Determination of dislocations density in Cu-OFE for CLIC project by using EBSD

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ABSTRACT: In the frame of the CLIC (Compact Lineal Collider) Study for the development of a two-beam accelerating technology for a future TeV- scale e^+e^- linear collider, we are especially interested in a better understanding of the superficial modifications on oxygen free electronic copper (Cu-OFE) caused by the interaction with vacuum arcs at high gradient operation. Electrical breakdown (BKD) phenomena are responsible of some of the surface damages observed in CLIC accelerating structures which are made out of the cited material. It is crucial to define the role of dislocations in BKD and therefore it is important to find a diagnostic technique which determines their presence and/or density. The study of the bibliography presents the Electron Backscatter Diffraction (EBSD) like a valid technique for the assessment of the dislocation density in complex three dimensional structures.

BKD phenomena in Cu-OFE:

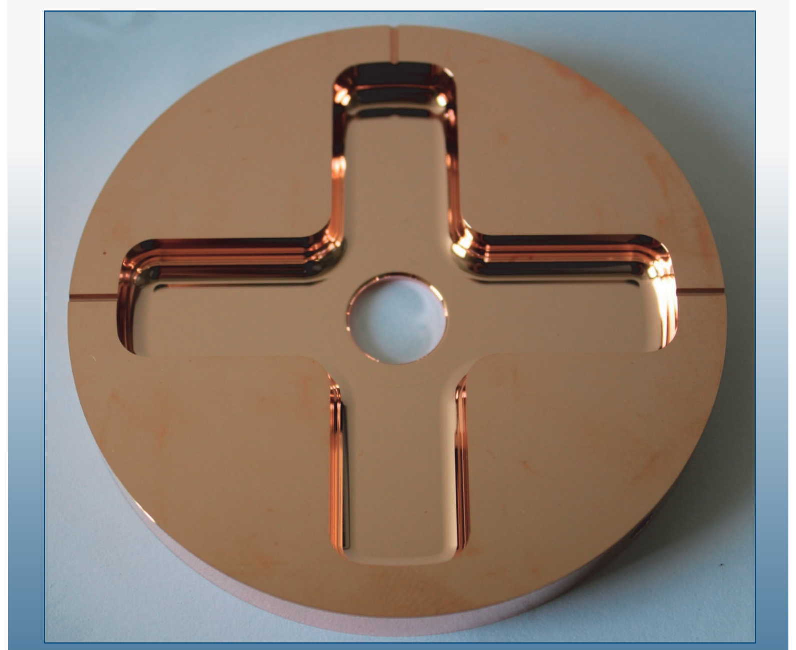

Figure 1: 80 mm diameter Cu-OFE disc for CLIC, after ultra precise machining. To satisfy the RF and the beam dynamic constraints, shape accuracy of ± 2.5 µm and Ra values below 25 nm are demanded

Oxygen free electronic copper (Cu-OFE) is the material most commonly used in normal conducting accelerating structures (AS). The Cu-OFE raw material used for the CLIC structures is provided in a multi-way forged and hammered hardened state.

For a deeper understanding of the interaction of vacuum arcs with the surface of the AS, specimens are observed by Scanning Electron Microscopy (SEM) after testing at high gradient.

The observed damages on the surface, are mainly micrometer-sized craters and frozen-in liquid on the surface.

How the BKD rate is related to the microstructure and the dislocation dynamics of the surface?

And, how we can study this?

