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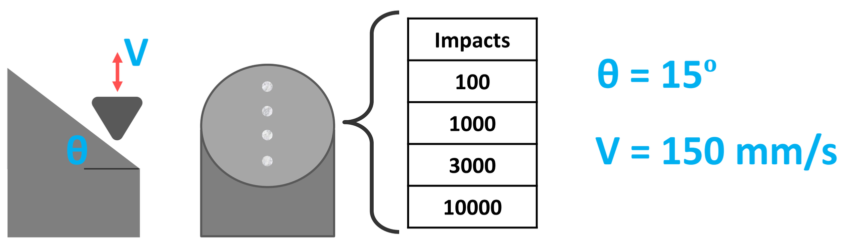
Introduction

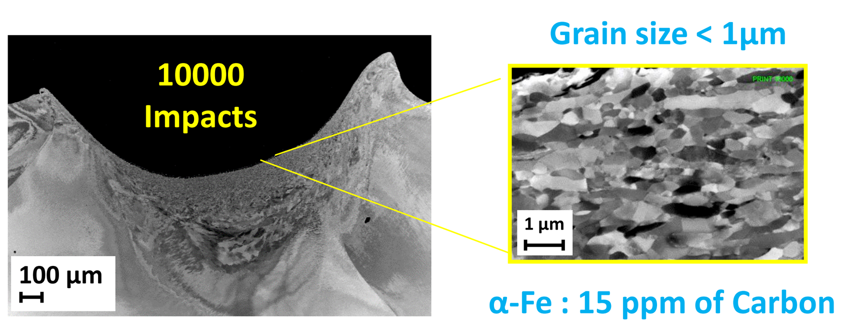
Mechanical surface treatments confer better local mechanical properties against wear or fatigue service conditions. In the case of impact-based treatments, a local microstructure's refinement in the near surface is produced by a severe plastic deformation of the material, leading to a **progressive reduction in the grain size over a few tens of microns**, and consequently an increase of the hardness and tribological properties. These zones are commonly known as Tribologically Transformed Surfaces (TTS). In this project **Micro-percussion tests** are implemented to obtain TTS surfaces on **pure iron samples**. For this procedure every impact is made at the same position by a rigid conical indenter, controlling the number, angle and velocity of impacts.

The main purpose of this work is to establish a complete description of the transformed microstructures; to understand the mechanisms involved in the formation and evolution of TTS; and discuss the correlation between grain size, dislocation density and the mechanical properties gradient in the deformed region. According to this, **EBSD crystal orientation mapping** has been used to determine the size of the plastically deformed zone, the grain size distribution, and an estimate of the GND density gradient in the cross section of the impacted zone. Moreover, **micro-pillar compression tests** are realized in the same EBSD region in order to quantify the evolution of mechanical properties and match these results with the acquired microstructure data.

