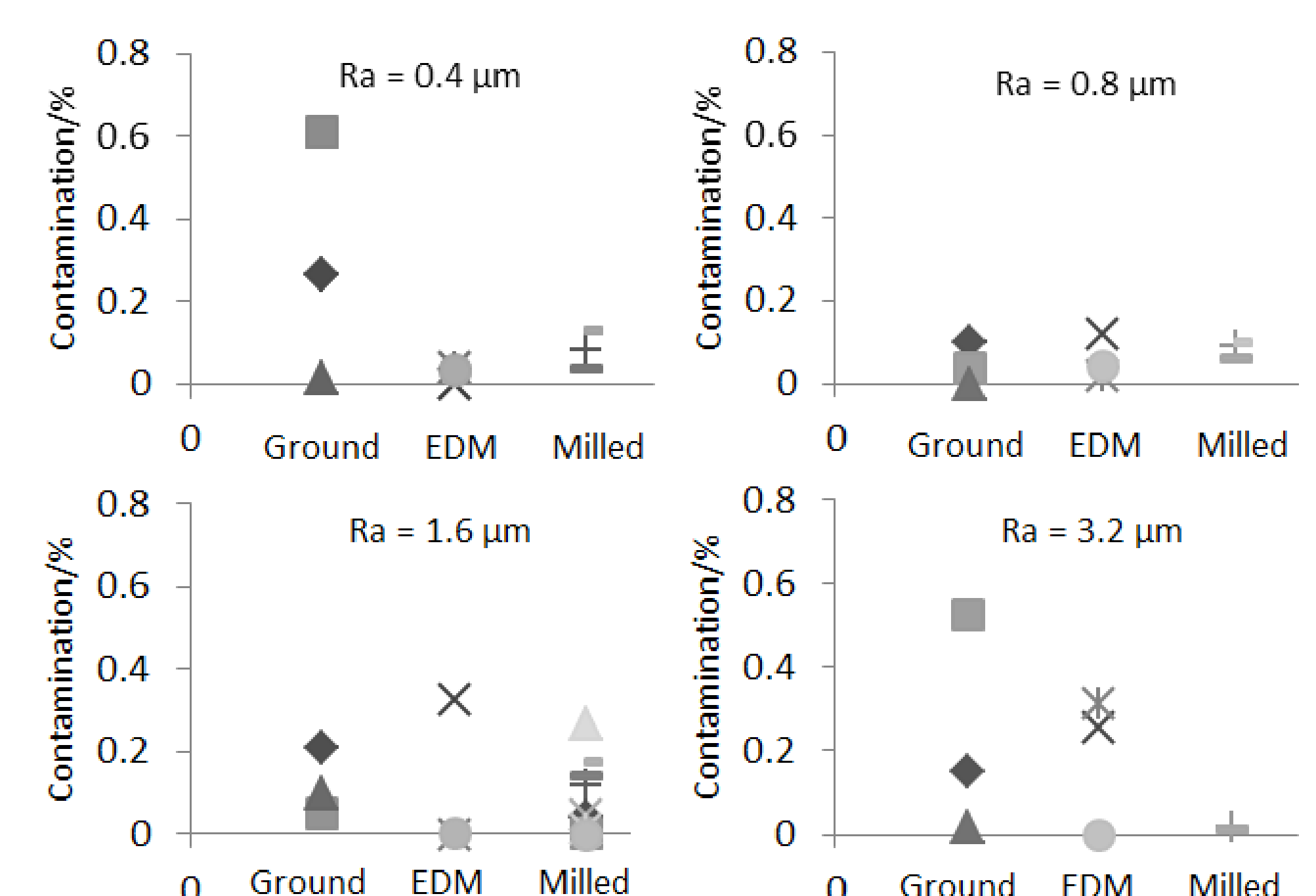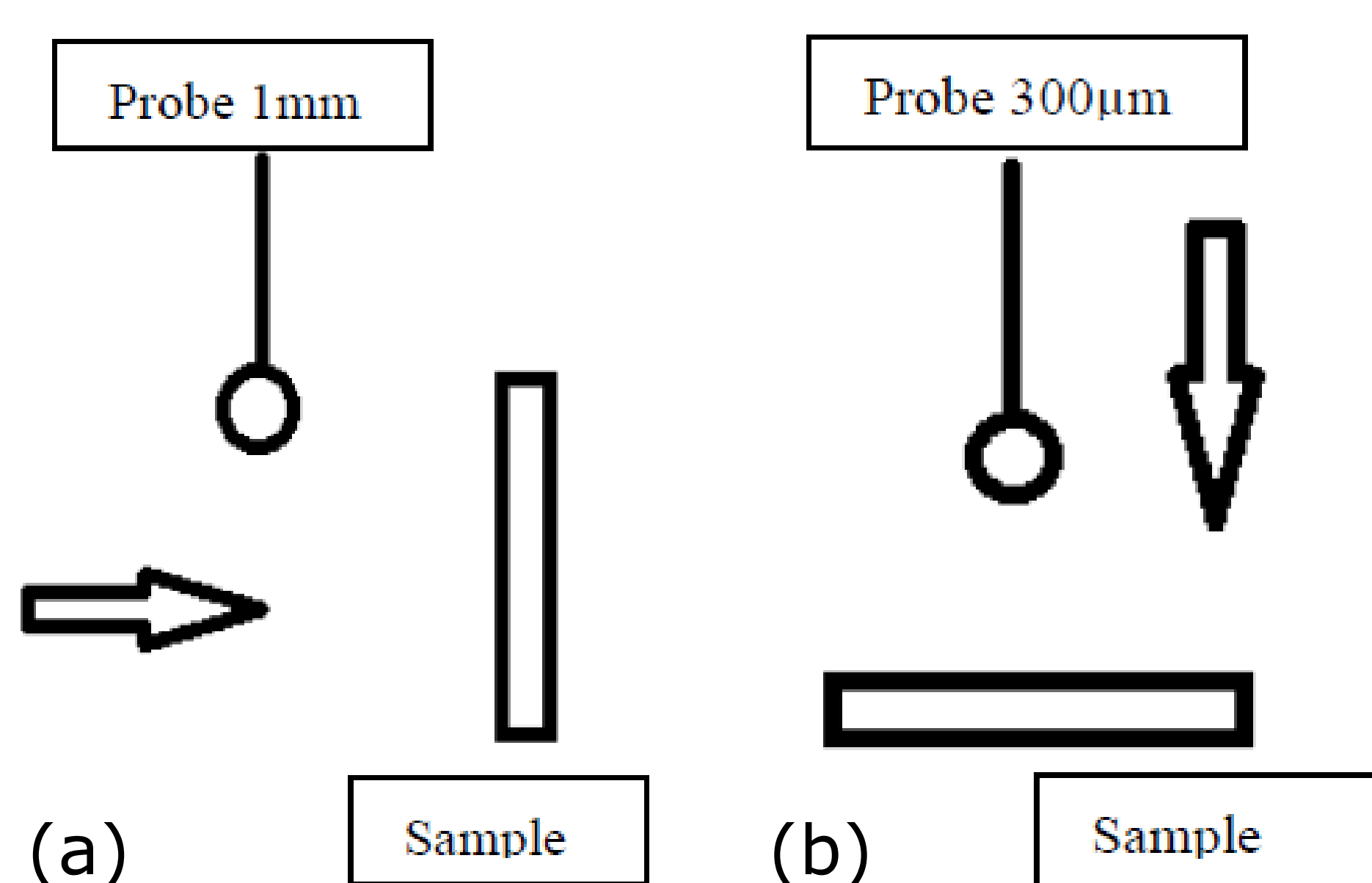- Resolution on par with SEM and confocal with same field of view
- Cost effective

Fig 5. Stylus contamination after probing various samples: each data point representing contamination after 50 contacts

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