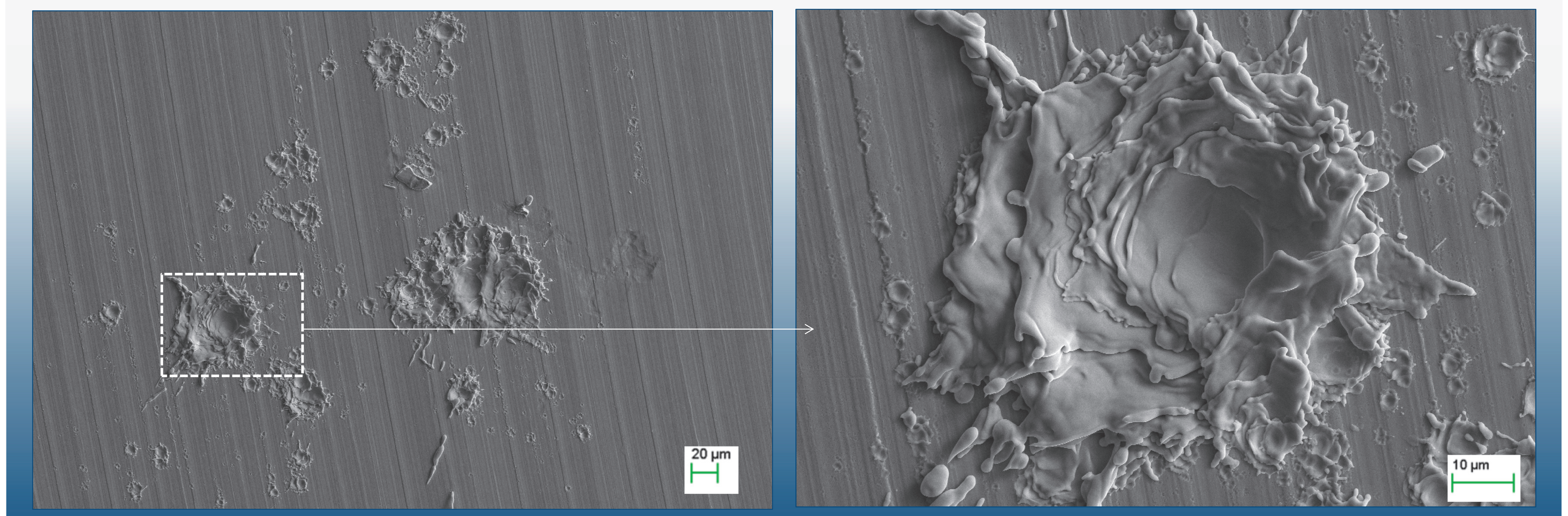

Figure 2: SEM images (20 kV) of craters produced by plasma-surface interaction on Cu-OFE

Dislocation density measurement using EBSD technique:

Internal structure and defects, determines many properties of the materials. Dislocations are linear imperfections in a crystalline array of atoms and we can distinguish two main types:

- SSDs: Statistically stored dislocations, which are the component of the dislocation's network for which no net lattice curvature results
- GNDs: Geometrically necessary dislocations, whose contribution results in curvature and fragmentation of the crystalline lattice

Dislocation presence (like a group concept) in the microstructure of the material can be studied using Electron Backscatter Diffraction (EBSD). This technique fulfills our following requirements:

- Non destructive
- Appropriate for 3D specimens
- Provides a good combination of spatial and angular resolution
- Relatively reduced time of data collection

EBSD analysis is a very powerful tool for microstructural characterization. It identifies:

- Crystal orientation
- Grain size
- Global and local texture
- Phase identification
- Recrystallize/deformed fractions
- Substructure analysis
- Slip system activity
- Grain boundary characterization
- CSL boundary distribution
- Strain analysis

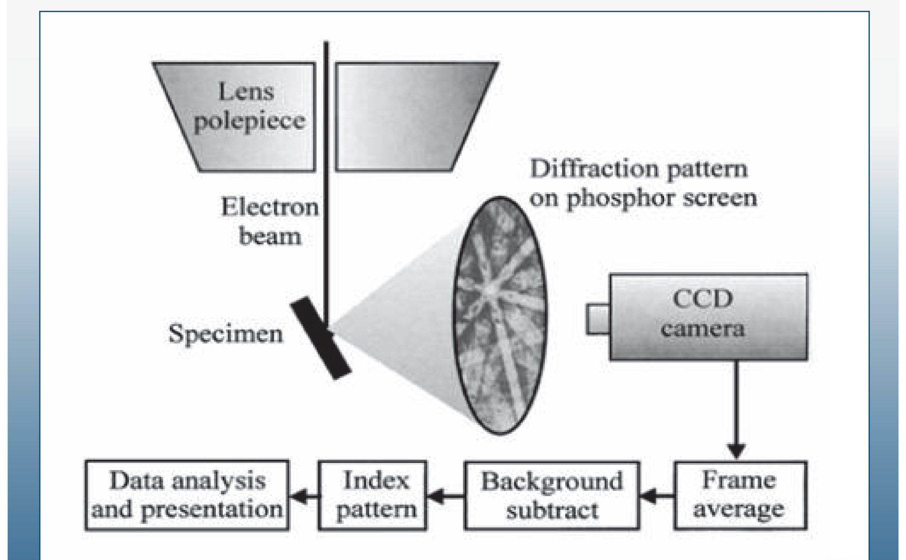

Figure 3: EBSD scheme in a SEM. The sample is tilted to 70 degrees with respect to the horizontal tilt axis

How?

