University of Southampton

Are we searching deep enough?

An investigation of wear and corrosion debris from CoCrMo taper junctions

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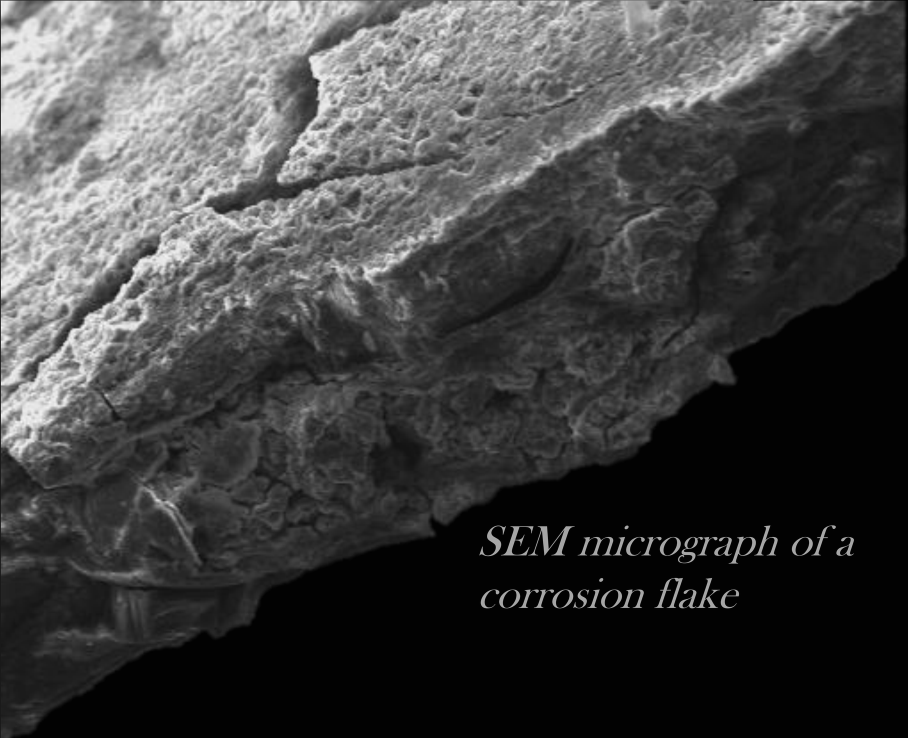
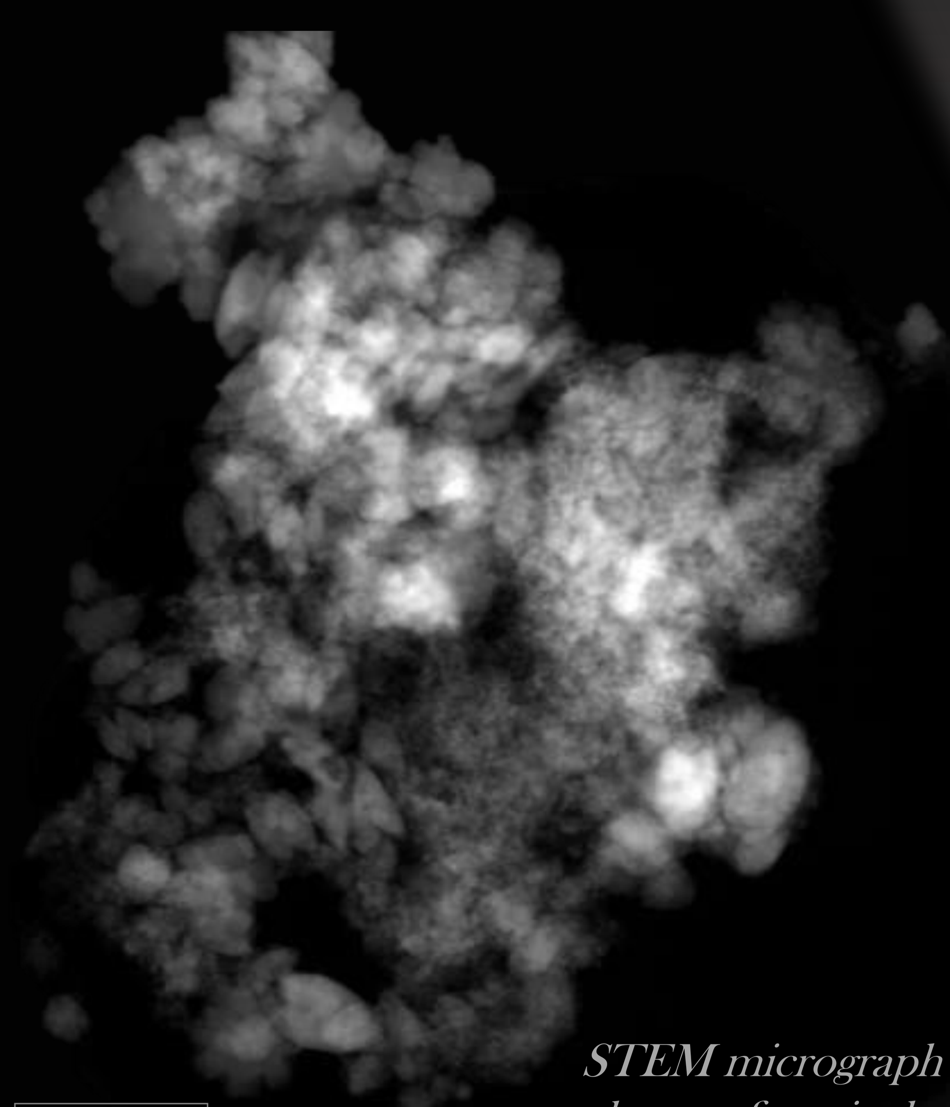


