MATERIAL FOR FABRICATION OF LARGE GRAIN CAVITIES for European XFEL

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Abstract

Material for large grain LG cavities for European XFEL has been developed in collaboration with industry.

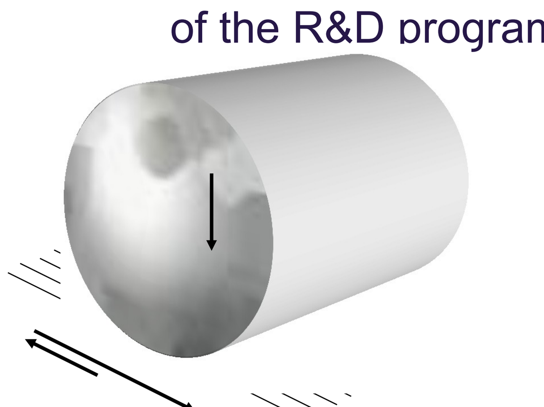
One of the aspects of LG material was electron beam melting of the ingots with big central crystal and required properties. The second was slicing of the discs cost effectively with tight thickness tolerances, high surface quality and at the same time keeping the ingot high purity.

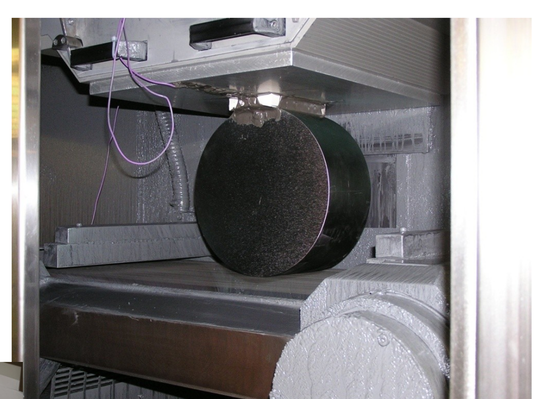
Surface and structural properties of grain boundary free grains on the LG discs are investigated. Measurements of the crystal orientation on the LG discs have been done by complete penetration using synchrotron radiation of DESY HASYLAB.

Two LG material features have been stressed in cavity production. The first was the influence of the LG crystal orientation on the anisotropic behavior during deep drawing. Another aspect was the impact of pronounced steps at grain boundaries on cavity behavior. 11 LG 9-cell cavities of XFEL-like shape have been fabricated and RF tested after BCP treatment.

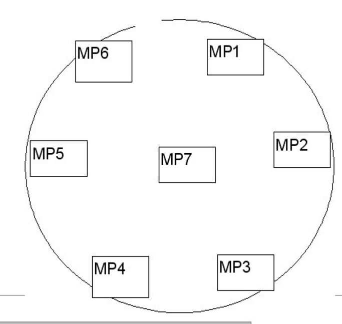
LG disc fabrication Heraeus:

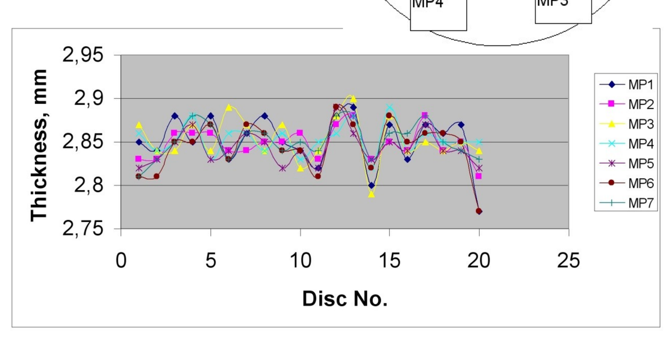
Development of LG disc production was done within the framework of the R&D program of DESY and the W. C. HERAEUS.



