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Dielectric loss measurements of CVD diamond disks for ITER windows

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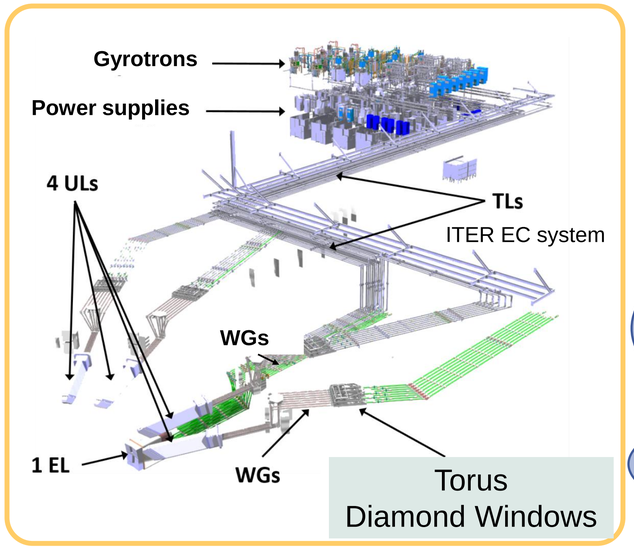
Introduction



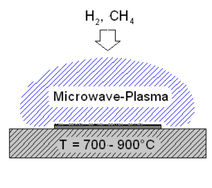
Torus Diamond Windows

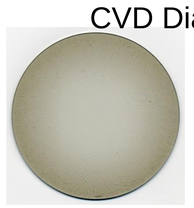
The windows of the Electron Cyclotron Heating & Current Drive (EC H&CD) system of ITER (used for plasma heating and stabilization) allow transmission of high power microwave beams and serve as vacuum and safety boundaries (confinement of hazardous materials e.g. tritium).
They consist of a chemical vapor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

High thermal conductivity
(λ: 2000 W/(m*K)

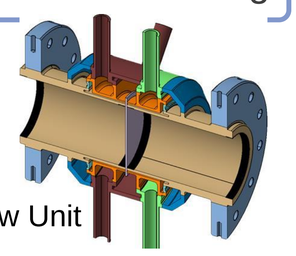
Mechanical stability
(**UBS**: σ_B ~ 500 MPa, depends on microstructure)
(**Fracture toughness**)

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





CVD Diamond disk



Diamond Window Unit

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

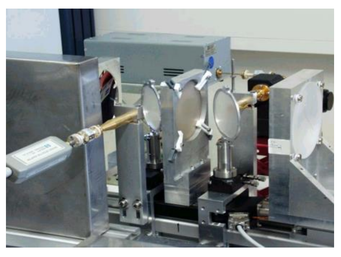
Determination of loss tangent

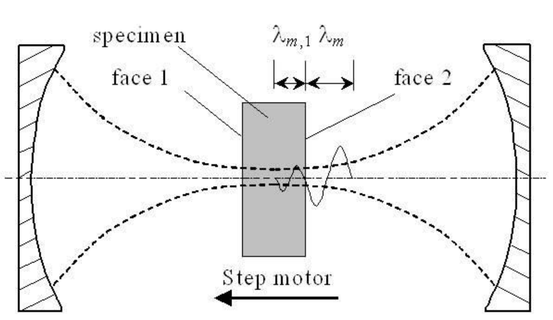
The normalized absorbed power $A = P_{abs}/P_0$ in a dielectric of thickness t can be calculated as: $A = (f/c) \cdot \pi \cdot (1+\varepsilon_r') \cdot \tan\delta \cdot t$

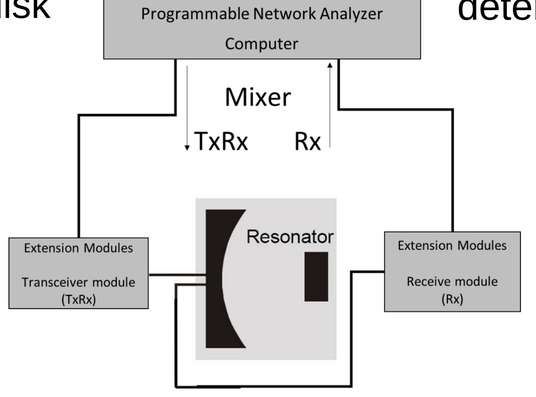
complex permittivity: $\varepsilon_r^* = \varepsilon_r' + i\cdot\varepsilon_r'' = \varepsilon_r'(1+i\tan\delta)$, dielectric loss tangent: $\tan\delta = \frac{\varepsilon_r''}{\varepsilon_r'}$

Spherical measurement setup (~140-220 GHz)

high resolution determination of tanδ at the center of the disk

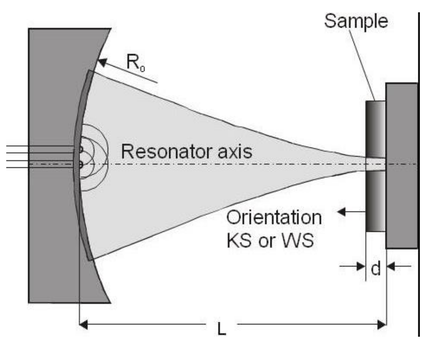


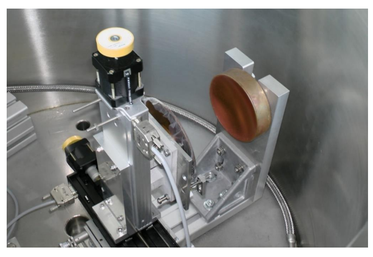




Hemispherical measurement setup (~120-170 GHz)

determination of distribution of tanδ over the disk area





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

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.