SEM micrograph of a corrosion flake



STEM micrograph of a cluster of particulate debris embedded in a matrix

Introduction and Methods

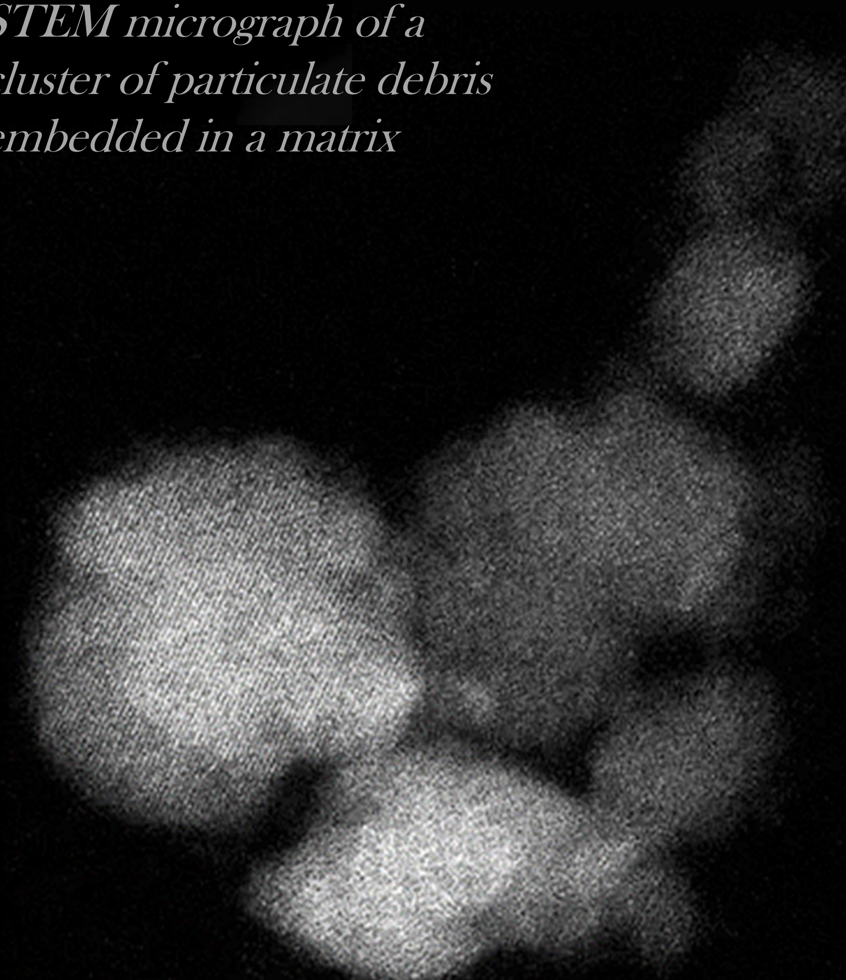
The wear and corrosion of taper junctions and the release of metallic particles and ions have been associated with adverse local tissue reactions, independently of the bearing surfaces. These solid and soluble products are suggested to be more reactive in-vivo than bearing debris.[1] Any increased reactivity would result from a difference in particle geometry and chemistry, which are influenced by the wear mechanisms and electrochemical conditions from which they were generated.

