DF 7: Focus: Microwave and THz Properties, Developments and Applications of Dielectric Materials

This dedicated focus session represents applications of dielectric materials from electronics up to Mega-Watt Fusion Heating systems. Part of the session are the different applications of dielectrics and the production and properties of these materials as well. Goal of the session is to join different fields to generate new ideas for dielectric applications and developments.

Organizer: Theo Scherer KIT Karlsruhe

Time: Tuesday 9:30–12:20 Location: GER 37

Topical Talk DF 7.1 Tue 9:30 GER 37

Synthesis of large-area single-crystal diamond by heteroepitaxy for application as dielectric window material — •Matthias Schreck, Stefan Gsell, and Martin Fischer — Institut für Physik, Universität Augsburg, 86135 Augsburg, GERMANY

Due to ist low dielectric loss tangent in combination with excellent mechanical properties and the unrivalled thermal conductivity, diamond is the optimum window material for the transmission of high power millimeter waves. Polycrystalline discs with diameters of about 100 mm synthesized by microwave plasma chemical vapor deposition (MWPCVD) are already in use as gyrotron exit windows or as injection windows for future thermonuclear fusion reactors. Since imperfections like graphitic bonds and C-H groups at grain boundaries still give rise to power absorption, the use of single crystals promises even lower loss tangents thus facilitating higher power levels. The present contribution reviews the efforts towards the synthesis of wafer-scale single-crystal diamond by heteroepitaxial growth using MWPCVD. The search for the optimum substrate material, the development of appropriate nucleation methods and the concepts for the scaling to wafer size are described. Particular attention is paid to dislocations which represent the crucial defect type. The role of dislocations in the development of intrinsic stress, the reduction of their density by growth of thick layers and by advanced deposition concepts is broadly discussed. Finally, the present state-of-the-art in terms of crystal quality and sample size is described.

DF 7.2 Tue 10:00 GER 37

Electron Cyclotron systems in future Fusion Power Plants, using dielectric microwave transmission windows — •Giovanni Grossetti, Gaetano Aiello, Francesco Mazzocchi, Andreas Meier, Theo Scherer, Sabine Schreck, Peter Spaeh, Dirk Strauss, and Alessandro Vaccaro — KIT, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein Leopoldshafen

Nuclear fusion has the potential to be a nearly unlimited, safe and CO2-free friendly energy source which would allow coping with the increasing demand in energy consumption, currently heavily based on the fast depleting fossil fuels (over 80%). Fusion devices are ring-shaped metal vessels provided with numerous openings for diagnostic systems and additional heating systems. One of the most important one is the Electron Cyclotron Heating and Current Drive system (ECH&CD), that aims to provide high power (several MW) in the rage of hundreds of GHz into the plasma, a hot gas composed by Deuterium and Tritium nuclei. In this paper we present the possible configurations of ECH&CD systems required by future fusion power plants. The focus will be on launching antenna systems without movable parts close to the plasma (i.e. remote steering concepts and truncated waveguides) and chemical vapor deposition (CVD) diamond windows. The latter are crucial to ensure flexibility in operation of Radio Frequency source (Gyrotrons), when the latter are capable to tune the beam frequency to the desired resonance.

Topical Talk DF 7.3 Tue 10:20 GER 37

Design, materials composition and manufacturing of components for advanced modular gyrotron prototypes — •Sebastian Ruess[1], Gaetano Aiello[2], Gerd Gantenbein[1], Tomasz Rzesnicki[1], Theo Scherer[2], Dirk Strauss[2], Manfred Thumm[1], Jörg Weggen[1], and John Jelonnek[1] — [1]IHM, — [2]IAM-WAP, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany

In frame of EUROfusion, Karlsruhe Institute of Technology (KIT) is performing major research on future gyrotrons for microwave heating of fusion plasma. Major factor for the success is to gain a fundamental understanding about the basic physics, the right materials composition in the assembly and, finally, the manufacturing technologies for future 2-MW gyrotrons operating in the frequency range from 170 GHz up to 240 GHz. The components of a first pre-prototype 2-MW, 170 GHz long-pulse gyrotron were already successfully in-house manufactured with an excellent quality. Furthermore, welding and solder joints have been achieved with an excellent leakage rate below < 10-12 mbar l/s. In particular, excellent solder joints between CVD diamond and copper as well as stainless steel and dispersion strengthened copper (Glidcop) were achieved. In addition, KIT is strongly involved in the development of ultra-low loss diamond discs for high power gyrotrons and fusion power plants. The ongoing KIT developments are focusing on the manufacturing, joining technologies and cooling concepts for advanced broadband CVD diamond double-disk and Brewster-angle windows.

