KFM 18: Diamond II + Poster

This dedicated focus session represents the production and applications of diamond and diamond related materials in the fields of dielectrics, electronics, high frequency techniques, GHz-THz- applications, mechanics and optics. Also materials/composites like carbides, boron-carbides and nitrides are related materials with excellent mechanical properties. Applications with integrated diamond or related materials in technical systems are part of this session (Nuclear fusion applications,high frequency heating systems and material processing).

Chair: Theo Scherer KIT Karlsruhe

Time: Wednesday 15:00–17:30 Location: E 124

Invited Talk KFM 18.1 Wed 15:00 E 124

Application of Diamond Technology to Microwave Systems in Nuclear Fusions Machines — •Giovanni Grossetti, Gaetano Aiello, Francesco Mazzocchi, Andreas Meier, Sabine Schreck, Peter Spaeh, Dirk Strauss, and Theo Scherer — Karlsruhe Institute of Technology (Institute of Applied Materials), P.O. Box 3640 76021 Karlsruhe Germany

The growing energy demand, set to increase by 37% by 2040, and the reduction of greenhouse gases are two key reasons why the energy landscape needs to be less reliant on fast-depleting fossil fuels. In this frame, Nuclear Fusion represents an option by being a nearly unlimited, safe and CO2-free friendly energy source. In order to reach and support the required conditions such that nuclear fusion reaction can occur, a gas mixture (deuterium and tritium) needs to be confined, e.g. through strong magnetic fields, and heated using microwave systems operating at the cyclotron frequency. Such systems shall meet several requirements from both the physics and the engineering point of view and make use of diamond disks grown by Chemical Vapor Deposition (CVD). In this paper we present an overview of the applications of such disks in components know as diamond windows, for both present machine and ITER, and future power plants.

KFM 18.2 Wed 15:30 E 124

Application of CVD Diamond Discs in High Power Fusion Gyrotrons and Power Plants — •Sebastian Ruess[1,2], Gaetano Aiello[3], Gerd Gantenbein[1], Manuel Gärtner[1], Tomasz Rzesnicki[1], Theo Scherer[3], Dirk Strauss[3], Manfred Thumm[1,2], Jörg Weggen[1], and John Jelonnek[1,2] — [1]IHM, — [2]IHE, — [3]IAM-AWP, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany

Karlsruhe Institute of Technology (KIT) is doing research and development in the field of megawatt-class RF sources (gyrotrons) for the Electron Cyclotron Resonance Heating (ECRH) systems of the International Thermonuclear Experimental Reactor (ITER) and the DEMOnstration Fusion Power Plant that will follow ITER. In the focus is the development and verification of the European coaxial-cavity gyrotron technology which shall lead to gyrotrons operating at an RF output power significantly larger than 1 MW CW and at an operating frequency up to 240 GHz.

Currently, the KIT is working on high-power broadband microwave output window systems for strongly overmoded waveguides based on ultra-low loss CVD-diamond. The ongoing research is focusing on the electromagnetic properties in combination with the manufacturing of very large windows (up to 180 mm) and the development of advanced technologies for joining of large diamond discs for advanced broadband CVD Brewster-angle windows. The simulation of the electrical large structures is requiring specific care. This presentation will focus on the related multiphysics simulations using the commercial tool CST.

KFM 18.3 Wed 15:50 E 124

Diamond Window Diagnostics For Fusion Applications — •Francesco Mazzocchi, Gaetano Aiello, Dirk Strauss, Andreas Meier, and Theo Scherer — KIT IAM AWP Hermann von Helmholtz Platz 1 76344 Eggenstein Leopoldshafen

The future nuclear fusion power plants will require Electron Cyclotron Heating and Current Drive (ECH&CD) systems to heat up and stabilize the plasma inside the vacuum vessel. One of the key components of such systems is the Chemical Vapor Deposition (CVD) diamond window. In this work, the latest assessment study on a set of diagnostics to be part of the window assembly is shown. The required diagnostics include arc and tritium detection, microwave stray radiation (perpendicular to the main beam and generated by cracks in the windows), pressure and disk temperature measurements. The devices must have a compact, simple and flexible layout, with a rugged design, to maximize serviceability and durability. To accommodate the diagnostics previously mentioned, a new design for the window housing was developed. To validate the concepts, a test bench was developed to carry out measurements under conditions similar to the operative ones.

