Testing of CVD diamond disks for the torus windows of the ITER EC H&CD system

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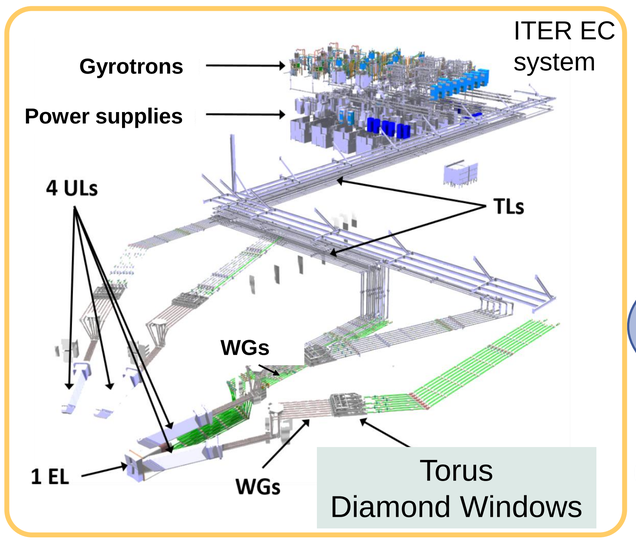
Introduction

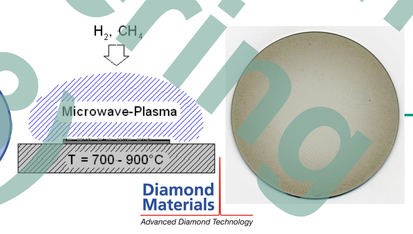


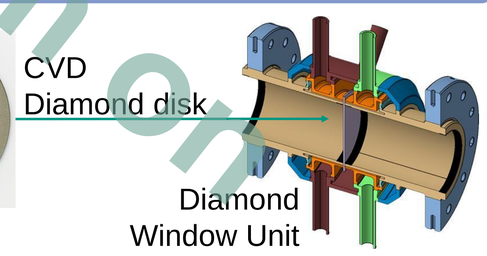
The windows of the Electron Cyclotron Heating & Current Drive (EC H&CD) system of ITER (used for plasma heating and stabilization) allow transmission of high power microwave beams and serve as vacuum and safety boundaries (confinement of hazardous materials e.g. tritium).
They consist of a chemical vapor deposition (CVD) **diamond disk** (poly) joined into a metallic housing.

High thermal conductivity
(λ = 2000 W/(m*K); 20°C)

Mechanical stability
(**UBS**: 300 < σ_B < 600 MPa, depends on microstructure,
(tension on growth (GS) or nucleation (NS) side)
(**fracture toughness**)

Low loss tangent
(tan $\delta_{central}$ < 2x10^{-5} (170 GHz)

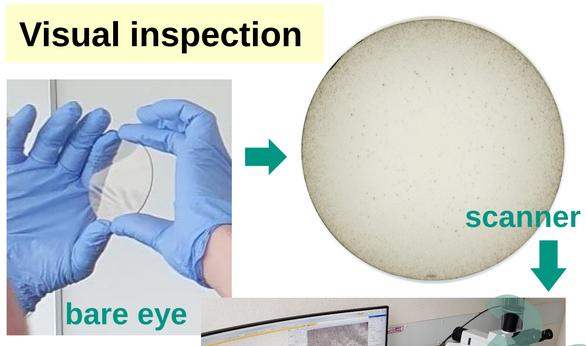


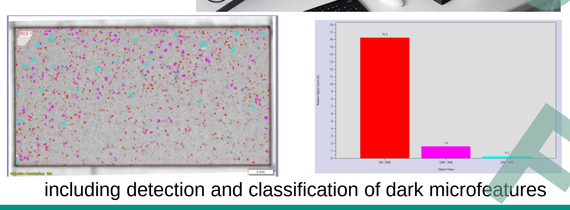


The loss tangent is very sensitive to disk manufacturing conditions (growing parameters, polishing, post treatment etc.) ➡ Verification necessary

