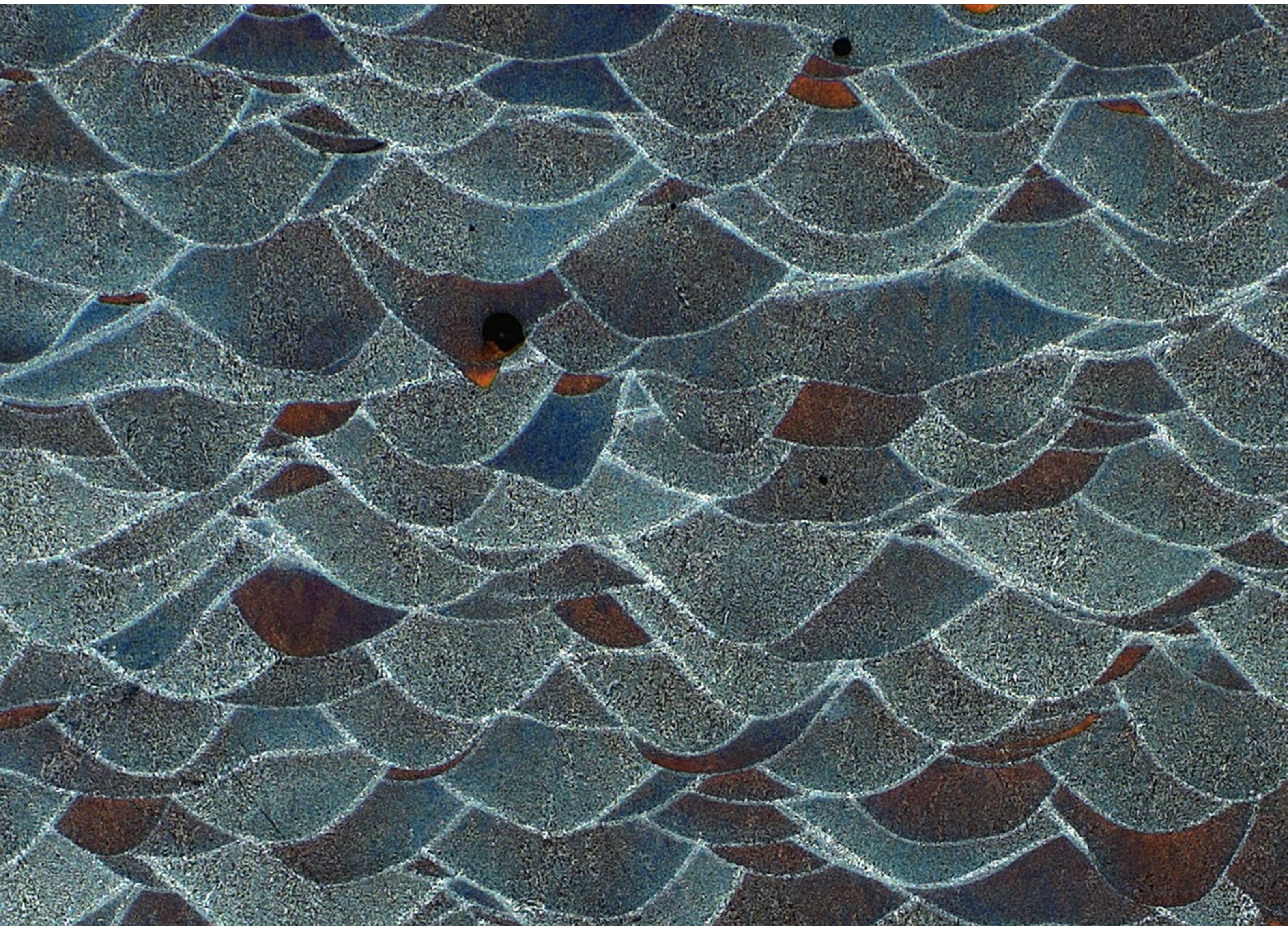
Application Note



Applications of Microscopy in Additive Manufacturing

Utilizing ZEISS Light and Electron Microscope Systems

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Applications of Microscopy in Additive Manufacturing

Utilizing ZEISS Light and Electron Microscope Systems

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Additive manufacturing (also known as 3D-printing) is a new and promising method for the production of components in engineering. Its layer by layer build-up process offers a number of new production possibilities. Of special interest is the high geometric and constructive freedom. It is possible to build up near net shape components with complex geometries and integrated functional properties, such as curved cooling channels in drills. Besides microstructural defects that significantly degrade the usage properties of components, the challenges faced in additive manufacturing are: the high level of dimensional accuracy required; surface quality; and the construction of complex tools with inner structures like cooling channels. Taking the example of additively manufactured indexable insert drills with curved cooling channels, we will show the suitability of microscopic methods for evaluating the quality of components produced in this way.