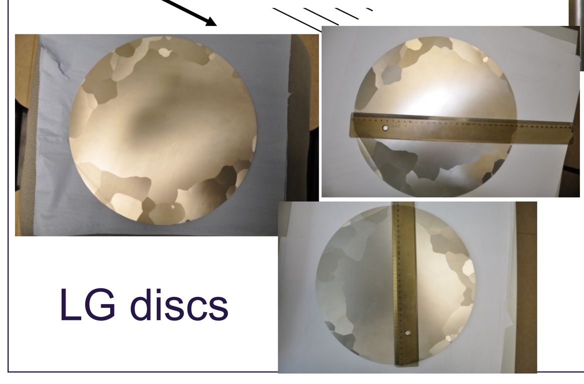


Cutting of the large grain Ingots by wire sawing at Heraeus



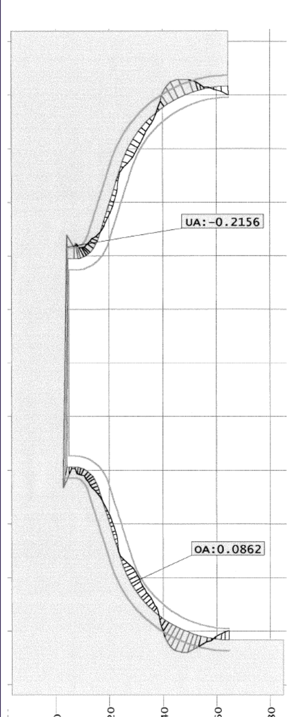


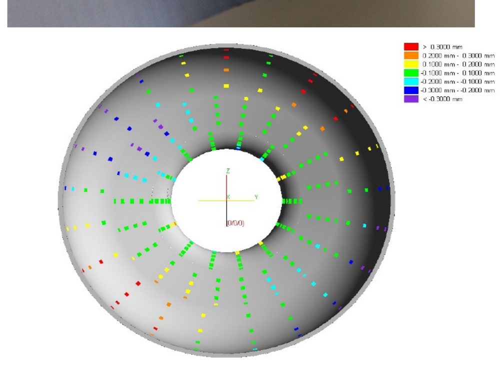
Measurement locations and thickness distribution in the LG discs (high quality)



LG discs

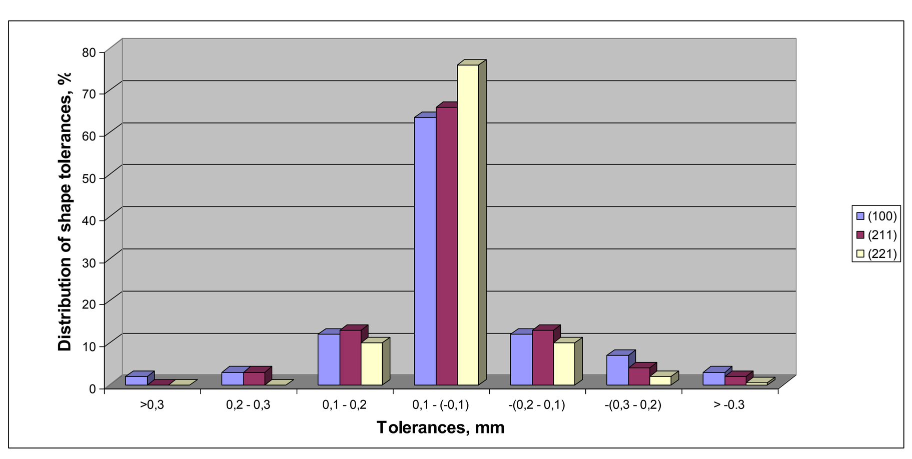
Deep drawing of LG half cells





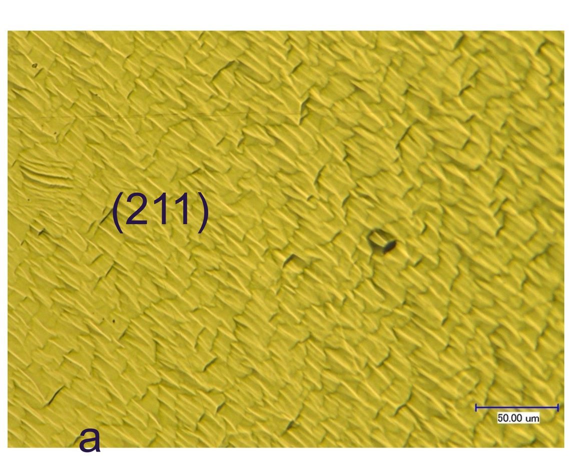
Tactile 3D-measurement shows deviation from tolerances (tolerance: +/-0,2 mm).

