ITER Torus Diamond Discs: Dielectric and Optical Characterization

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Motivation & Methods

The electron cyclotron heating systems in nuclear fusion devices like ITER require dielectric low-loss transmission diamond windows.

As part of a contract with F4E, 62 diamond discs for ITER torus windows with diameters of 70 mm and thicknesses of 1.11 mm were qualified.

Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6	Batch 7	Batch 8	Batch 9	
02.06.22	13.12.22	25.05.23	29.02.24	23.07.24	23.01.25	05.06.25	06.11.25	06.11.25	→23.07.26

Dielectric measurement

- using open Fabry-Perot resonators in hemispherical and spherical configuration
- complex permittivity: $\varepsilon_r^* = \varepsilon_r' + i\cdot\varepsilon_r'' = \varepsilon_r'(1+i\tan\delta)$

  dielectric loss tangent: $\tan\delta = \frac{\varepsilon_r''}{\varepsilon_r'}$

Optical characterisation

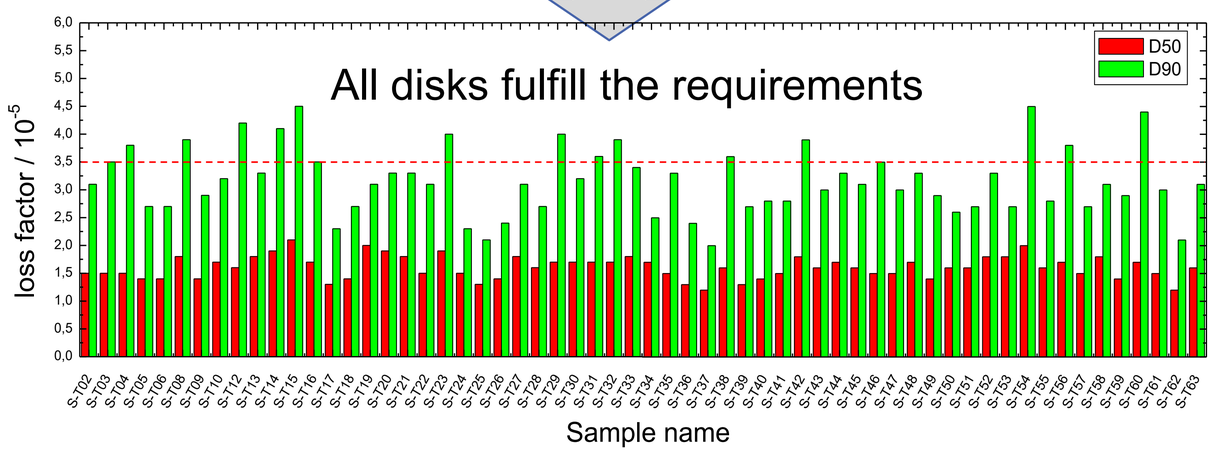
- EFI (extented focal images) and multiple layers acquisitions
- Detection and classification of microfeatures using greyscale images

Polarisation measurement

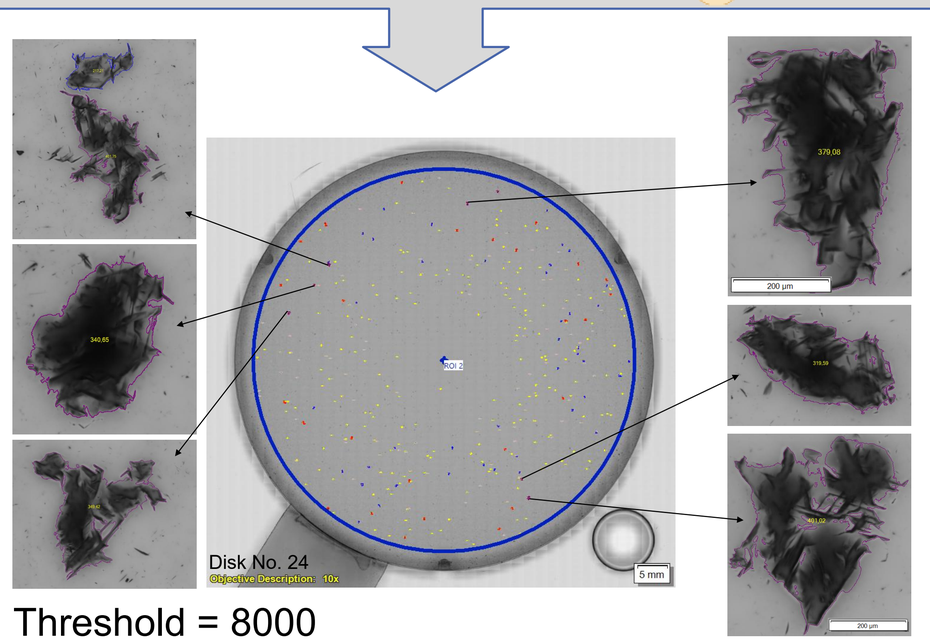
- Diamond shows birefringence properties when subjected to residual stress
- Determination of retardation by polarimeter and polarizing foils