Impact based surfaces - TTS

Micro – Percussion Test

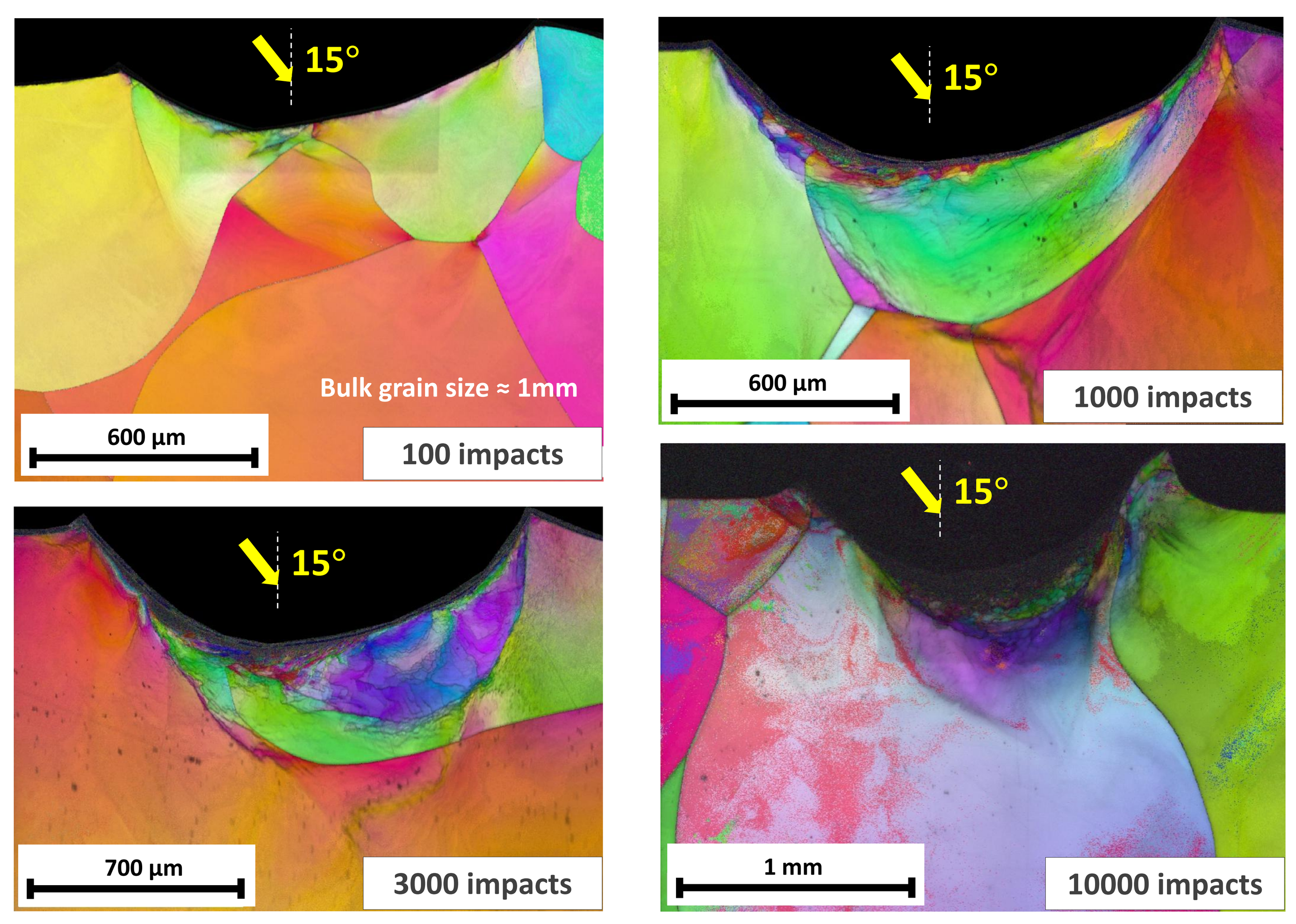




A pure Iron sample is impacted repetitively by a conical tungsten carbide tip. Four prints are created using a different amount of impacts. The angle and the impact velocity are controlled. The microstructure in the near surface is refined below a grain size of 1 µm.

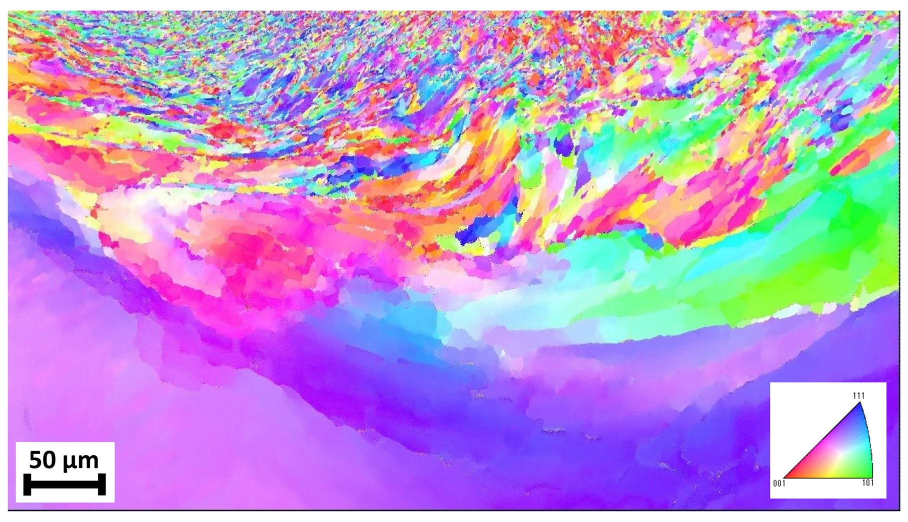
EBSD characterization of the Tribologically Transformed Surfaces (TTS)

