Multi-Scale *In Situ* Studies of Deformation Mechanism of L-PBF 316L Stainless Steels

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❑ Background

- 316L stainless steels are primary material of fission and fusion reactors:
- 316L SS: excellent corrosion resistance, but low yielding strength
- Laser powder bed fusion (L-PBF) with 100% buy to fly ratio, versus conventional (<10%)
- L-PBF : refining microstructure, improving mechanical properties
- L-PBF rapid-heating-cooling uniqueness: dense porosities, high residual stress
- Synchrotron X-ray is powerful for *in situ* materials characterization

❑ *In situ* synchrotron experimental set-up.

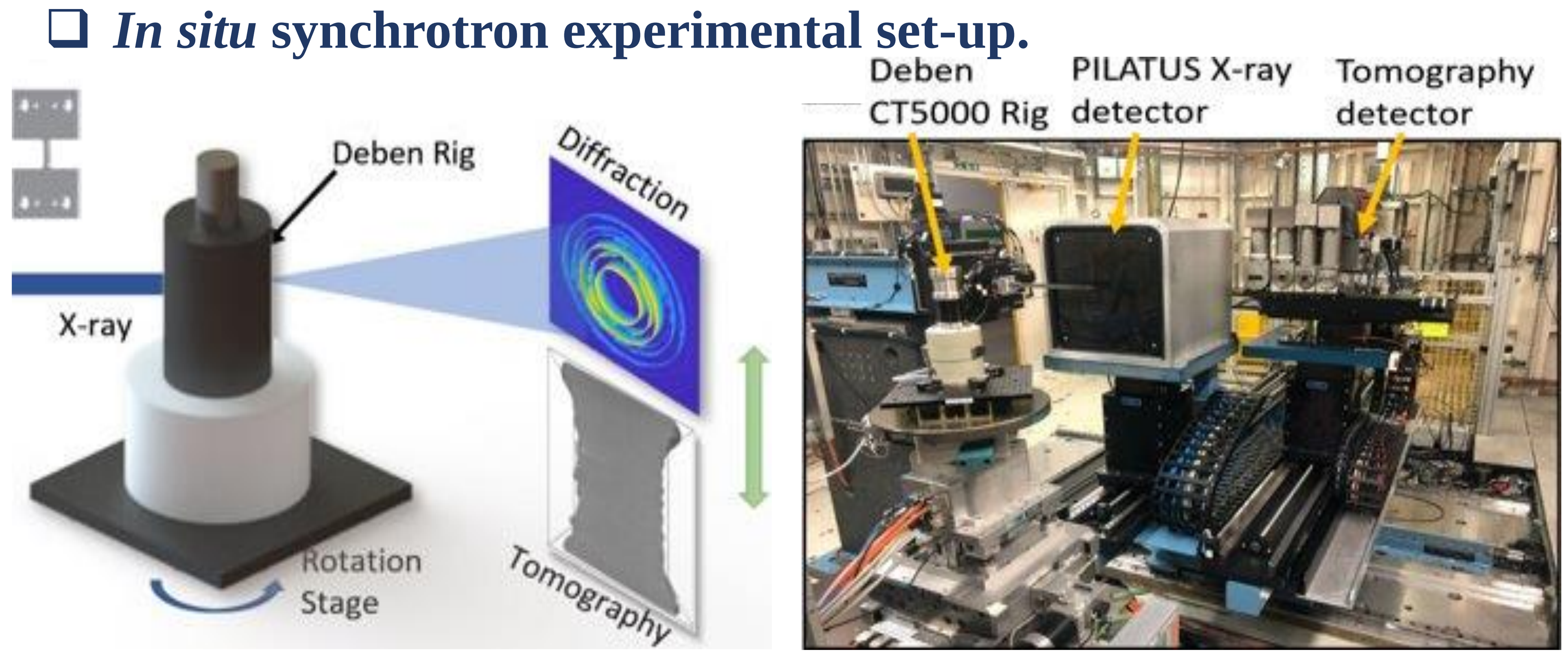

Fig 1 Experimental set-up

❑ *In situ* synchrotron diffraction:

- L-PBF 316L SS: better mechanical performance
- Stacking faults form during deformation.
- 200-reflection (red): weak = absorb more energy

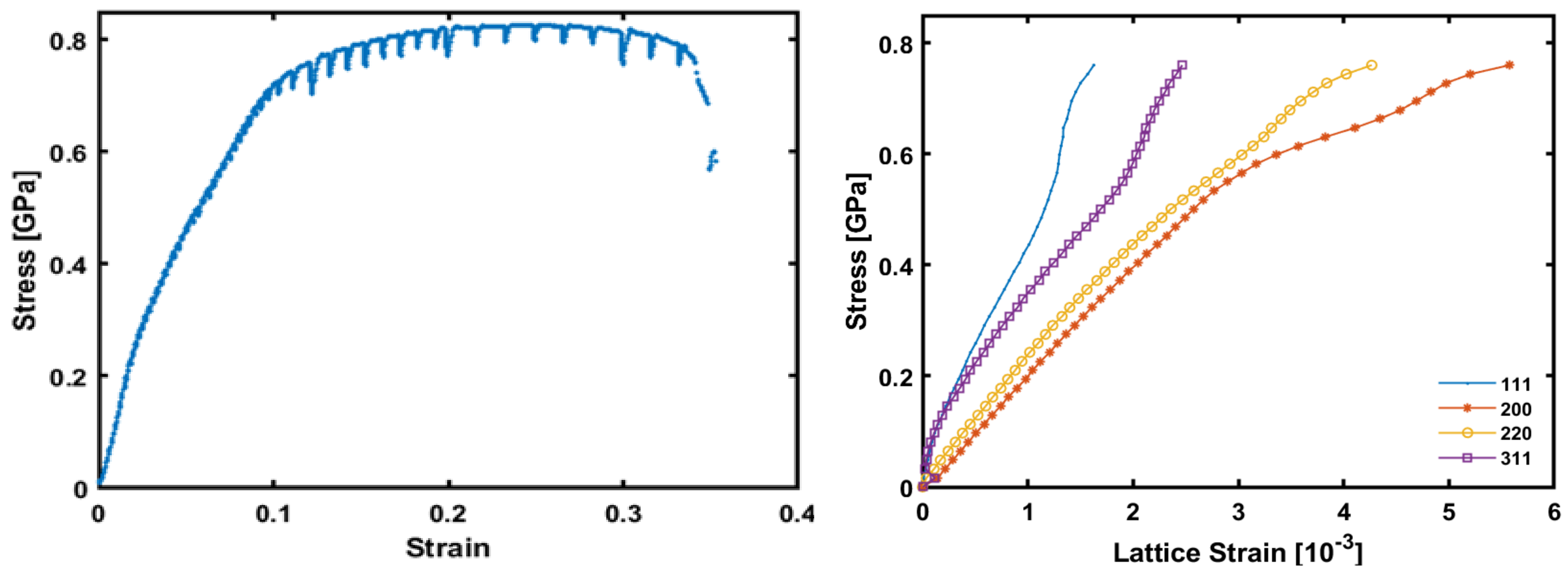

Fig 3 Stress-strain and stress-lattice strain curves

❑ *In situ* synchrotron tomography:

- Surface roughness: increases during tensile testing.
- Pore growth: elongate and network with each other to form larger pores.

