DF 6: Focus Session: Applications of Dielectric Materials in Microwave Technology

Organized by Theo Scherer

Time: Monday 15:00–18:40 Location: H26

Topical Talk DF 6.1 Mon 15:00 H26

CVD diamond for nuclear fusion experiments — •Eckhard Wörner and Christoph Wild — Diamond Materials GmbH, Freiburg, Germany

Its outstanding physical properties make diamond an ideal material for demanding optical and thermal applications and the possibility to grow diamond by Chemical Vapor Deposition (CVD) finally makes it available for industrial use.

While it's common knowledge that diamond is the hardest material only few people know that it is also the material with the highest thermal conductivity, Debye Temperature and atomic density. In addition it's chemically inert, consists of lightweight strongly bound carbon atoms and is optical transparent from the ultraviolet to the far infrared. So it should come as no surprise that fusion experiments take advantage of its unique properties. Inertial confinement fusion uses hollow diamond spheres as capsules to be filled with deuterium and tritium whereas magnetic confinement fusion uses diamond windows to seal the torus from ambient atmosphere while being transparent for ultra-high power microwave radiation.

Diamond Materials GmbH, a Fraunhofer Spin-Off founded about 10 years ago, is one of the leading companies in the world that can grow large area optical grade CVD diamond. In our presentation we will describe growth and processing and focus on the preparation of diamond windows and spheres for nuclear fusion experiments.

Topical Talk DF 6.2 Mon 15:30 H26

Torus Diamond Window for the ITER ECRH Upper launcher — •Sabine Schreck, Gaetano Aiello, Giovanni Grossetti, Francesco Mazzocchi, Andreas Meier, Peter Spaeh, Dirk Strauss, Alessandro Vaccaro, and Theo Scherer — Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany

The ITER ECRH window consists of an ultra-low loss CVD diamond disk mounted in a system of metallic parts (Cu/SS). It has to fulfil adequate transmission capability for high power mm-waves, is part of the primary vacuum boundary of the ITER vacuum vessel and has the function of tritium confinement. Being classified as Protection Important Component, high requirements for quality and safety apply to the window. The window assembly cannot be entirely covered by codes and standards and therefore an ad-hoc qualification program is required including the testing of prototypes. Both, structural integrity and the mm-wave transmission capability shall be demonstrated. At KIT, dedicated FABRY-PEROT-resonators are available, to measure the loss tangent of the diamond disk and also its distribution over the disk area. The window design has been improved based on the gained experience with former prototypes of which the second one was already optimized with regard to its mm-wave properties. Recently, the design for two new prototypes has been developed and, after manufacturing, they will be qualified by passing a dedicated test program. First results on the qualification of the bare diamond disks for the prototypes are already available and show a very low dielectric loss.

DF 6.3 Mon 16:00 H26

Requirements for materials in high power mm-wave systems for Nuclear Fusion applications — •Giovanni Grossetti, Gaetano Aiello, Francesco Mazzocchi, Andreas Meier, Theo Scherer, Sabine Schreck, Peter Spaeh, Dirk Strauss, and Alessandro Vaccaro — Karlsruhe Institute of Technology (Institute of Applied Materials), P.O. Box 3640 76021 Karlsruhe Germany

Material science is a key ingredient for granting the success of a complex project like Nuclear Fusion and a great effort is placed to verify and validate components that will work under very harsh conditions in future fusion power plants.

In this paper we present an overview of the requirements for materials which shall be met for ensuring a high reliability, addressing to a specific system called Electron Cyclotron Heating and Current Drive system (hereafter, ECH&CD). Its goals and objectives are to provide heating and driving current into a Deuterium-Tritium plasma, by injecting localized high power mm-wave for plasma assisted breakdown, ramp up/down, pure heating, impurities control, disruption control and to mitigate plasma instabilities like the sawtooth and the Neoclassical Tearing Mode (NTM).

With respect to materials, the main issues are due to the high neutron flux that can cause material activation, to the high power (MW) of the mm-wave used and to safety, in order to grant Tritium compatibility of components like diamond window assemblies.

Topical Talk DF 6.4 Mon 16:20 H26

Double-disc Diamond Windows for Fusion Applications — •Alessandro Vaccaro, Gaetano Aiello, Giovanni Grossetti, Francesco Mazzocchi, Andreas Meier, Theo Scherer, Sabine Schreck, Peter Spaeh, and Dirk Strauss — Karlsruhe Institute of Technology (Institute of Applied Materials), P.O. Box 3640 76021 Karlsruhe Germany

Diamond windows are employed in Electron-Cyclotron Heating & Current Drive (EC H&CD) systems in fusion devices. By injecting high-power mm-waves beams, these systems heat up the plasma and counteract the formation of instabilities. Acquiring a complete understanding of what happens during operation of diamond windows is an important task. In fact, such units handle powers in the order of Megawatts and therefore small resonant cavities can easily become sources of high-intensity localized heating.

