KFM 18: Focus Session: Diamond and related dielectric materials

This focus session contains basic diamond research due to optical and dielectric properties for applications in low and high power electronics. High frequency and high microwave power applications are discussed. The use of diamond material in GHz up to THz range is the main purpose of this session.

Organizer: Prof. Dr. Theo Scherer (KIT, Karlsruhe)

Time: Wednesday 15:00–16:50 Location: H5

Invited Talk KFM 18.1 Wed 15:00 H5

Deep understanding of advanced optical and dielectric materials for fusion diagnostic applications — •Anatoli I. Popov[1], E Kotomin[1], V Kuzovkov[1], A Lushchik[2], and Theo A Scherer[3] — [1]Institute of Solid State Physics, University of Latvia, 8 Kengaraga str., LV-1063 Riga, Latvia — [2]Institute of Physics, University of Tartu, W. Ostwald Str. 1, 50411, Tartu, Estonia — [3]Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, D-76344 Eggenstein-Leopoldshafen, Germany

In this talk, I will give a short overview of the most interesting results obtained in the framework of two EUROfusion Enabling Research projects - Advanced experimental and theoretical analysis of defect evolution and structural disordering in optical and dielectric materials for fusion applications (AETA) (2019-2020) and Investigation of defects and disorder in nonirradiated and irradiated Doped Diamond and Related Materials for fusion diagnostic applications (DDRM) Theoretical and Experimental analysis (2021-2023).

In a series of joint works by ISSP UL (Latvia), UT (Estonia), and KIT (Germany), radiation damage of some promising functional materials (Al2O3, MgAl2O4, SiO2, and diamond) from the priority list of the EUROfusion consortium was studied under neutron, proton, heavy-ion. Their optical, dielectric, vibrational & magnetic properties were carefully studied. Based on this study, we developed new theoretical methods able to evaluate and predict some important properties of these materials as well as their radiation damage evolution under extreme reactor conditions.

KFM 18.2 Wed 15:30 H5

Physics of natural and artificial diamond gemstones — •Theo Scherer — Karlsruhe Institut of Technology (KIT-IAM-AWP)

Diamond gemstones were very well appreciated in the antique world. Independent on the purpose of jewelry, diamond is a crystalline solid state material with excellent physical and chemical properties as a high Young modulus or a very high thermal conductivity. By doping the material with boron, electrical conductivity can be observed. This is important for electronic devices. In this talk the wide range of production of gemstones and technical applications like high frequency high power microwave transmission diamond windows for nuclear fusion power plants will be presented. Different diamond classifications, cuts and colors by impurities will be shown. A comparison of natural diamonds and artificial produces ones are topic of the discussion.

KFM 18.3 Wed 15:50 H5

Basic considerations for fracture toughness measurements of MPA CVD diamond to be used in nuclear fusion — •Gaetano Aiello, Theo Scherer, Andreas Meier, Sabine Schreck, and Dirk Strauss — Karlsruhe Institute of Technology, Institute for Applied Materials, D-76344 Eggenstein-Leopoldshafen, Germany

In nuclear fusion, Microwave Plasma Assisted (MPA) Chemical Vapour Deposition (CVD) polycrystalline diamond is the only material allowing for transmission of high power microwave beams (1-2 MW) in long-pulse gyrotron operations. The reason lies in the combination of extraordinary thermal, mechanical and optical properties of diamond, which is used in the shape of disks having thickness of 1 to 2 mm for windows. Being diamond a brittle material, failure to fracture is the main failure mode. Accordingly, an appropriate mechanical characterization is required as diamond plays a major safety role in fusion machines. Due to limited body of work in literature, fracture toughness measurements have to be first carried out for this material and then a design criterion for structural integrity assessment has to be applied. In this work, the preliminary activities aiming to define the optimum experimental measurement method of fracture toughness for thin diamond samples are shown and discussed. An outlook to the next steps is also given.

KFM 18.4 Wed 16:10 H5

Development diamond based Kinetic Inductance Detectors — •Francesco Mazzocchi, Dirk Strauss, and Theo Scherer — Karlsruhe Institute Of Technology

Kinetic Inductance Detectors (KIDs) have proven themselves as a very versatile cryogenic detector technology capable of applications in various fields due to their flexibility of design, sensibility and ease of production. We have recently proposed a polarization sensitive Lumped Elements KID as sensor for an innovative polarimetric diagnostics based on quantum cascade lasers (QCL) for application in the nuclear fusion. Each detector unit is composed by 4 pixels arranged at the vertices of a square, each pixels being sensible to only one polarization direction. The current system is based on niobium nitride (NbN) superconductor over High Resistivity Silicon (HRSi) substrate. Such material delivers good performances but its relatively high dielectric constant and loss tangent lead to increased substrate losses. Using a transparent substrate may improve this aspect and also the radiation resistance of such devices. Diamond is the substrate of choice, being a material already widely studied and used in the fusion environment as high power microwave window, due to its outstanding optical and mechanical performances. In this work we present the preliminary design study for a diamond based Kinetic Inductance Detector and subsequent characterization measurements of the first prototypes.

KFM 18.5 Wed 16:30 H5

Characterization of - A survey of electrical and dielectric properties — •Theo Scherer — Karlsruhe Institute of Technology (KIT-IAM-AWP)

p-Boron-doped polycrystalline CVD diamond samples were produced and delivered by the German company Diamond Materials in Freiburg (Germany). In a first step, main properties of this candidates for diagnostic and/or heating windows in future nuclear fusion reactors were investigated. By a special measurement technique, it was possible to determine the Boron doping concentration in Diamond by measurement of the resistive properties by using the van der Pauw method. So prepared, an irradiation campaign with neutrons and/or heavy ions on these samples will follow. The second material investigated, was r-plane single crystalline sapphire. For the first characterization the dielectric properties of a 3*-wafer in dependency of the frequency in a FABRY-PEROT resonator setup was performed. Also, this is the preparation for the next irradiation experiments in this project.