Introduction

Additive manufacturing revolutionizes the production of tools because, as a rapid prototyping technique, it allows the fabrication of 3D parts with complex geometry directly from alloy or ceramic powders.

The occurring microstructure of the components depends particularly on the powder characteristics, as well as the process conditions.

Microscopic examinations of the generated components and their microstructures are required to understand the influence of process guiding and to control the requested quality.

Powder Characterization Using Optical Light and Scanning Electron Microscopy

Additive manufacturing is a powder based process; the components are built up by a CAD supported laser, layer by layer melting of the powder. Amongst other things, the properties of the tools produced in this way depend on the powder characteristics and microscopic methods are an adequate means of determining them. Light microscopes such as ZEISS Axio Zoom.V16 enable particle size analysis (cf. Figure 1 a), b).

The steel powder in Figure 1a) shows a monomodal particle size distribution, AlSi10 in contrast is distributed bimodally (Figure 1b). The morphology of the powders can be examined with the help of scanning electron microscopy (cf. Figure 1 c, d).

For example agglomerations and the roundness of the particles, which is necessary for a well flowing powder in the process, can be detected.

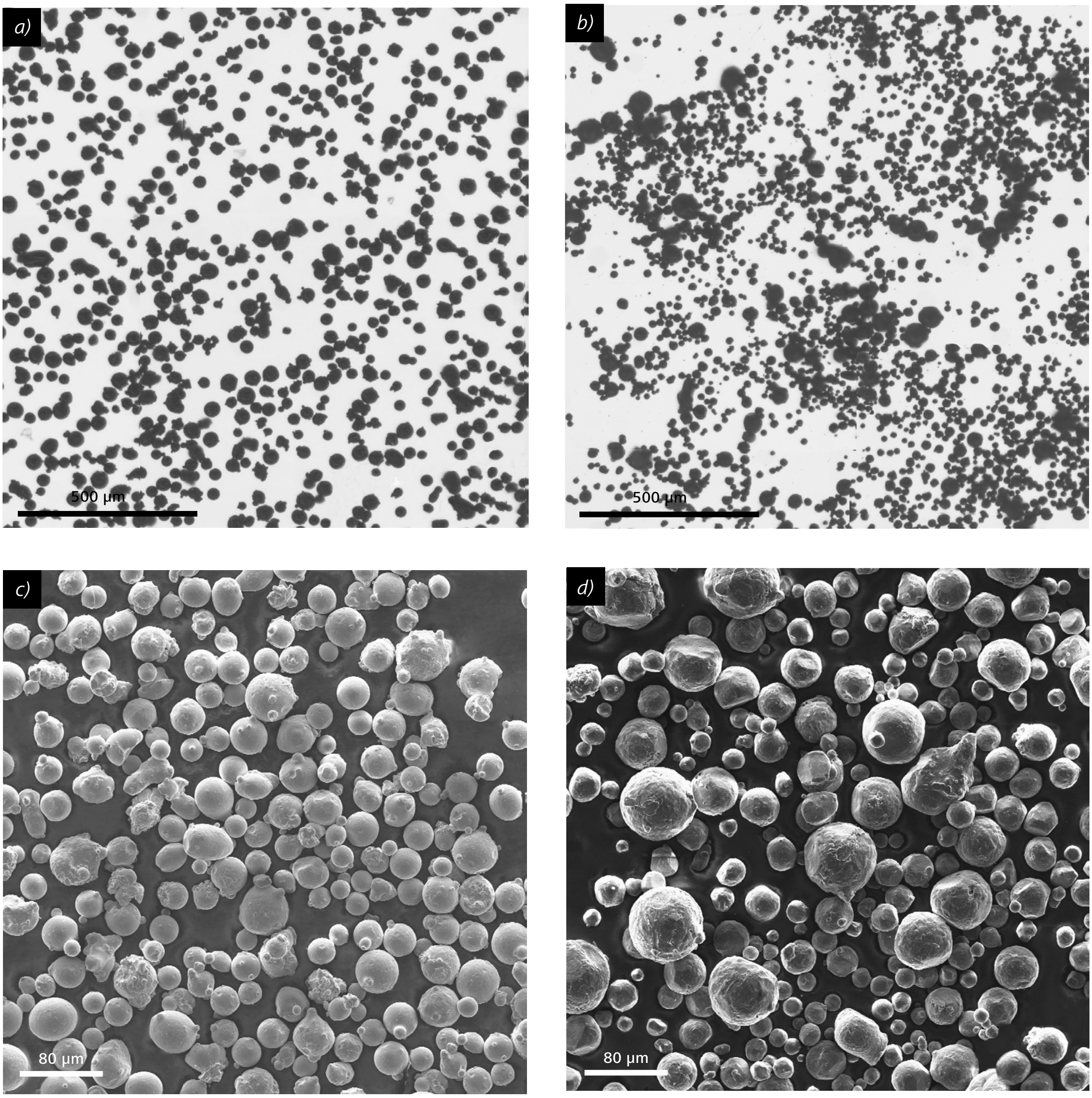

Figure 1 *Micrographs of steel (316L) (a, c) and AlSi10 (b, d) Powders used for powder characterization; a, b) Light microscopy, transmitted light, bright field, 80×; c, d) SEM, SE, WD 10 mm, EHT 10 kV, 500×*