Qualification of the diamond disks

Visual inspection





including detection and classification of dark microfeatures

Loss tangent

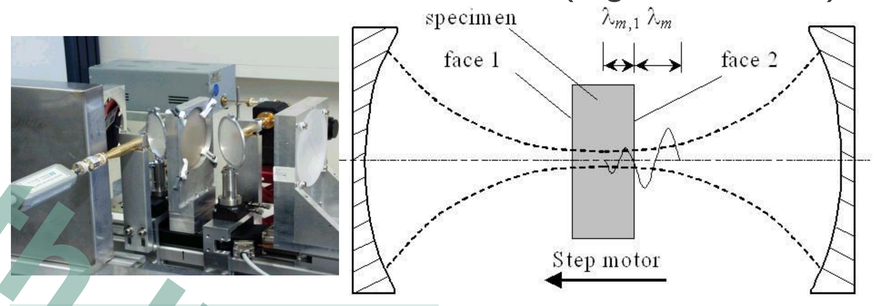
Absorbed power $A = P_{abs}/P_0 = (f/c)\cdot\pi\cdot(1+\varepsilon_r')\cdot\tan\delta\cdot t$

$\varepsilon_r^* = \varepsilon_r' + i\cdot\varepsilon_r'' = \varepsilon_r'(1+i\tan\delta)$, complex permittivity

$\tan\delta = \varepsilon_r''/\varepsilon_r'$ loss tangent

Spherical measurement setup (~140-220 GHz)

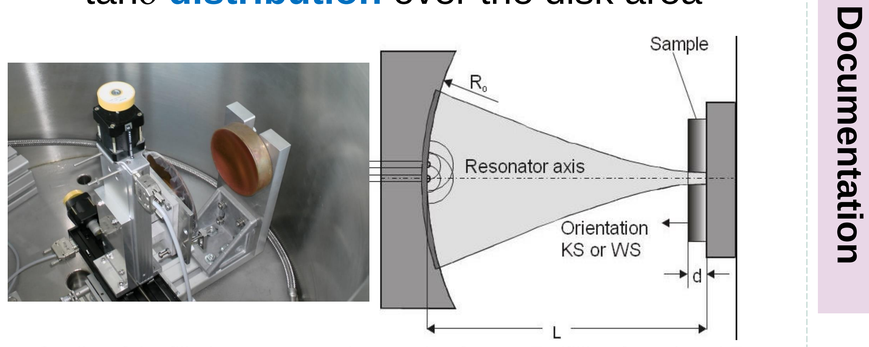
tanδ at the **center of the disk** (high resolution)



$$\tan\delta = F_F\left(\frac{1}{Q_m} - \frac{1}{Q_0}\cdot F_L\right)$$

Hemispherical meas. setup (~120-170 GHz)