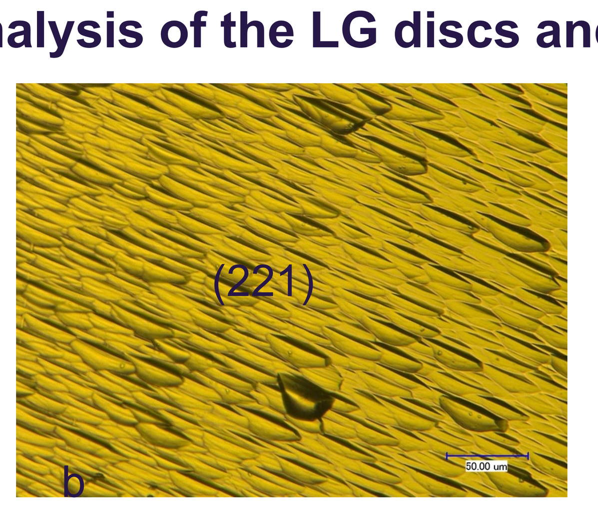
Dependence of the half cell shape accuracy from the crystal orientation of the main central crystal

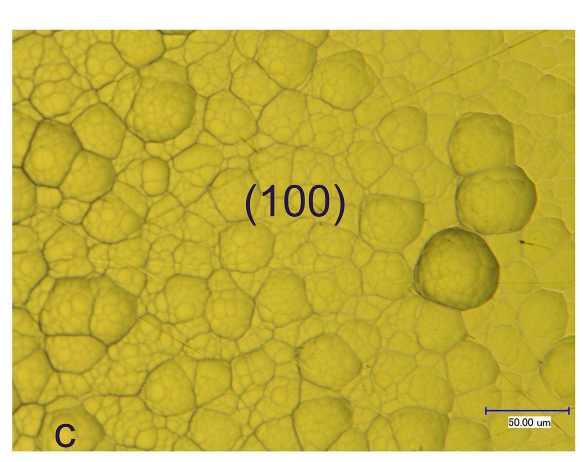


Averaged deviation from ideal shape of the half cell for different crystal orientations. Crystallographic plane (100) parallel to the sheet surface produce more shape deviation on deep drawing, compare to (211), (221)

Surface analysis of the LG discs and half cells







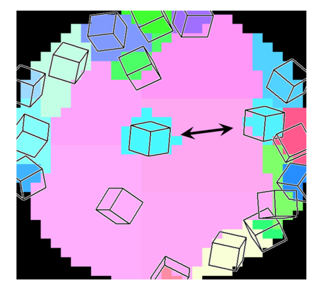
a - Central Crystal for cavities AC154 und AC158
b - Central Crystal for cavities AC155, AC156 und AC157
c - Central Crystal for cavities AC151, AC152 und AC153

Surface roughness (averaged values) of the central and close to them crystals with different orientations after ca. 80 µm BCP

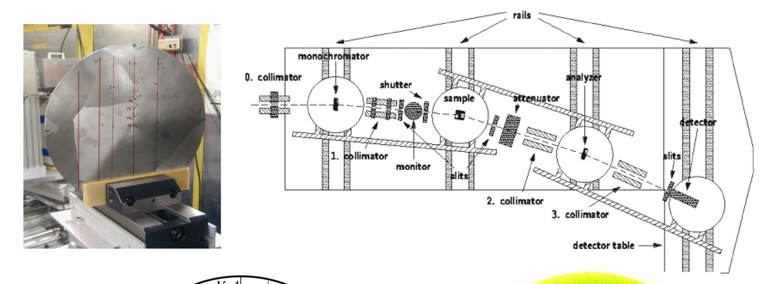
	(211)	(221)	(100)	(111)	(110)
Ra	0,15	0,2	0,24	0,35	0,36
Ry	0,95	1,29	1,4	2,23	2,56
Rz	0,57	0,85	0,89	1,7	1,94
Rq	0,19	0,25	0,3	0,42	0,44