20 min. break

Topical Talk DF 7.4 Tue 11:10 GER 37

Dielectric diamond window for the ITER EC H&CD Upper Launcher: design, analysis and qualification — •Gaetano Aiello[1], Mario Gagliardi[2], Giovanni Grossetti[1], Francesco Mazzocchi[1], Andreas Meier[1], Gabriella Saibene[2], Sabine Schreck[1], Peter Spaeh[1], Dirk Strauss[1], Alessandro Vaccaro[1], and Theo Scherer[1] — [1]Karlsruhe Institute of Technology, Institute for Applied Materials, D-76021 Karlsruhe, Germany — [2]Fusion for Energy, E-08019 Barcelona, Spain

The diamond window is a sub-component of the EC H&CD Upper Launcher and it is part of the ITER first vacuum and tritium confinement system while allowing the transmission of high power microwave beams from the gyrotrons into the plasma. The window consists of an ultra-low loss CVD diamond disc brazed to two copper cuffs and this structure is then integrated into a metallic housing by welding. Being a Protection Important Component, the most stringent requirements in the ITER safety, quality, seismic, vacuum and tritium classifications apply. In this work, we present the development of the window design and the qualification process aiming to meet the requirements via the applicable ASME code and a dedicated program. The window is in fact a unique component that cannot be entirely covered by Codes and Standards. At KIT, FABRY-PEROT resonators measure the loss tangent of the diamond disc which is then used as input to the FEM analyses aiming to validate the design. In the context of the OPE467 contract with F4E, technical specifications are approaching the final phase for the manufacturing and testing of two window prototypes.

DF 7.5 Tue 11:40 GER 37

THz Diagnostics for fusion - A new challenge for dielectric windows — •Francesco Mazzocchi, Giovanni Grossetti, Dirk Strauss, and Theo Scherer — Karlsruhe Institüt für Technologie, Hermann Von Helmholtz Platz 1, 76344, Eggenstein Leopoldshafen

Polarimetry is a reliable methodology to estimate fundamental plasma parameters such as electronic density and poloidal field from the measure of the Faraday rotation angle. In this work we present a conceptual study of an innovative polarimetric system. The device foresees multiple lines of sight, so that the estimation of the aforementioned parameters can be performed at different cords. Dielectric windows play a fundamental role in this case, given the number beamlines that require access to the vacuum vessel. In order to have an appreciable Faraday rotation, sources in the range of the low THz are needed. Quantum Cascade Lasers represent a very promising solution but to work at low frequency (around 1.6 THz) they require cryogenic temperatures. The power output of such devices is still several order of magnitudes below the level guaranteed by the more common laser sources employed so far, such as DCN gas lasers. Therefore a strong focus on the production and characterization of ultra low loss dielectric materials (e.g.

diamond, sapphire) for the cryostat and torus windows in the THz range is mandatory, to ensure the polarimeter probe beam absorption to be negligible and the device to work correctly.

DF 7.6 Tue 12:00 GER 37

Dielectric investigation methods in the THz frequency range
— •Theo Scherer, Francesco Mazzocchi, and Giovanni Grossetti — Karlsruhe Institute of Technology, D-76344 Eggenstein-Leopoldshafen, Germany

CVD diamond disks for high power heating applications are being investigated by different low- and high power measurement setups in the frequency range of > 100 GHz. To understand the loss mechanisms in diamond material the determination of the frequency dependence of dielectric constant and loss tangent at higher frequencies up to several THz is essential. It is well known from the experience with other window materials for high power fusion applications (ECRH) like silicon or sapphire, electrons and phonons are responsible for microwave losses. In diamond the sp2-carbon content and surface roughness determines surface losses. Additionally, the electronic surface states of such dielectrics for different chemical finishing of the diamond disks can be studied in the THz region. Different resonator setups to determine dielectric properties in the THz-range will be discussed.