EBSD patterns are obtained by focusing electron beam on a crystalline sample

To accommodate plastic deformation, the material generates dislocations which disturbs the structure of the lattice and that leads in a reduction of EBSD patterns (Kikuchi bands) quality

This can be directly related with the residual strain of the specimen and represented in local misorientation maps

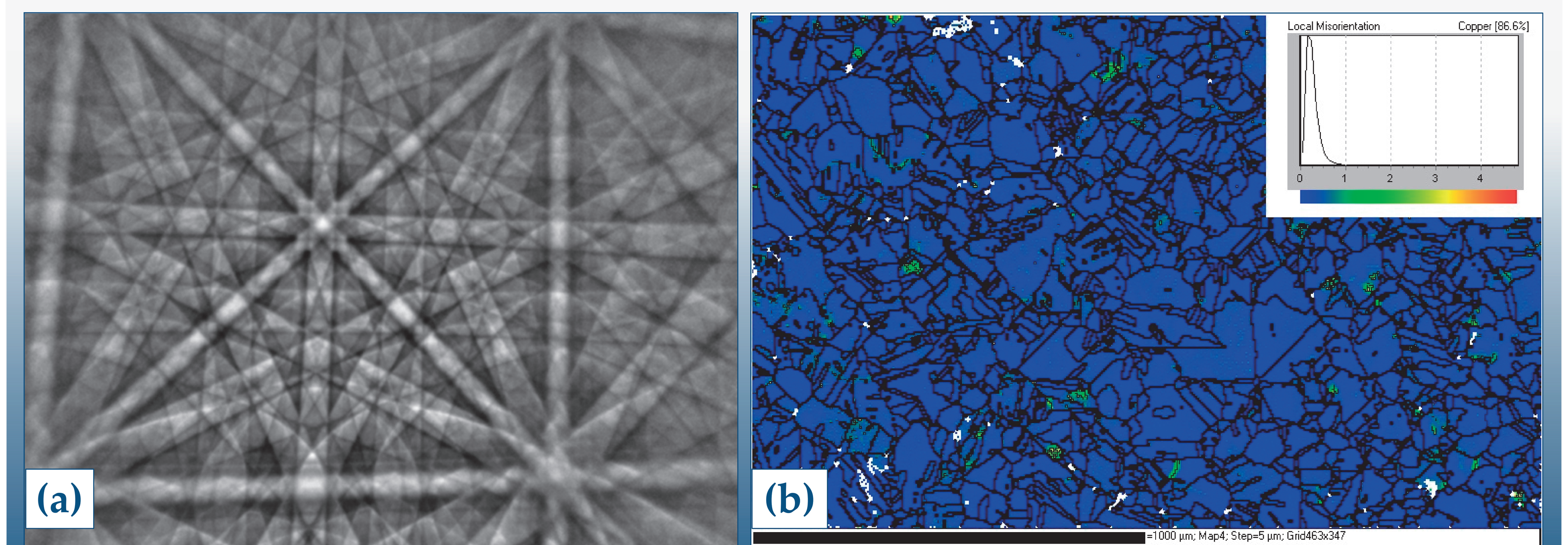

Figure 4: (a) EBSD pattern with Kikuchi bands (b) Example of local misorientation map in Cu-OFE sample and legend. Higher dislocation density areas are represented in green color

- Internal structure and defects associated to it, determine many properties of the materials. Therefore, a deeper understanding of the dislocations role in the material response to the BKD's could help us to understand why areas with same surface status are highly affected by the phenomena;
- TEM and XRD are the two most common methods, one for small probing region with details and one for large region at the expense of spatial resolution. However, EBSD have bridged these two methods and provide good combination of spatial and angular resolutions for measuring dislocation density;
- To accommodate plastic deformation, the material generates dislocations which disturbs the structure of the lattice and that leads in a reduction of EBSD pattern quality. This can be directly related with the residual strain of the specimen and represented in local misorientation maps;
- For this reason, we propose EBSD like a promising technique for the study of dislocations density in CLIC Cu-OFE specimens.