Slip lines of the crystal on a half cell after deep drawing

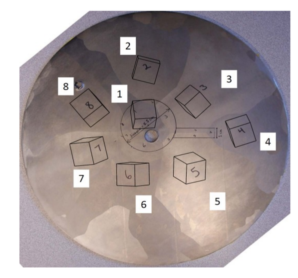
Characterization of the crystals in LG discs



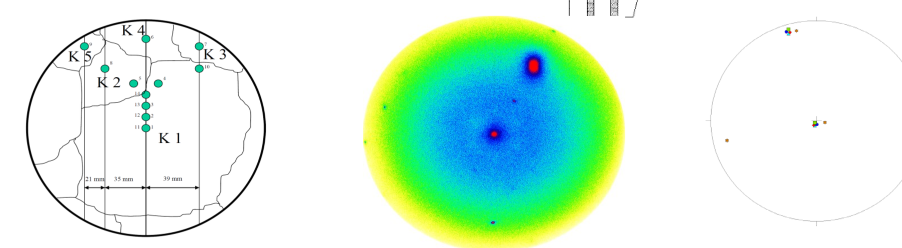
Heraeus: (T. Bieler. SSTIN10. Surface characterization)



Bulk crystal characterization on BW5 of DESY HASYLAB



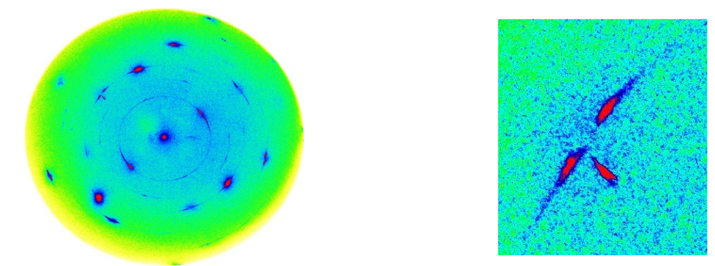
Central LG with an island



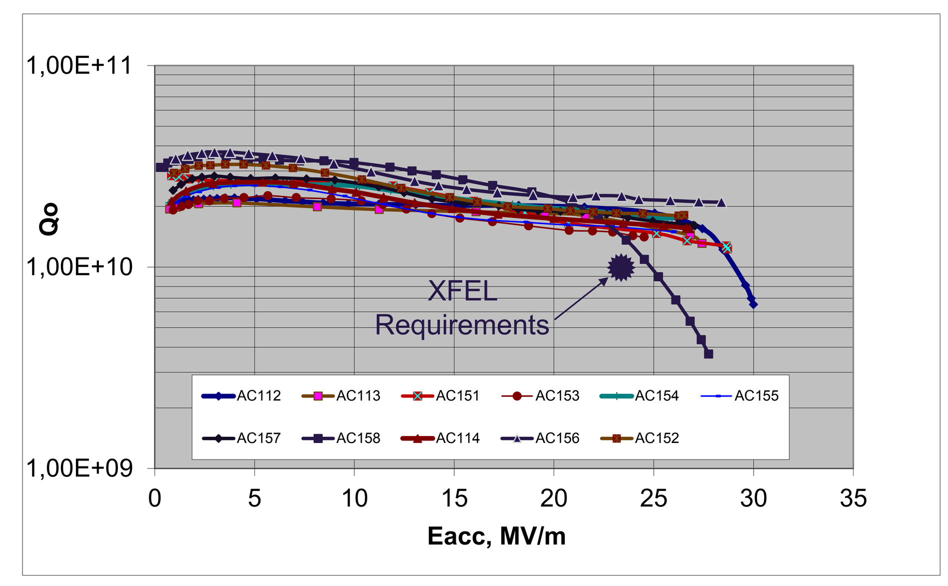
HERAUS: Central crystal of high quality. Right figure represents ition of several measured locations on the central crystal, what confirm the high quality.