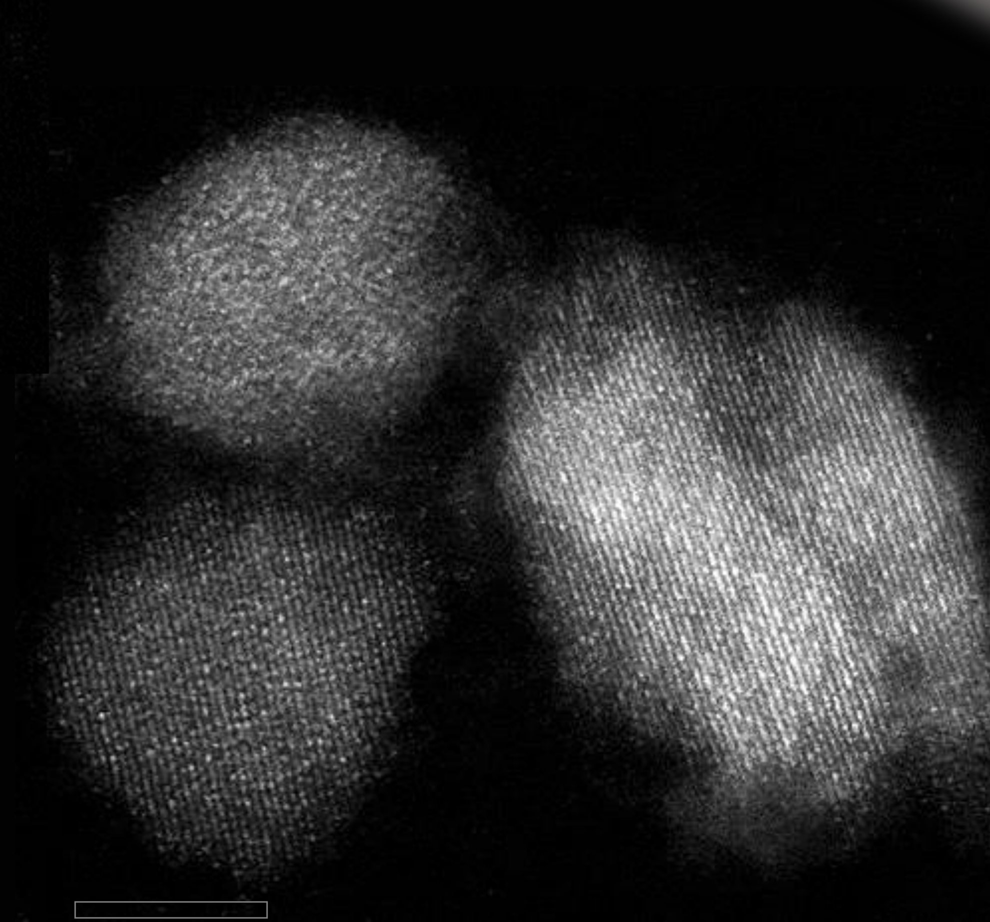
The study aimed to determine the nature of wear and corrosion products retrieved from around two revised CoCrMo tapers junctions (CPT/Adept and CPT/BHR). Scanning electron microscopy (FEI Quanta 200, SEM) and energy dispersive X-ray analysis (EDX) revealed the organo-metallic nature of the 'as retrieved' corrosion flakes.

High resolution imaging and chemical characterisation was performed using a combination of transmission electron microscopy (Tecnai T12 TEM, operated at 120 kV) and scanning transmission electron microscopy, with a cold-FEG JEOL ARM 200F STEM, operated at 200 kV, and fitted with EDX.