tanδ **distribution** over the disk area

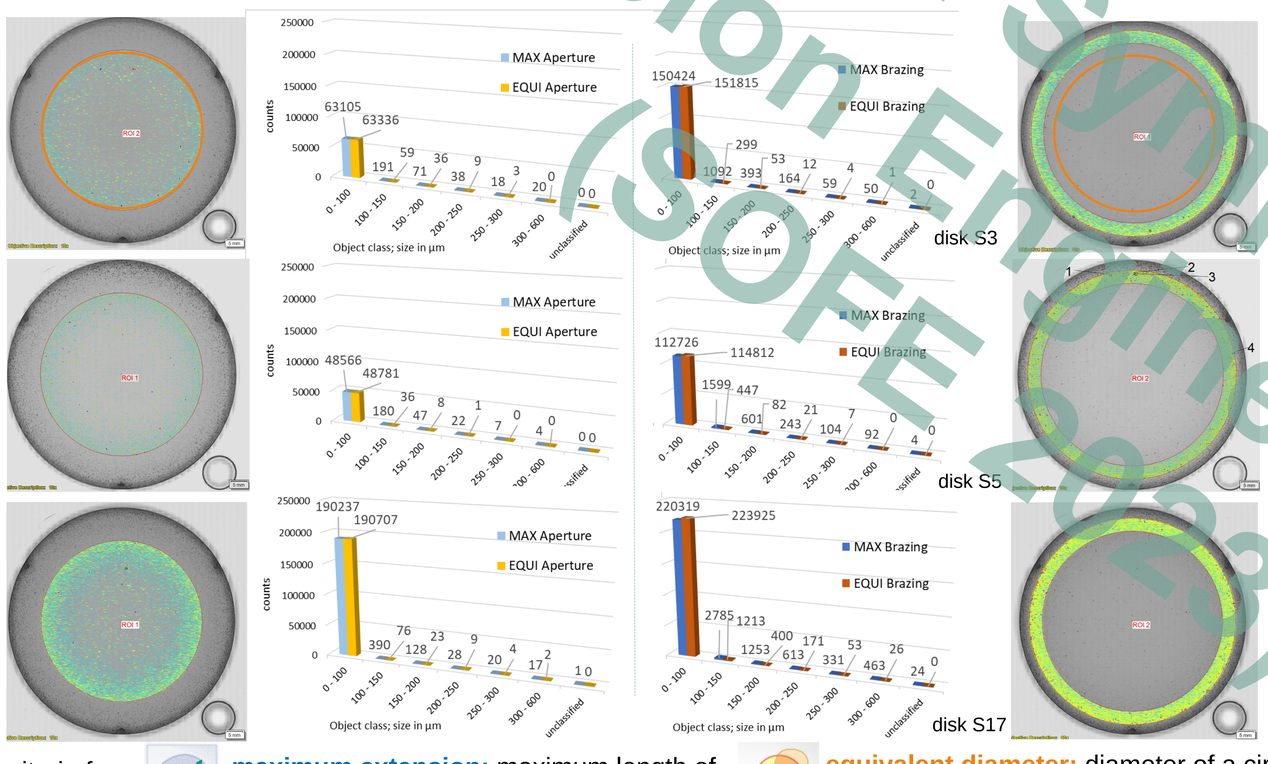


with: Q_0 = Quality of the empty resonator, Q_m = Quality of the filled resonator and correction factors F_F (filling factor) and F_L (loading factor), depending on the surface resistances of mirrors and sample, resonator geometry, resonance frequency and ε_r of the sample; t disk thickness.

Documentation

Results – Status of work

Microscopy

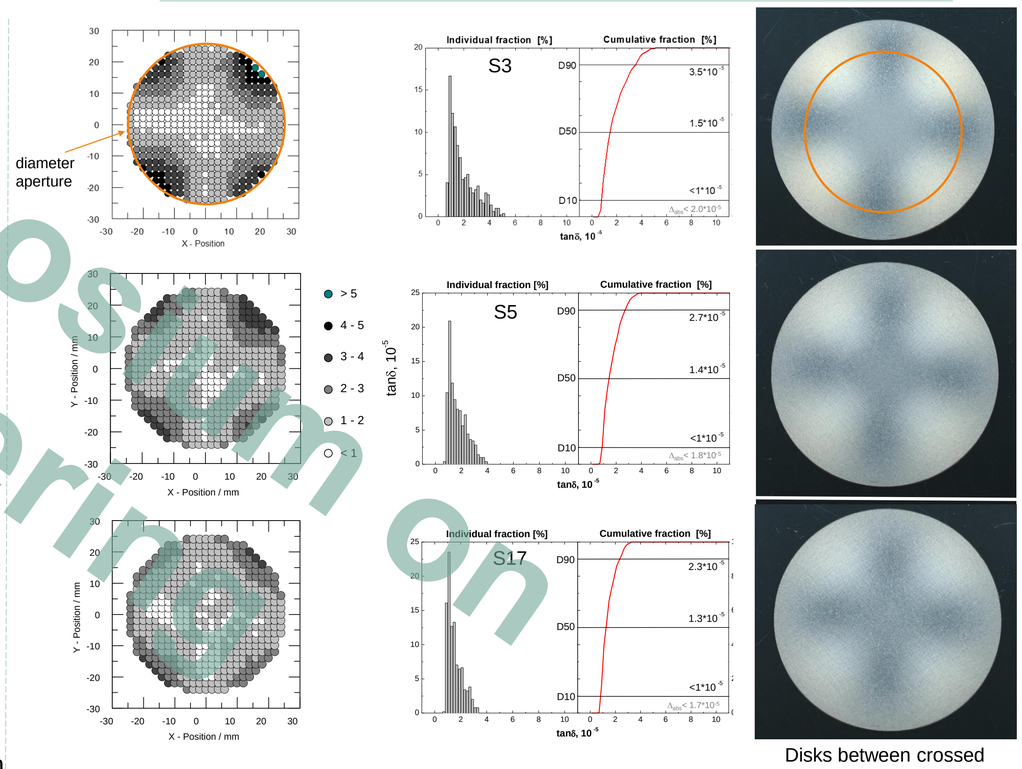


Two criteria for microfeature size:

maximum extension: maximum length of a line that connects two boundary points

equivalent diameter: diameter of a circle with the same area determined for the feature

Loss tangent / polarisation effect



Central loss tangent for all disks < 0.5*10^{-5} (170 GHz)

Disks between crossed polarization foils (visible light)

Outlook

62 disks manufactured by Diamond Materials GmbH Co. KG need to be qualified within the next 1-2 years. Selected disks will be used for „proof of concept“ prototypes for an adjusted design (F4E) and the Final Design Review of the complete Diamond Window Unit is pending.

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