TTS Evolution according to the amount of impacts

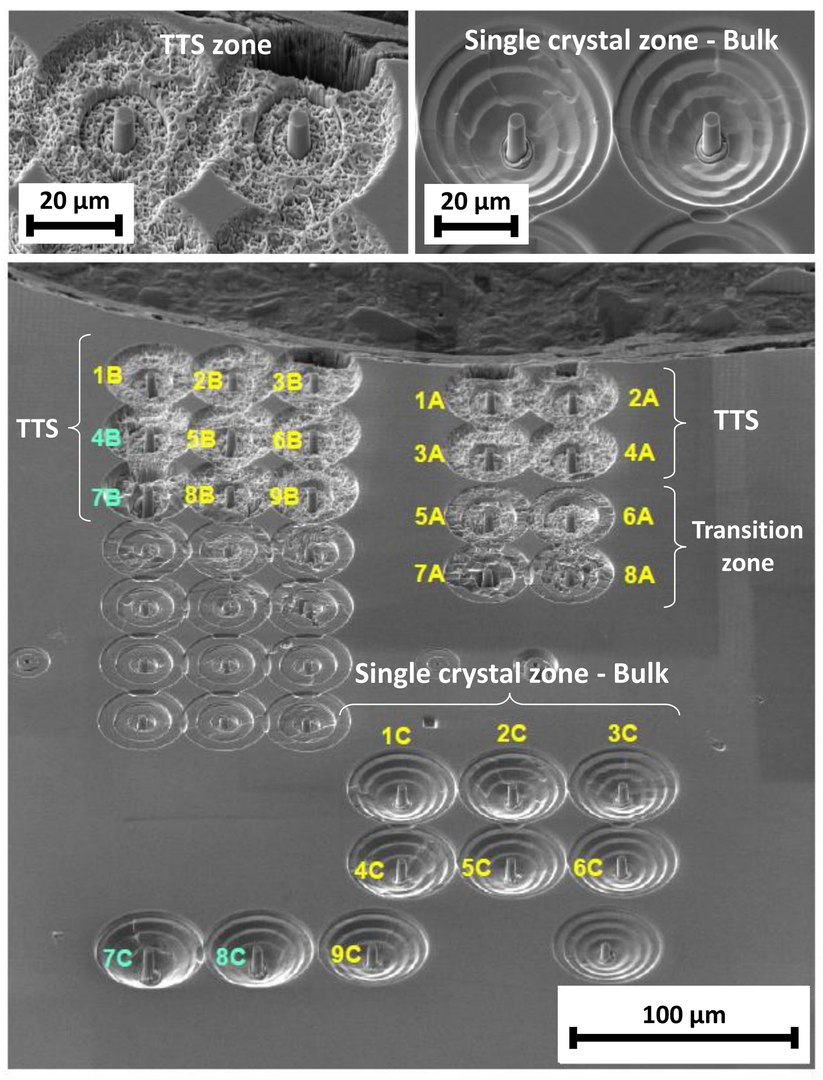


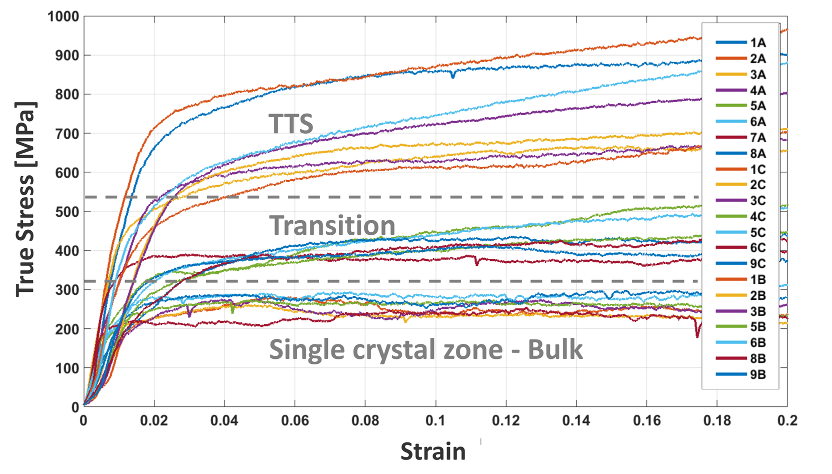
EBSD on the 10000 impacts print

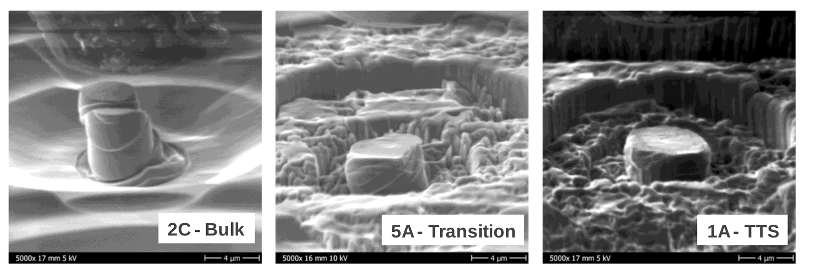
The 10000 impacts print exhibits the largest TTS thickness (~150 µm), presenting an interesting grain size gradient and consequently the increase of mechanical properties on the near surface. A more detailed EBSD map (3 µm step size) is effectuated in order to estimate the GND density and grain size distribution and compare them with the micro-pillars compressions tests on the same region.