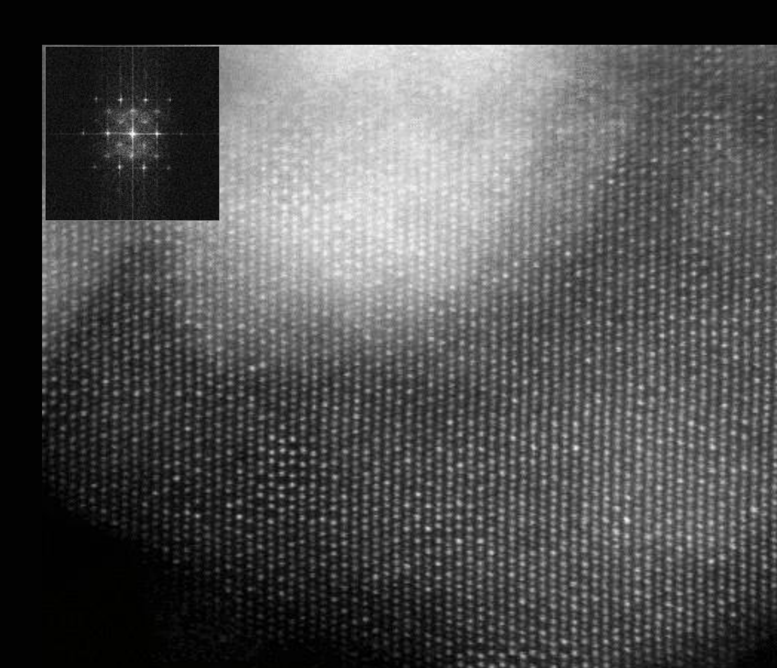
The conditions for high resolution imaging (i.e. clean particles, released from the biological matrix) were achieved with a chemical treatment (incubation with 12N KOH, at 37°C, for 48h).

A total of 206 particles from 40 STEM micrographs were used for particle size distribution (PSD) and chemical characterisation with EDX.