Radiographical (CT) Non-destructive Analysis
Computed tomography (CT) is a powerful method to examine the inner structures of additively manufactured components and can therefore be used to check dimensional accuracy. CT comparison of a conventionally and an additively manufactured steel drill (cf. Figure 2) clearly shows the advantages of 3D printing. It allows the integrated fabrication of curved cooling channels whereas cooling channels in conventionally produced drills have to be machined later. CT sections of a 3D printed drill (cf. Figure 3) allow the size measurement of inner structures, e.g. cross-section area and dimensions of the cooling channels, wall thickness and thus allow quality controlling.

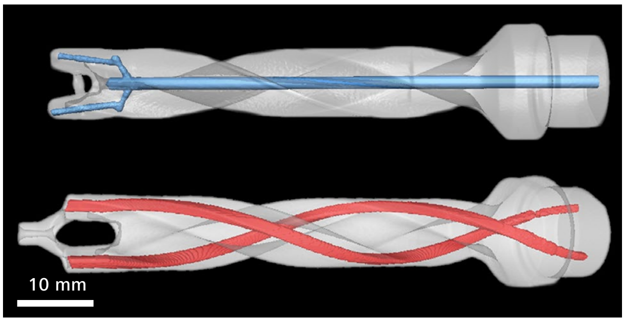

Figure 2 *CT images of steel drills with cooling channels; top: conventionally produced with later machined cooling channels; bottom: additively manufactured with curved cooling channels (red).*

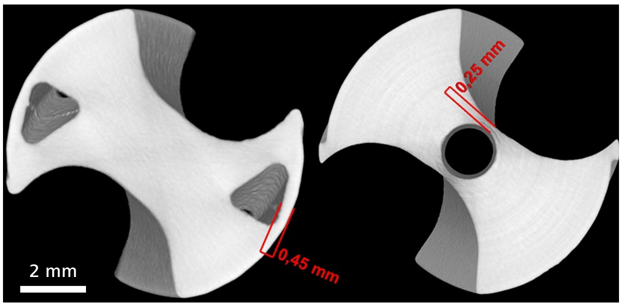

Figure 3 *CT section through additively (left) and conventionally (right) manufactured drill, measuring of differences in wall thickness*

Size and Geometry of the Components (Testing the Dimensional Accuracy)
Required dimensional accuracy is a major challenge in additive manufacturing. Size and geometry can be reviewed easily with the help of ZEISS Smartzoom 5. Figure 4 shows the tip of an additively manufactured cutting insert. This micrograph is suitable to examine the requested geometry of the cutting insert (e.g. size and location of cooling channels, diameter of cutting insert).