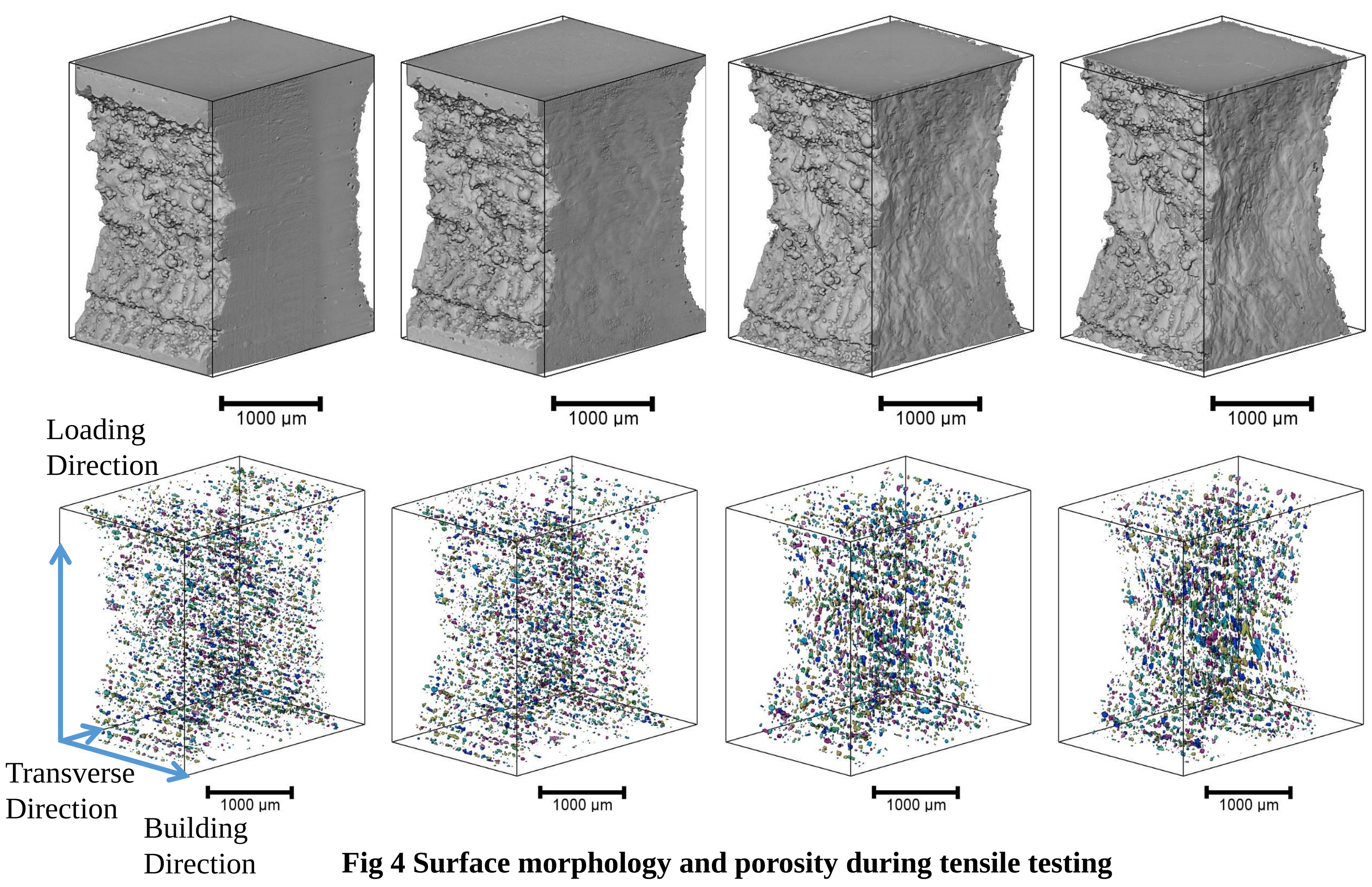

Fig 4 Surface morphology and porosity during tensile testing

❑ Ex situ characterizations of as-built sample:

- Two types of pores exist in L-PBF 316LSS: gas entrapment, keyhole.
- Overlapped melt pools observed in transvers direction.
- Solidification cells with cellular walls exist in building direction.
- High dislocation densities and misorientated grains contribute to mechanical performance of L-PBF 316L SS.