In this paper, we investigate a unit with a double-disc configuration. The study aims to evaluate localized power deposition on the unit's cooling channels and is carried out by developing a ray-tracing code that uses a hybrid approach; our code accounts for the waves' phase and thus reproduces the effects of interference. This goal is achieved by calculating reflection/transmission coefficients under the hypothesis of thin films and applying them only to the incident and back-refracted waves. The results show that mm-wave beams in off-axis position are potentially responsible of high heat flux deposition on the cooling channels that can, in turn, trigger nucleated boiling of the cooling water.

20 min break

Topical Talk DF 6.5 Mon 17:10 H26

Dielectric Characterization for Industrial Microwave Applications — •Sergey Soldatov, Vasileios Ramopoulos, Guido Link, and John Jelonnek — Kalsruher Institute of Technology IHM, Germany

Volumetric and selective heating of dielectric materials is a unique feature of microwave heating technology, that can provided a significant reduction in processing time and increase in energy efficiency. Therefore the use of microwave technology faces growing interest in various fields of industrial applications. As any production technology so also microwave assisted processes typically need process specific and optimized system designs. Those typically can be realized by electromagnetic and multiphysics simulations. The inevitable basis for this is a detailed knowledge about the dielectric behavior of any material involved at the frequency and temperature range of interest. This includes potential tooling materials as well the processed goods. In case the process leads to irreversible modification of those materials, due to phase changes or chemical reactions, than beside the temperature dependence the time dependence of the dielectric properties is of interest as well. Based on this, specific in-situ measurement techniques have been developed at KIT based on the transmission reflection method as well as the cavity perturbation method in the 2.45 GHz ISM-band. The system design of those dielectric test sets will be presented and discussed including some experimental results on specific materials.

DF 6.6 Mon 17:40 H26

A drying and thermoelastic model for microwave ablation of concrete — •benjamin Lepers — KIT, IHM, Hermann von Helmholtz Platz 1, 76344 Eggenstein Leopoldshafen

The use of high power microwaves to perform explosive spalling of concrete surfaces is a promising technique with applications in the area of concrete facilities decommissioning. The mechanism that creates explosive spalling is due to a combination of the thermal stress from high temperature gradients and the pore pressure generated from the water vaporization and water transport through a porous medium. In this paper a one dimensional model solving the heat and diffusion equations for liquid and vapor phase with the COMSOL Multiphysics finite element software is presented. The modelling of the drying process is based on the spatial reaction engineering approach (SREA). This paper discusses the influence of the relative activation energy parameter and effective diffusion coefficients on the temperature, water content and pore pressure in the case of fast microwave heating of concrete. This model is then used for a 3d geometry with a sealed insulated block of concrete and an conical waveguide antenna to compute the thermal stress, pore pressure and total stress.

DF 6.7 Mon 18:00 H26

Stoichiometry effect on microwave properties of all-oxide BST thin film varactors — •Patrick Salg[1], Arzhang Mani[1], Mohammad Nikfalazar[2], Aldin Radetinac[1], Rolf Jacoby[2], Lambert Alff[1], and Philipp Komissinskiy[1] — [1]Institute of Materials Science, TU Darmstadt, Germany — [2]Institute for Microwave Engineering and Photonics, TU Darmstadt, Germany

We present all-oxide ferroelectric varactors using a bottom electrode of the highly conducting perovskite $SrMoO_3$ [1]. Thin-film epitaxial heterostructures of $SrMoO_3$ with a room-temperature resistivity of 30 $\mu\Omega$cm and the functional tunable dielectric $Ba_xSr_{1-x}TiO_3$ with $(x = 0.2 - 0.6)$ were grown by pulsed laser deposition. As top electrode, sputtered amorphous Au/Pt layers were used and patterned by lift-off. The effect of stoichiometry of the $Ba_xSr_{1-x}TiO_3$ layer on the microwave properties of the varactors was investigated at frequencies up to 10 GHz at room temperature. A zero-bias quality factor of the varactors with $Ba_{0.4}Sr_{0.6}TiO_3$ of 110 at 1 GHz and 20 at 10 GHz was achieved. These values are more than 10 times higher than the ones previously reported in the literature for varactors with other oxide electrodes. The capacitance tunability of the varactors is above 50% at 8 V and stable in a broad frequency range from 100 MHz up to 10 GHz. The obtained results suggest a high potential of all-oxide ferroelectric varactors for microwave applications.

[1] A. Radetinac *et al.*, *Highly conducting $SrMoO_3$ thin films for microwave applications*, Appl. Phys. Lett. **105**, 114108 (2014).

DF 6.8 Mon 18:20 H26

Dielectric materials for high frequency detector applications — •Theo Scherer — KIT Karlsruhe, IAM-AWP

Superconducting detectors like Hot-Electron-Bolometers (HEBs) are used for the detection of signals in radioastronomy in the range of several hundrets of GHz up to THz. The dielectric properties and the phonon-conductance of substrate materials is essential for the 3dB-bandwidth of such a device. A comparison of different appropriate dielectrics is shown and the best candidates for real sensor devices will be discussed.