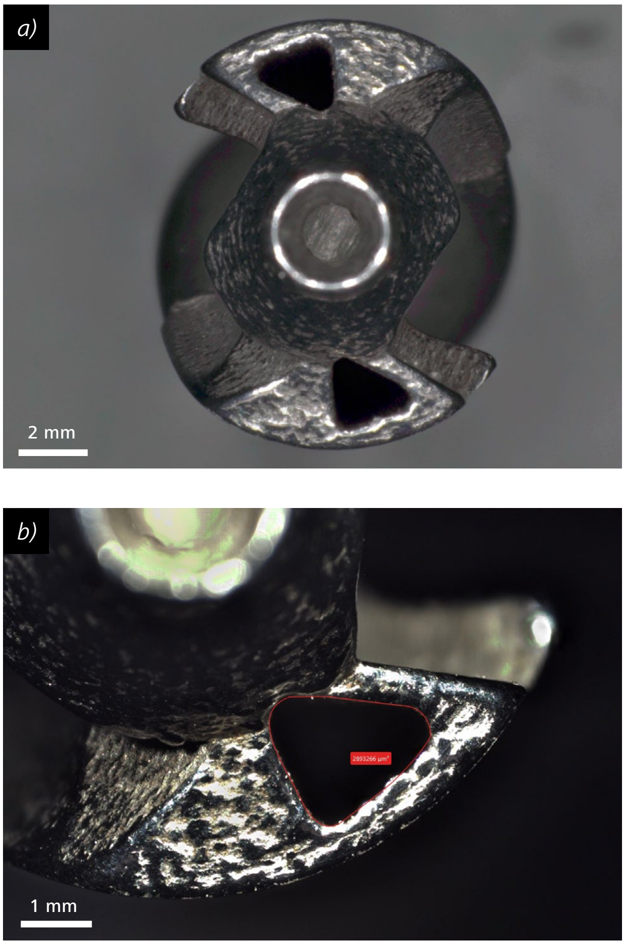

Figure 4 *Size and geometry measurement with ZEISS Smartzoom 5: Tip of an additively manufactured cutting insert; a) Overview, 20×, ringlight, HDR; b) Detailed view and measurement of the cooling channel, 40×, ringlight*

Microstructural Evolution of Additively Manufactured Components with ZEISS Axio Imager.Z2m
Light microscopes are powerful tools to check the microstructure of additively manufactured components. Microstructural defects, inhomogenities and phase distributions are of particular interest as they influence the usage properties appreciably. Furthermore, influences of production parameters can be seen with the help of materialographic sample preparation followed by microscopic examinations.

The microstructural evolution of SLM processed components can be illustrated with the help of the light microscope ZEISS Axio Imager.Z2m. Figure 5 shows the influence of the linear energy density on porosity, its distribution and the size of the pores, quantitative characteristics (fraction of porosity, area-weighted D90-distribution characteristic value of pore size) can be determined with the help of

ZEISS AxioVision Rel 9.1 software. Polished sections of SLM (selective laser melting) produced materials (cf. Figure 6) show the typical micro-structure of additively manufactured samples with regular patterns due to the process guiding. The regular pattern of the laser tracks is clearly visible in the cross-section (Figure 6a), for a better visualization some of the laser tracks are exemplarily sketched with white lines. The longitudinal section in Figure 6b shows the layer construction that occurs as a result of the individual, melted layers that develop at each crossing of the laser.