KFM 18.4 Wed 16:10 E 124

Loss mechanisms of microwave and THz radiation in poly and single crystalline diamond — •Theo Scherer — Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany

To understand the microwave and THz wave propagation in poly and single crystalline diamond, the losses caused by free charge carrier absorption, dipole relaxation, phonon resonance absorption and disorder absorption will be discussed. The main loss parameter in such dielectrics is the loss tangent. Intergrain scattering effects in polycrystalline diamond are a limiting factor for further reduction of losses in that materials. The way to come to losses of $<$ 10E-6 in loss tangent will be shown and discussed. One important application of low loss diamond in disk shape is the transmission of Megawatt power for plasma heating in future fusion reactors as electrical power plants.

KFM 18.5 Wed 16:30 E 124

Influence of WC-Co on the High-Frequency Properties of Soft Ferromagnetic Fe-Co-Hf-N Films Used for Sensor Application — •Stefan Beirle, Klaus Seemann, and Harald Leiste — Karlsruhe Institute of Technology (IAM-AWP), 76344 Eggenstein-Leopoldshafen, Germany

The thermal and mechanical induced high frequency property changes of soft ferromagnetic Fe-Co-Hf-N films with an in-plane uniaxial anisotropy are promising for the application for sensor systems. For example, one can use the sensor signal to measure the cutting tool temperature during metal processing. Consequently, it is necessary to investigate how the ferromagnetic film interacts with a cemented carbide substrate, which is typically used for cutting tools, but consists itself of a hard ferromagnetic Co phase. In order to overcome the exchange interactions between the substrate and the ferromagnetic film, it is possible to predeposit a non-ferromagnetic buffer layer on the WC-Co substrate. For this purpose different hard coatings like Ti-N, Ti-Al-N and an electrically insulating Si-O buffer layer were investigated. In order to determine the static and dynamic magnetic properties of the film, MOKE measurements were carried out as well as the complex permeability was determined. The buffer materials show a different decoupling behaviour regarding the high frequency permeability due to different electrical and microstructural properties. The decoupled films show ferromagnetic resonance absorbance and the FWHM of the resonance line can be tuned by increasing the electrically insulating buffer layer thickness.

KFM 18.6 Wed 16:50 E 124

Mechanical load study on Diamond Window Mock-up — •Andreas Meier, Theo Scherer, Gaetano Aiello, Giovanni Grossetti, Francesco Mazzocchi, Sabine Schreck, and Dirk Strauss — KIT Karlsruhe, 76344 Eggenstein-Leopoldshafen, Germany

An Electron Cyclotron Heating (ECH) is an effective heating system in nuclear fusion reactors. The power transfer of the microwave radiation into the torus is realized by diamond windows which are relevant components for the retention of tritium. Mechanical stability and leak tightness are essential characteristics. A mock-up, consisting of a large diamond disk, diameter 80mm and thickness 1.11mm, brazed on cylindrical copper cuffs (diameter 70mm) was tested under different pressure scenarios and cyclic loads. Leak tightness measurements

identified leak rates directly by using helium gas.

KFM 18.7 Wed 16:50 E 124

Torus Diamond Window for ITER - R&D and Qualification activities for a Protection Important Component — •Sabine Schreck, Gaetano Aiello, Stefan Dieterle, Andreas Meier, Dirk Strauss, and Theo Scherer — Karlsruher Institut für Technologie

The diamond window is part of the ITER ECRH Upper Launcher system and consists of an ultra-low loss CVD diamond disk mounted in a system of metallic parts. The window has to fulfil adequate transmission capability for high power mm-waves and it serves as primary vacuum and tritium boundary of the ITER vacuum vessel. Classified as Protection Important Component high requirements for quality and safety apply. As the window cannot be entirely covered by codes and standards an ad-hoc qualification program is required, including prototyping and previous R&D. Diamond disks with a low dielectric loss tangent <2*10-5), a diameter of 65 mm and a thickness of 1.11 mm are planned to be integrated into the window housing. This thickness satisfies the resonance condition for the 170 GHz beam, ensuring a high transmission. But the disks also need to be validated with respect to the mechanical loads, especially to the pressure loads. R&D activities have been performed with the aim to verify the resistance of the disk against these loads. Flexural strength measurements of diamond disks (D = 30 mm, d = 1.11 mm) have been executed using a ring to ring set-up, giving information on the failure behaviour. Further, high pressure tests up to 2 bar of a mock-up (disk brazed to a copper cuff) are under examination.