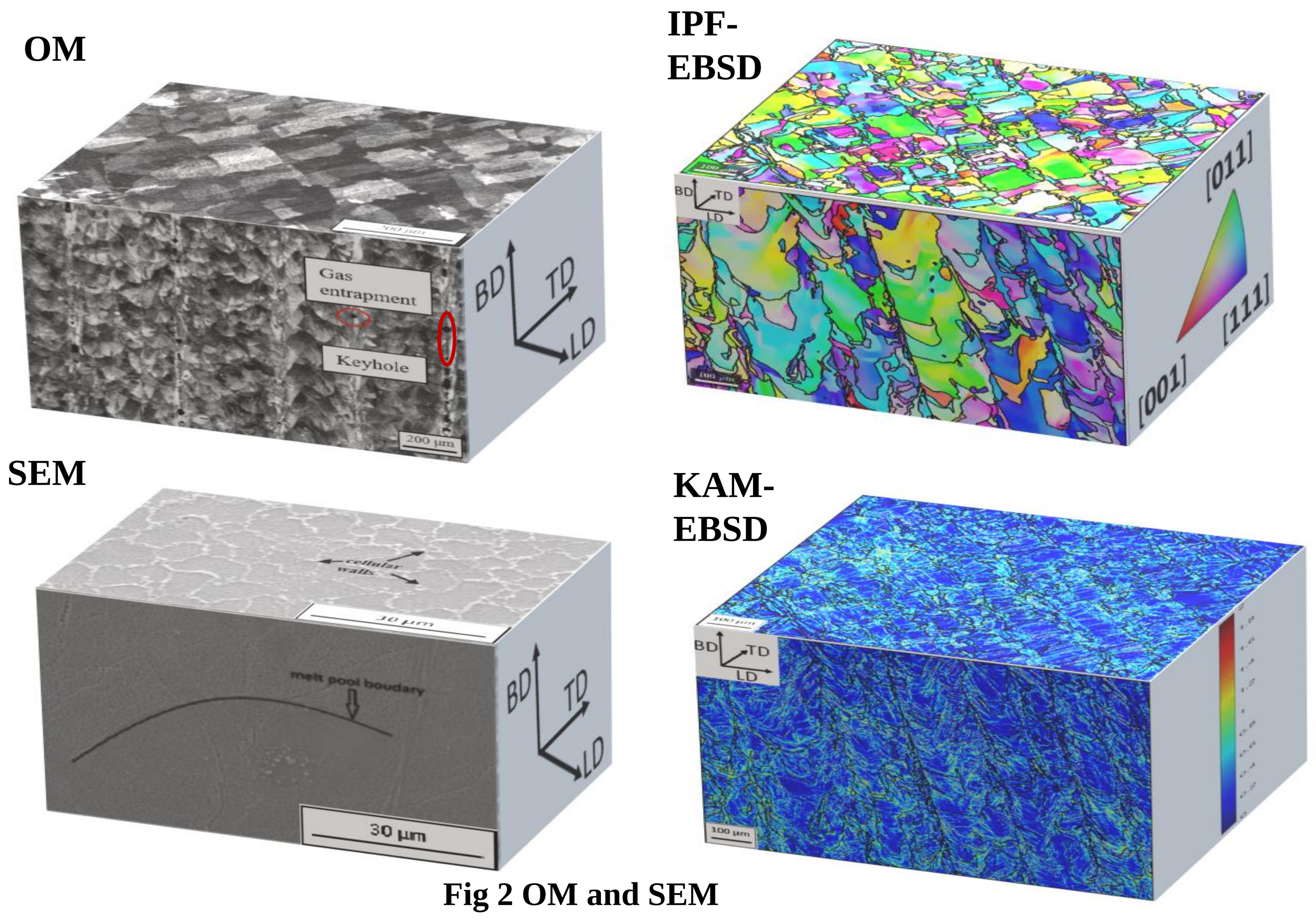

Fig 2 OM and SEM

❑ Ex situ characterization of fractured sample:

- Corrugated surface
- Mainly [101] (green) grains: more rigid, less ductile
- Small proportion of [001] (red): undergo more deformation