µ-pillars compression: gradient of mechanical properties



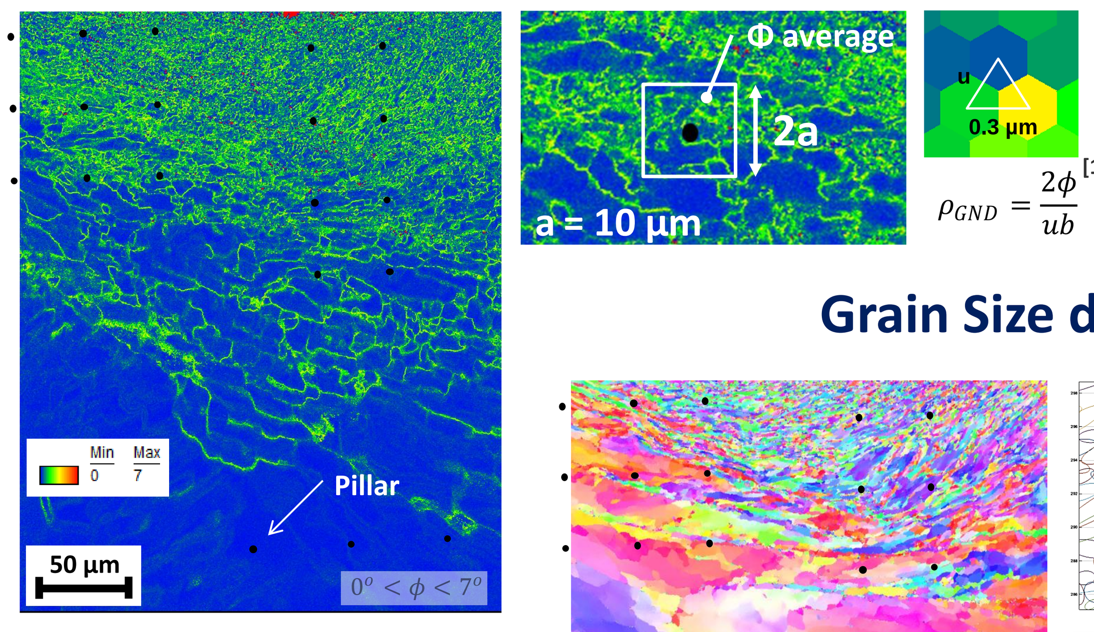




Pillars of 4 µm diameter and 8 µm height are fabricated (FIB) and compressed in different positions with respect to the near surface. The true stress-strain curves present a gradient on the yield stress. Pillars in single crystal deform in well oriented slip planes, contrary to the polycrystalline pillars, where deformation is completely homogeneous.