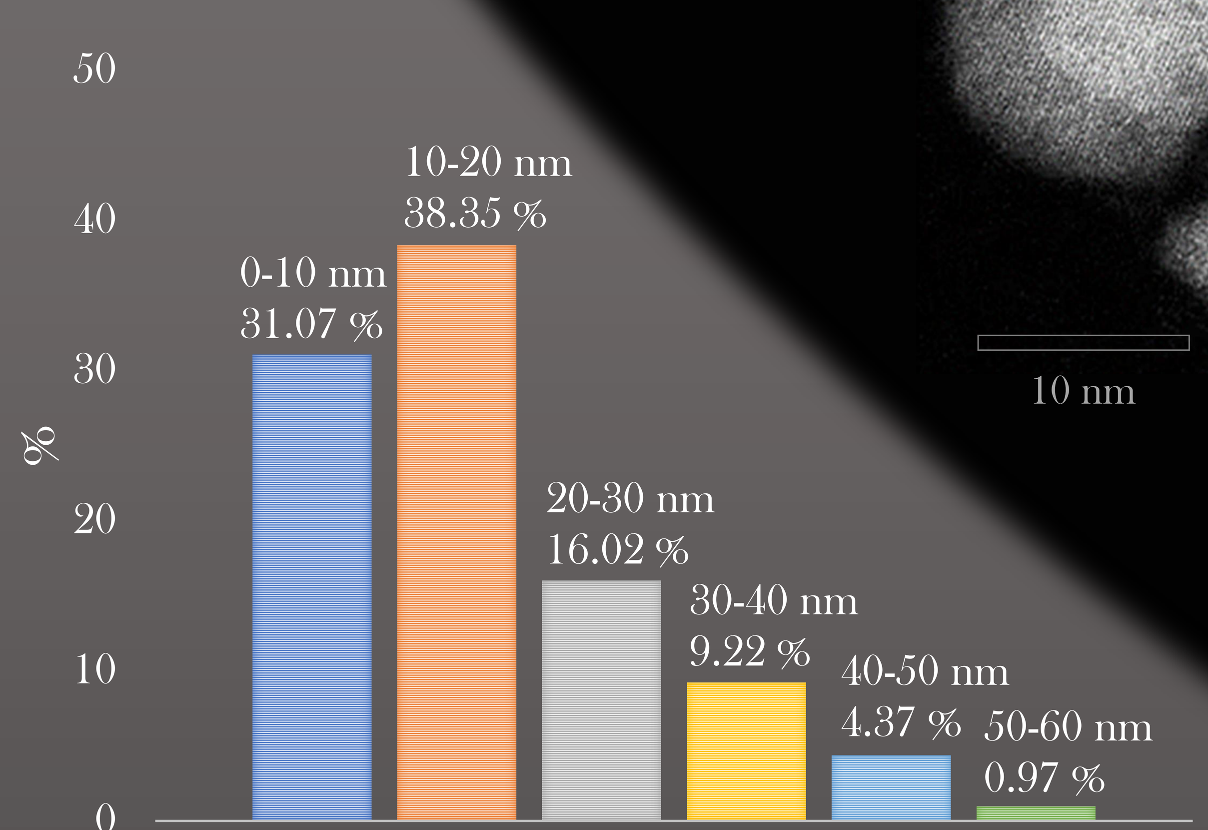


STEM micrographs of nanosized crystalline particles

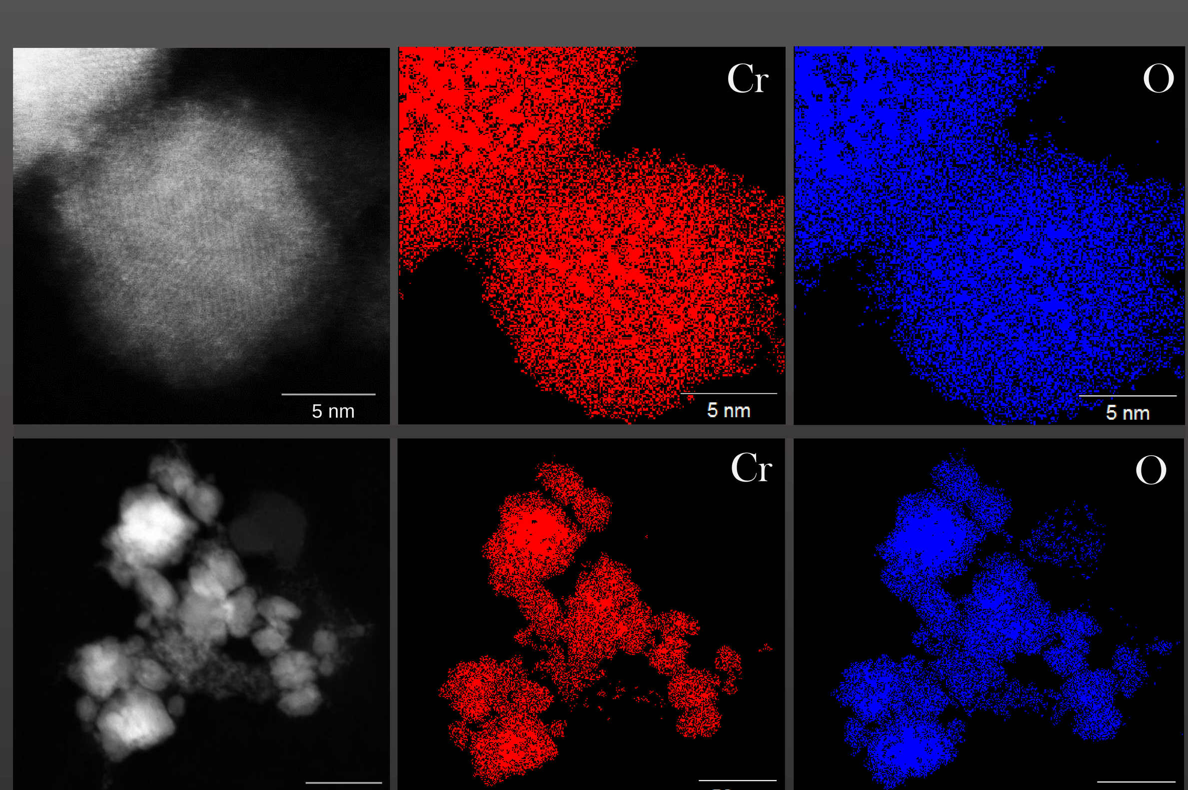


HR-STEM micrograph depicting the atomic planes of a crystalline particle

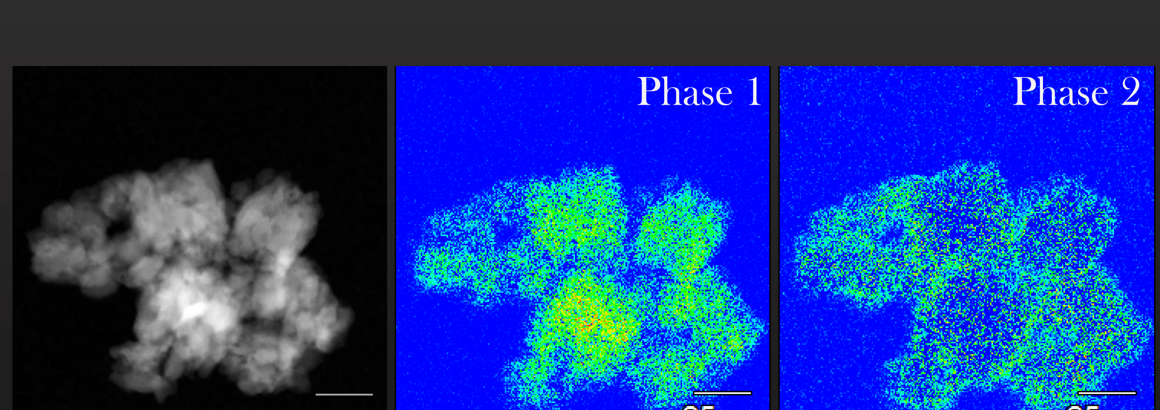
Results



Size distribution (PSD) of particles from taper junctions



Elemental composition – STEM/EDX Mapping



Phase distribution – STEM/EDX Mapping with Compass Function

Proportion of Co, Cr and Mo

Metal particles		
Element line	Element Wt.%	Wt.% error
Cr K	87.06	±0.65
Co K	11.93	±1.44
Mo K	1.01	±0.01

Phase 1 – metal particles		
Element line	Element Wt.%	Wt.% error
Cr K	89.61	±0.53
Co K	8.93	±1.07
Mo K	1.46	±0.27

Phase 2 – bio corona		
Element line	Element Wt.%	Wt.% error
Cr K	81.66	±0.67
Co K	17.72	±1.48
Mo K	0.62	±0.28

Conclusions

The wear and corrosion flakes collected from around revised CoCrMo taper junctions have an organo-metallic structure and consist of nanosized metallic particles embedded in a biological matrix.

A comprehensive understanding of the metal debris requires the fragmentation and digestion of the surrounding matrix and the release of the small building blocks. Of the three main elements found in the CoCrMo alloy, Cr has the major proportion in the particles (mean 87.06%), followed by Co and Mo. The composition of the biological matrix (phase 2) varies among the clusters and it generally shows an increased Co content (8.93% vs 17.72%). This can be attributed to cobalt's solubility and affinity to bind to proteins.

The study is the first to show the real size of the particles released from taper junctions and provides reliable evidence of particulate debris as small as 3 nm, which cannot be always investigated with low resolution techniques. With STEM, large corrosion flakes, consisting of clustered nanoparticles embedded in a diffuse matrix, and individual nanosized particles could be imaged.

The majority of the particles were crystalline and contained mainly Cr and O, with traces of Co and Mo. These results suggest that particles are chromium oxides, with a size distribution shifted towards the low range (size range: 2.77 nm - 59.77 nm, mean d_{max}: 17.41 nm), in comparison to particles released from the bearing surfaces (5 nm - 800 nm).[2-6]

References: [1] Langton et al, Bone Joint J, 2013, 95(B):S28; [2] Doorn et al, J Biomed Mater Res, 1998, 42(1):103-111; [3] Catelas et al, Proc Inst Mech Eng H, 2006, 220(2):195-208; [4] Pourzal et al, Wear, 2011, 271(9-10):1658-1666; [5] Billi et al, Clin Orthop Relat Res, 2012, 470(2):339-350; [6] Kavanaugh et al, 2013, STP 1560

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