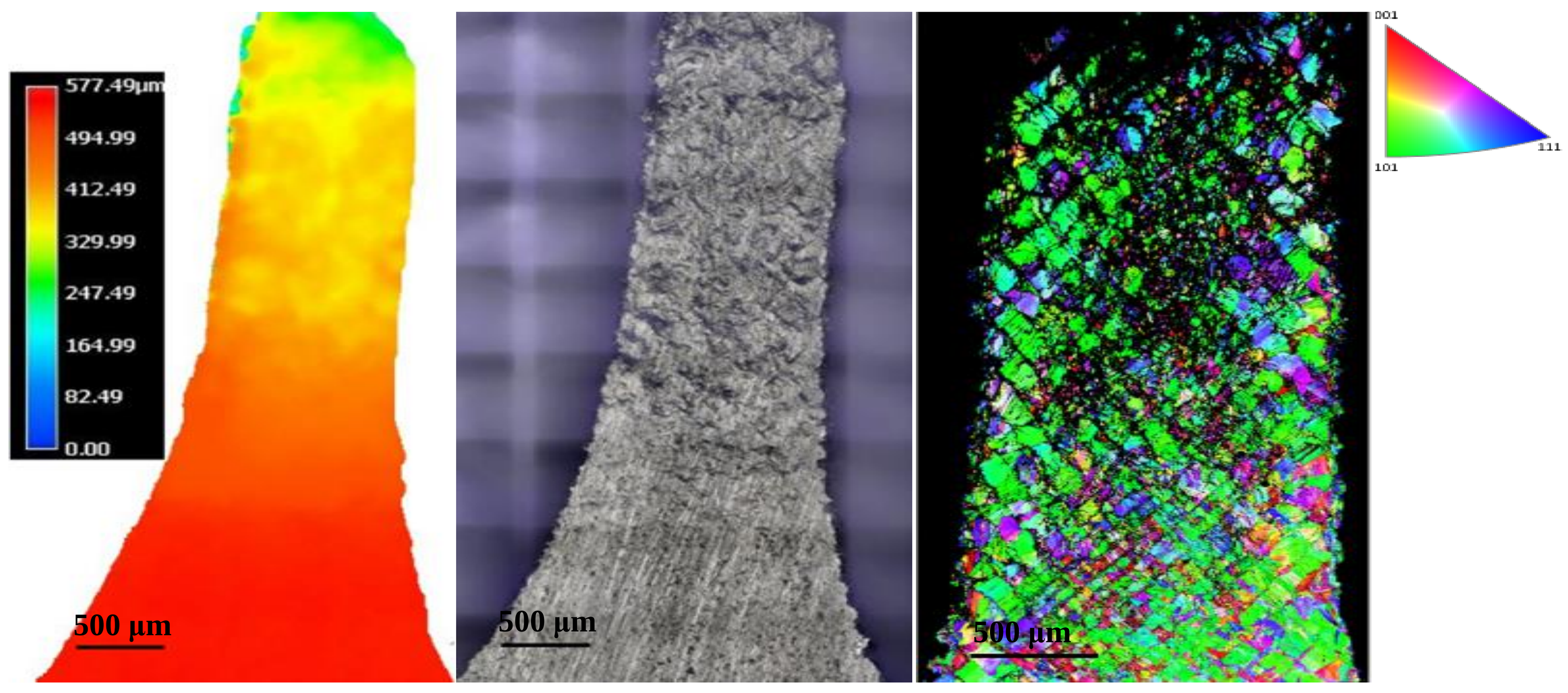

Fig 5 Height map, OM and IPF map

❑ Conclusion:

- The mechanical performance of L-PBF 316L SS is related to the microstructure and porosity.
- Overlapped melt pools, porosities and fine solidification cells observed on as-built sample.
- L-PBF 316L SS has high dislocation densities, resulting in high strength, good ductility, and steady strain hardening ability.
- Small pores grow and elongate during tensile deformation,
- According to EBSD and lattice strain-stress curves, grains of [001] experience more deformation, leading to a corrugated surface.

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