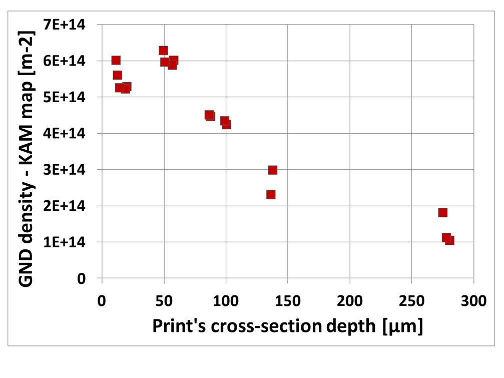
GND density and grain size distribution

Kernel Average Misorientation

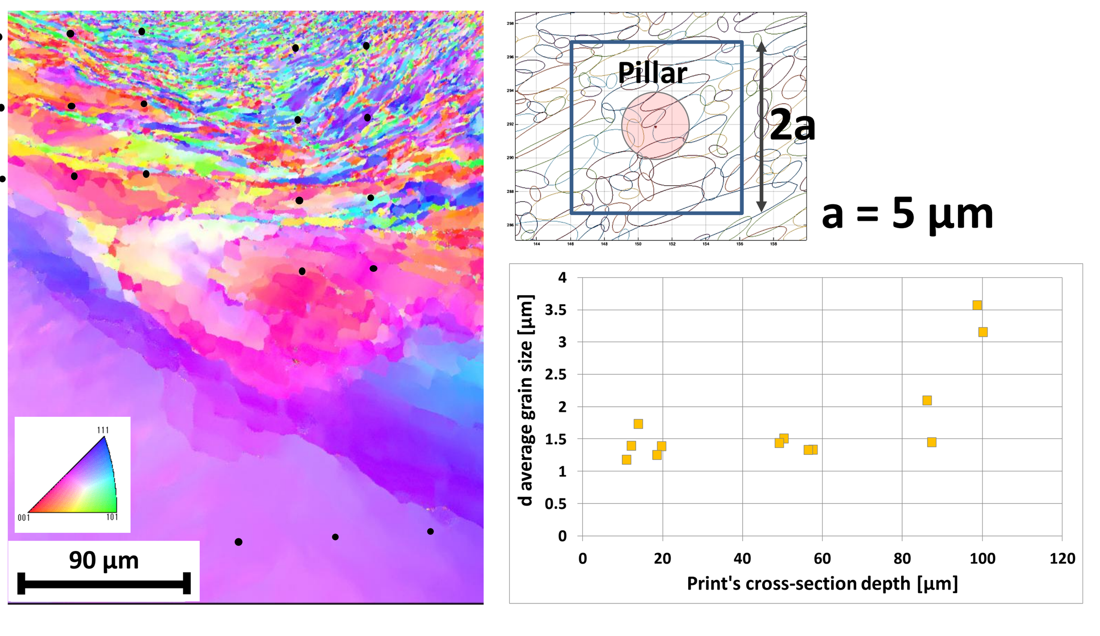


$$\rho_{GND} = \frac{2\phi}{ub}$$ [1]

■ The GND density is estimated from the KAM map in the surrounding area of each pillar. An average misorientation angle (ϕ) is calculated for this purpose.
■ The average grain size is estimated for each pillar.