Ningxia: (T. Bieler. SSTIN10)

No obvious preference for definite orientations.

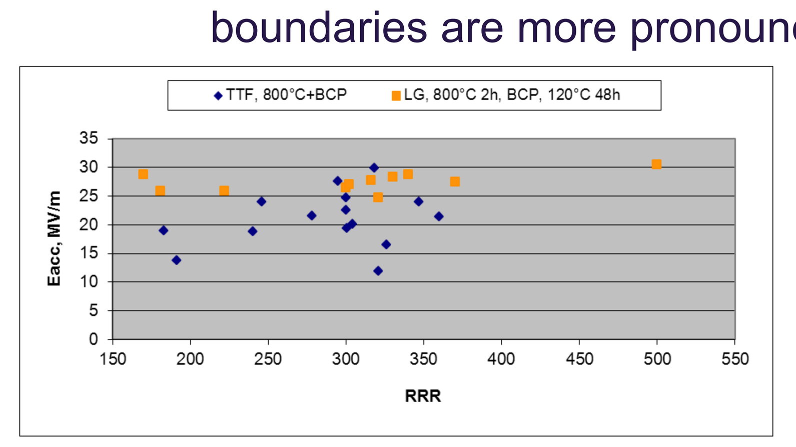


Ningxia: Signal splitting of reflexes (indication for several single crystals)



Eacc of all 11nine-cell DESY cavities from LG Nb of Fa. HERAEUS are fabricated at Fa. RI. Treatment: 100µm BCP, 800°C 2h, 20µm BCP, HPR and 125°C, 50 h baking. 100 µm BCP done at Fa. RI. In AC155 and AC156 steps on grain boundaries smoothed by grinding

Very smooth (shiny) surface in grain areas after BCP; the steps at grain boundaries are more pronounced as in polycrystalline material



Comparison of the Eacc performance of large grain (LG) 9-cell cavities with similarly treated fine grain TTF cavities.

BCP works for LG better and more stable compare to fine grain cavities

Pro and Contra for LG XFEL cavity fabrication

Pro

- LG discs more cost effective as fine grain sheets (32% according estimation for XFEL CVs pre-series)
- Wire saw procedure allows getting better surface quality and thickness tolerances in discs
- Eddy current scanning can be avoided
- Accelerating gradient of 25-30 MV/m can be reached by BCP only. Best result after EP 45 MV/m reached on two cavities
- Onset of Q-drop in large grain cavities is typically at 10% higher gradients. It is sufficient to bake the BCP-treated cavity at 120 °C for only 12 -24h. (G. Ciovati, SRF 2007)
- The complete chain of the LG cavity technique beginning with material production and ending with cavity installation into a cryomodule was successfully tested.

Contra

- The industry was not in position to produce in rather short time (2 years) the required amount of ca. 20 tons of LG material for the European XFEL.
- Only one company has industrial experiences for cavity mechanical fabrication
- Mechanical fabrication works, but need additional effort due to not sufficiently precise shape of half cells (clamping for trimming, trimming accuracy, frequency measurement, assembling of half cells for welding)
- Smaller shape accuracy as for fine grain

Summary

- 9-cell cavities can be built from LG material without significant difficulties or special problems.
- Performance on the level of 25-30 MV/m (Bp=110-130 mT) can be achieved in a stable and reproducible manner with BCP treatment in LG TESLA shape cavities. EP treatment is in work. Best two cavities reached after EP Eacc of 45 MV/m
- The complete chain of the LG cavity technique beginning with material production and ending with cavity installation into a cryomodule was successfully tested. Cavity AC112 is installed into cryomodule 3***, cavity AC113 is installed in cryomodule PXFEL1 of the FLASH accelerator at DESY.
- Unfortunately the industry was not in position to produce in rather short time (2 years) the required amount of ca. 20 tons of LG material for the European XFEL. Therefore it was decided not to use LG for XFEL. High potential of LG cavities has to be taken into consideration for future accelerators

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