Qualification Process and first Results

Diamond disk(s) fabricated at manufacturer

Geometrical characterisation of the disk(s)
(Thickness, Diameter, Concentricity, Planarity, Surface roughness)

Delivery from Manufacturer to KIT
(delivery in batches 4-10 disks)

Freight reception and inspection

Dielectric Measurements (FABRY-PEROT):
Central loss tangent (double spherical set-up)
Mapping of loss tangent (hemispherical set-up)

Microscopic inspection
(irregularities, micro-cracks, etc.)

Disk(s) acceptance (or refusal) by KIT

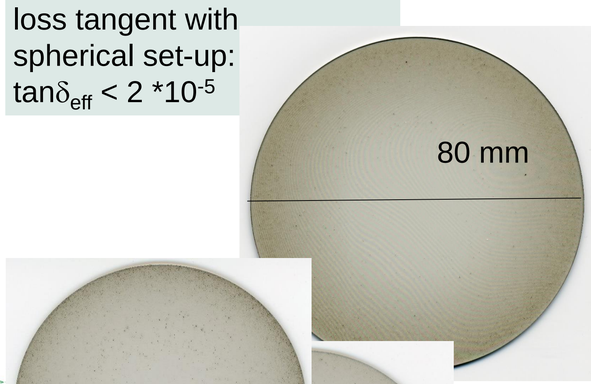
Preparation and delivery to disk manufacturer / window assembler

Disk(s) intermediate storage

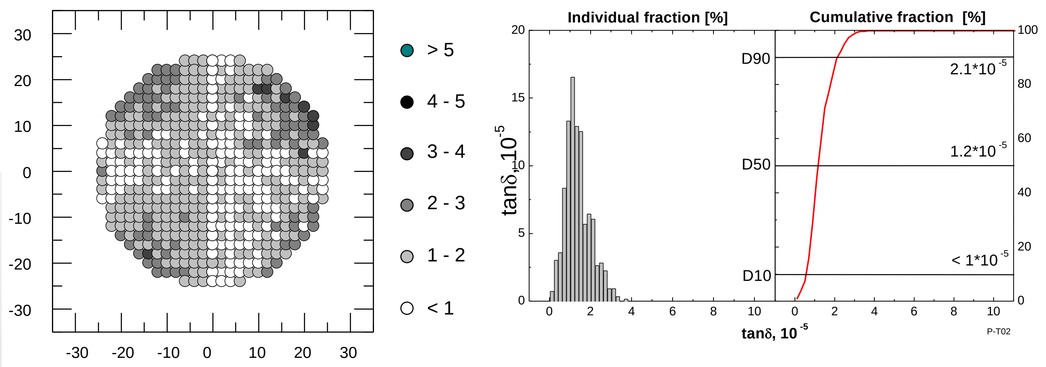
important single steps to be traced via Control Plans (TCP)

Specifications for 170 GHz:
loss tangent with hemispherical set-up:
D50 <3.5*10^{-5} ; D90 <6*10^{-5}

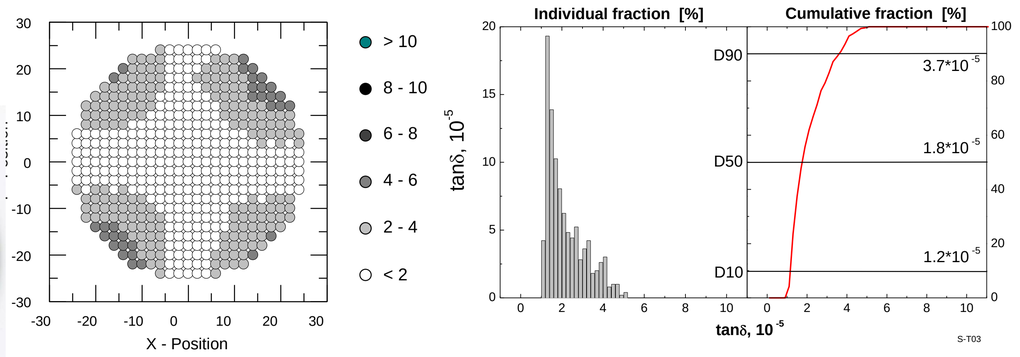
loss tangent with spherical set-up:
tanδ_{eff} < 2 *10^{-5}



Diamond Materials
Advanced Diamond Technology



dielectric losses tanδ_{eff} : 4 *10^{-6} (central measurement) (170 GHz)



dielectric losses tanδ_{eff} : 3 *10^{-6} (central measurement) (170GHz)

Outlook

62 diamond disks manufcatured by Diamond Materials need to be qualified within the next 1-2 years. Selected disks will be used for the manufacturing of „proof of concept“ prototypes for the adjusted design. Final Design Review of the complete Diamond Window Unit is owing. In parallel there are developments ongoing for the disk and window inspection during ITER operation.

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