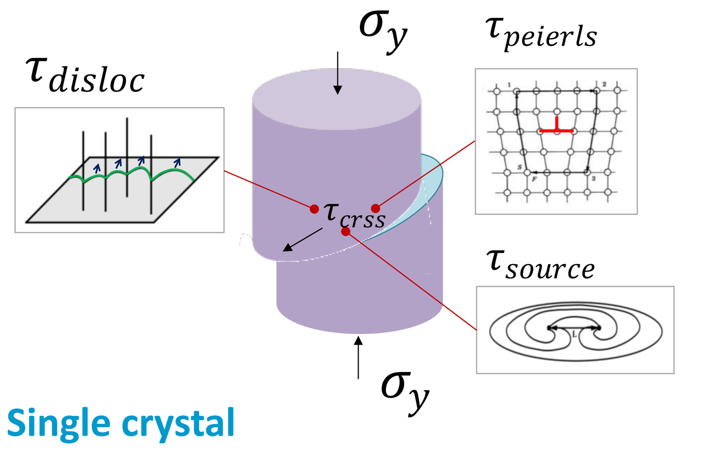


Grain Size distribution



Discussion and Conclusions

	Constant	Units	Value
Pure Iron properties	Burgers vector	b [pm]	248.25
	Young's Modulus	E [GPa]	211
	Poisson's Coeff	v	0.3
	Shear's Modulus	G [GPa]	81.15
$\tau_{peierls} = \left(1 - \frac{T_t}{T_c}\right)\tau^*_{0_{edge}}$	Test temperature	Tt [K]	298
	Critical temperature	Tc [K]	325 [2]
$\tau_{disloc} = \alpha G b\sqrt{\rho + \rho_\Delta}$	Alpha (0.1 - 1)	α	0.2 [3]
$\rho = \rho_0 + \rho_{GND}$	SSD density α-Fe	ρo [m-2] [4]	1.20E+14
$\tau_{source} = KG\frac{ln(\bar{\lambda}/b)}{\bar{\lambda}/b}$, $\bar{\lambda} \approx D$	Source-strengthening constant	K	0.1 [5]
$\sigma_y = \sigma_o + \frac{K_{h-p}}{\sqrt{d}}$	Constant K_{h-p}	K [MPa m0.5]	0.44 [6]



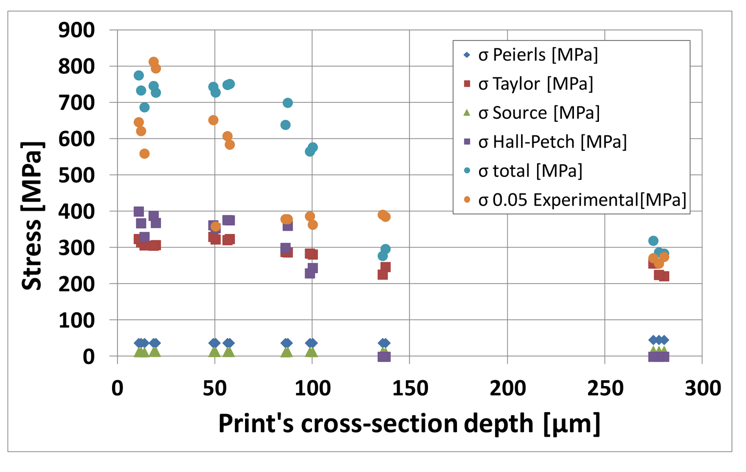
Orientation	Schmid Factor (m)
100	0.4082
101	0.4082
111	0.2722
Polycrystal	0.3333

Single crystal

$$\tau_{crss} = \tau_{peierls} + \tau_{disloc} + \tau_{source} \;\text{[5]} \Rightarrow \sigma_y = \frac{\tau_{crss}}{m}$$

Poly-crystal

$$\tau_{crss} = \cdots + \tau_{h-p} \Rightarrow \sigma_y \cong 3\tau_{crss} = 3\left(\tau_o + \tau_{h-p}\right) = \sigma_o + \frac{K_{h-p}}{\sqrt{d}}$$



Conclusions

■ The µ-compression tests expose the mechanical properties increase due to the microstructure refinement.
■ The EBSD map data permits to assess an estimate of the GND density evolution and grain size distribution and correlate this information with the experimental results using theoretical models.

Acknowledgement

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