Results

Qualification by loss tangent measurements
Requirements @ 170 GHz:
loss $\tan\delta$ (D50 / D90 quantil) : ≤ $3.5\cdot10^{-5}$/ ≤ $6\cdot10^{-5}$



Typical extended focal images (EFI) of a disc by equivalent diameter

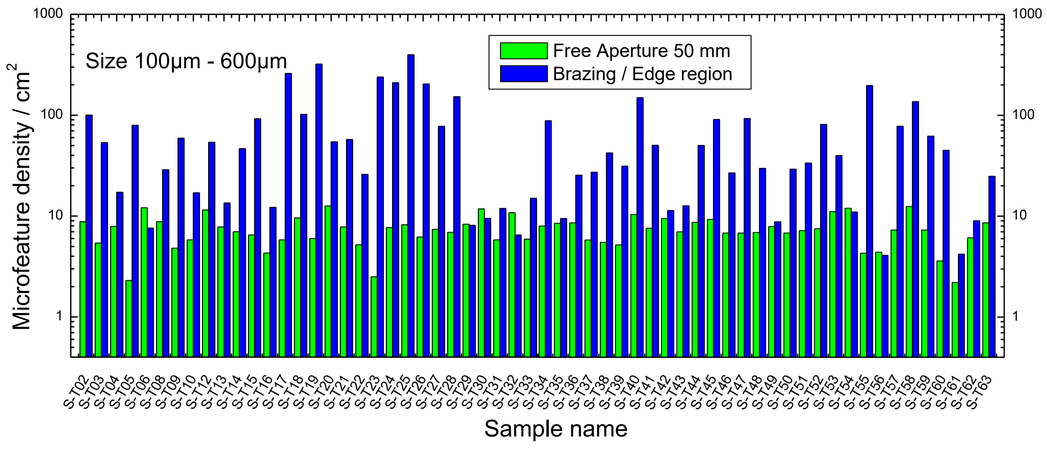


Agglomeration of microcracks

Threshold = 8000

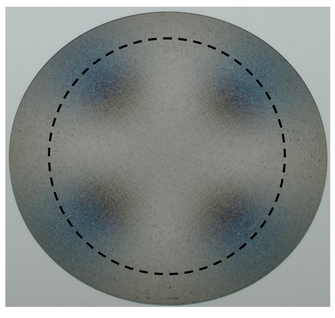
Individual settings, in particular the threshold and the classification features, were set to the same values for all discs.

The wide range in the number of microfeature is shown in the diagram below.

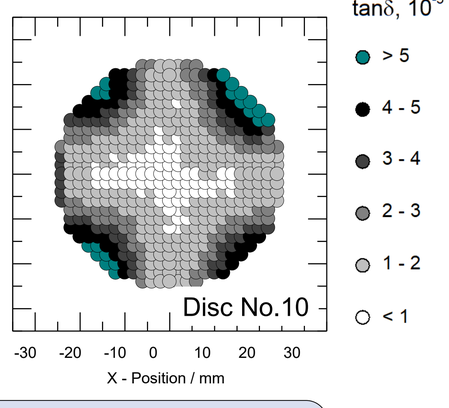


Birefringence due to residual stress

Visible light linear polarized



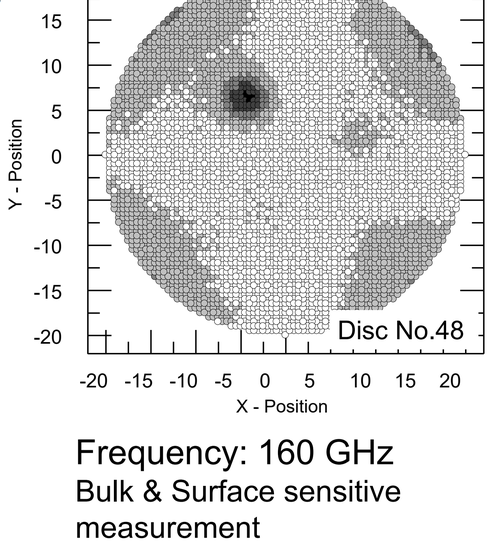
Frequency: 170 GHz linear polarized



Additional dielectric losses resulted from birefringence

Central loss: $\tan\delta_{\text{all discs}}$: ≤ $2\cdot10^{-5}$

Localised increase due to graphitic phases – one disk!



Frequency: 160 GHz
Bulk & Surface sensitive measurement

Summary

All diamond discs exhibit the lowest dielectric losses at their centres. The spatially resolved measurements all fulfill the requirements, although additional losses due to birefringence effects increase the D90 quantile. The microscopy investigation showed different distributions of the microfeatures among the discs.

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