KFM 18.8 Wed 16:50 E 124

Hybrid-UV-Vis-Detektoren aus Silizium-Fotodioden und darüberliegenden polykristallinen Diamantschichten — •Alexander Lawerenz[1], Mario Bähr[1], Ralf Röder[1], Nicolas Wöhrl[2] und Volker Buck[2] — [1]CiS Forschungsinstitut für Mikrosensorik GmbH, Konrad-Zuse-Str. 14, D-99099 Erfurt — [2]Universität Duisburg-Essen, Fakultät für Physik, Lotharstr. 1, 47057 Duisburg

Es wurde ein Detektor entwickelt und hergestellt, der gleichzeitig und unabhängig UV-Licht mit Wellenlängen < ca. 230 nm und sichtbares Licht (bis in den UV-C-Bereich) detektiert. Dazu wurden auf 100 mm großen Siliziumwafern Siliziumfotodioden und darüberliegend UV-Photoresistoren, bestehend aus strukturierten 20 um dicken polykristallinen Diamantschichten, monolithisch aufgebaut. Es wurde ein Prozessschritt entwickelt, der einerseits das Substrat mit der aktiven Diodenstruktur vor der Diamantprozessierung schützt und die beiden Sensoren isoliert, andererseits aber das einfache Freilegen der Kontakte für die Siliziumdiode nach der Diamantprozessierung ermöglicht. Es gelang mittels einer 100 nm dicken Aluminiummaske, die 20 um dicken Diamantschichten mittels Sauerstoff-Plasmaätzen zu strukturieren, ohne dass das frei geätzte Substrat sichtbar geschädigt wurde. Des Weiteren konnte als Metallisierung das Ti/Au-Kathodenzerstäuben etabliert werden, die auf den relativ rauen Diamantoberflächen eine ausreichend gute Haftung mit einem geringen Kontaktwiderstand ermöglicht.

KFM 18.9 Wed 16:50 E 124

Diamant und ägyptische Pyramiden — •Peter-Michael Wilde — DE-15711 Königs Wusterhausen

Zwischen den Dimensionen der Diamantstruktur [1] und der äußeren Gestalt ägyptischer Pyramiden [2] liegen 11 Größenordnungen.

Es wird gezeigt, dass trotz dieser großen Unterschiede zwischen beiden Objektgruppen ein enger Zusammenhang besteht. Die Zahl Quadratwurzel aus 2 spielt hierbei die maßgebliche Rolle.

Zu Beginn dieses Jahrhunderts ist es in Berlin gelungen, Kristalle mit dem Habitus ägyptischer Pyramiden im System Kohlenstoff-Silicium-Germanium auf einem Siliciumsubstrat im Mikrometer-Maßstab nachzubilden.

[1] W. Kleber, H.-J. Bautsch, J. Bohm, Einführung in die Kristallographie, Verlag Technik Berlin München (1990) [2] F. Müller-Römer, Der Bau der Pyramiden im Alten Ägypten, Utz Verlag (2011)

KFM 18.10 Wed 16:50 E 124

Cross-sectional Microstructure, Stress Gradients, and Mechanical Properties in Diamond Films Revealed by X-ray Nanodiffraction and Microcantilever Testing — David Gruber[1], •Nicolas Wöhrl[2], Hadwig Sternschulte[3], Manfred Burghammer[4], Juraj Todt[5], and Jozef Keckes[1] — [1]Department für Materialphysik, Montanuniversität Leoben, Austria — [2]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany — [3]Fakultät für Allgemeinwissenschaften, Hochschule Augsburg, Germany — [4]ESRF, Grenoble, France — [5]Erich-Schmidt-Institut, Austrian Academy of Sciences, Leoben, Austria

Ultrananocrystalline diamond (UNCD) films consist of randomly oriented diamond grains embedded in an amorphous C:H matrix. Usually, the grain size is determined by XRD or TEM, revealing information from the total UNCD film or only locally from selected areas with low statistics. Here, we present a cross-sectional X-ray nanodiffraction study of diamond multi-layers with varying grain size from microcrystalline diamond to UNCD. X-ray nanodiffraction was performed in transmission geometry using a beam diameter of 30 nm. The sample was scanned in equidistant steps, revealing depth gradients of texture, grain size and residual stress. Young's modulus and fracture stress in both UNCD and microcrystalline sublayers were measured with micro cantilevers fabricated by FIB milling. A cross-sectional nanoindenter-based mapping of Young's modulus was carried out on a slice of the layer system prepared by FIB. The results show complex gradients of microstructure, stress state and mechanical properties.