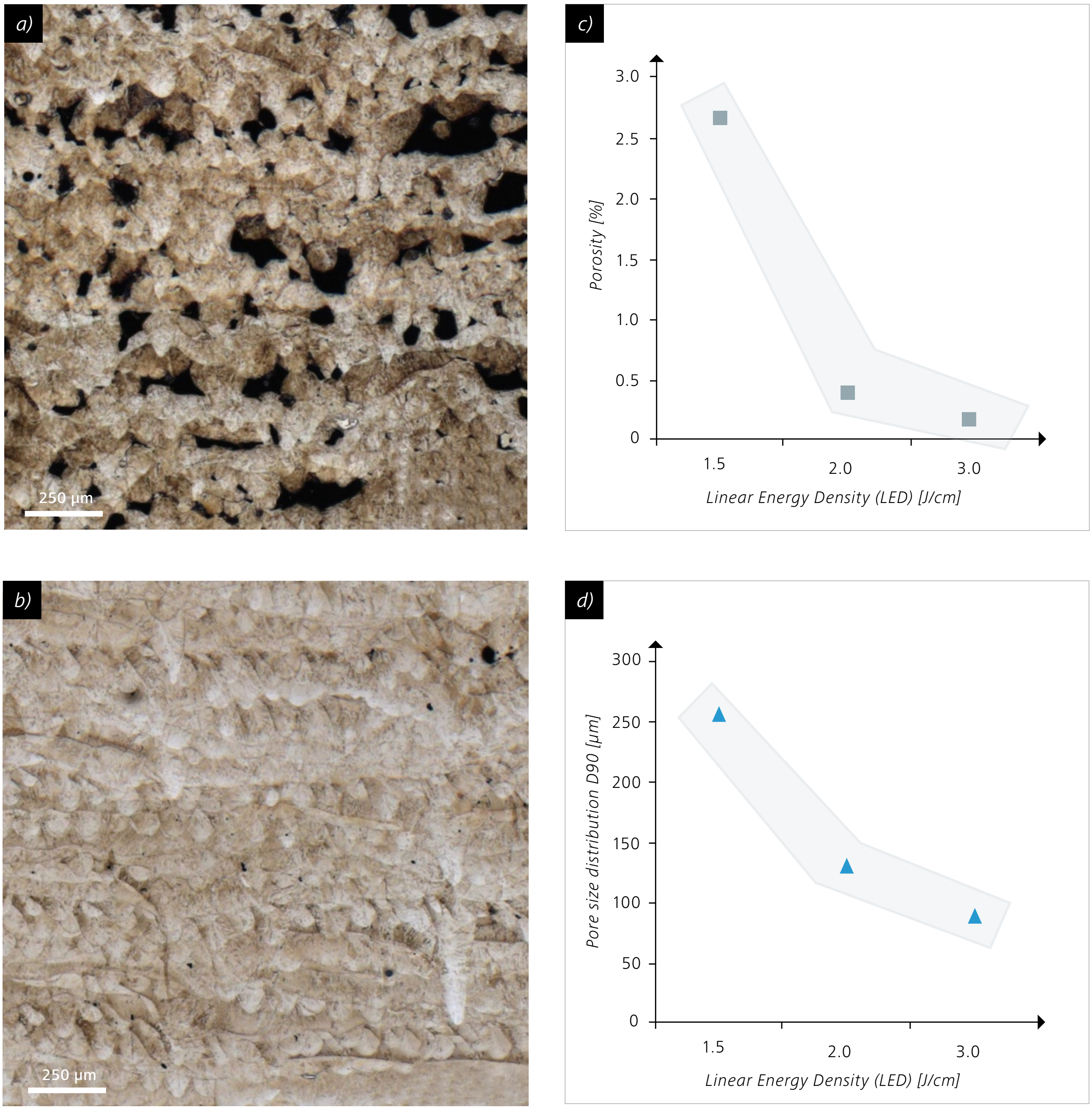

Figure 5 *Microstructural evolution in test cubes made of X3NiCoMoTi18-9-5 in response to the linear energy density (LED) for determination of porosity and defect size; a) SLM, high LED, V2A etchant, cross-section, 50×; b) SLM, low LED, V2A etchant, cross-section, 50×; c) Overall porosity in relation to LED, porosity decreases with higher LED; d) Pore size in relation to LED, pore size decreases with higher LED.*

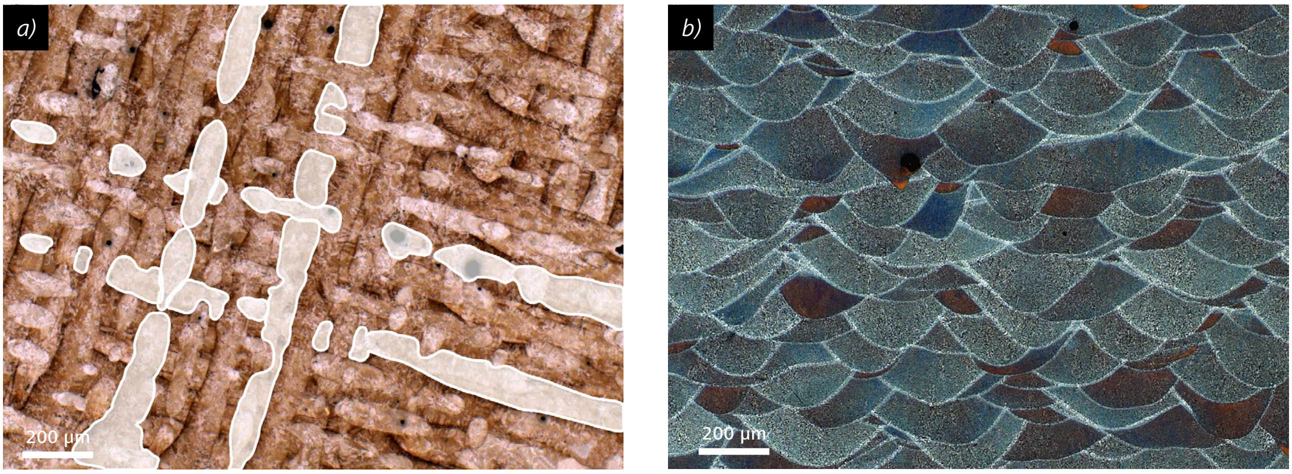

Figure 6 *Microstructure formation appropriate to laser direction for SLM samples, a) X3NiCoMoTi18-9-5 (1.2709), SLM, V2A-etchant, cross-section 100×; b) AlSi10Mg, SLM, 10%-NaOH etched, longitudinal section, 100×*

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