KFM 13: Diamond I

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 9:30–12:50 Location: E 020

Invited Talk KFM 13.1 Wed 9:30 E 020

Advanced Cell Adhesion of Modified Ultrananocrystalline Diamond Surfaces — •Cyril Popov — Institute of Nanostructure Technologies and Analytics, Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Germany

The interactions of different types of cells with ultrananocrystalline diamond (UNCD) surfaces with H-, O- and NH2-terminations were investigated with respect to cell density and viability. No cyto- or genotoxicity, no adverse effects on the cell viability and physiological responses were detected. The observed fast and strong attachment of the cells was attributed to a favorable combination of topography, surface chemistry and wettability. The enhanced attachment of the neurons was especially advantageous for the immunocytochemical procedures where the cell losses during washing steps were significantly reduced by one order of magnitude. In addition, applying photolithography the integration of a titanium grid structure under the UNCD films allowed for individual assignment of physiologically characterized neurons. The patterning of the UNCD surface termination by a hard mask and two modification steps resulted in guided cell attachment and growth.

KFM 13.2 Wed 10:00 E 020

Quantum Coins and Nano Sensors: Development of Unforgeable Diamond Money — •Alexander Schmidt, Johann Peter Reithmaier, and Cyril Popov — Institute of Nanostructure Technologies and Analytics, Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

The integration of NV centers within diamond nanostructures such as nanopillars and AFM tips can be used for the development of quantum coins implementation and quantum sensing of magnetic fields at a nanoscale. Here we report on our two main fabrication procedures for structuring of nanocrystalline diamond (NCD) films: First, for highly dense arrays of nanopillars and second for AFM tips. The fabrication process of nanopillars consisted of their definition by electron beam lithography (EBL) applying a hard mask and subsequent inductively coupled plasma reactive ion etching (ICP RIE) with oxygen. The lateral distances of the pillar arrays with 200, 100 and 50 nm diameter were decreased up to the highest package density achieveable. NCD AFM tips were fabricated by means of the moulding technique, using conventional photolithography and anisotropic wet etching of the silicon substrate.

KFM 13.3 Wed 10:20 E 020

Application of UNCD Layers as Implant Coatings — •Daniel Merker[1], Silviya Stateva[2], Rolf Merz[3], Michael Kopnarski[3], Johann Peter Reithmaier[1], Margarita Apostolova[2], and Cyril Popov[1] — [1]Institut für Nanostrukturtechnologie und Analytik, Kassel, Germany — [2]Roumen Tsanev Institute of Molecular Biology, Sofia, Bulgaria — [3]Institut für Oberflächen- und Schichtanalytik GmbH, Kaiserslautern, Germany

Due to the excellent mechanical properties combined with good biocompatibility thin diamond layers are considered as a promising material for biomedical applications like implant coatings. We performed tribological measurements of ultrananocrystalline diamond (UNCD) coated titanium samples against steel and diamond counterparts to investigate their friction behavior. The key property of an implant coating is the interaction with the surrounding tissue to prevent inflammatory responses but on the other hand to promote the integration of the implant into the tissue. We prepared UNCD samples with and without plasma modification of the surface and used three different cell lines related to the generation of new blood vessels and bone matter to study the effects of the different surfaces on the cell adhesion by immunostaining studies and the protein content of the cells by bioinformatic analysis of the proteome. Additionally, we aim to provide the coating with antimicrobial ability by embedding silver nanoparticles into the coating that release silver ions which are known as effective antibacterial agents.

KFM 13.4 Wed 10:40 E 020

Magnetic Resonance in Defect Spins via Spin Waves — •Clara Mühlherr, Vladyslav Shkolnykov, and Guido Burkard — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

Searching for quantum systems to realize quantum computation, the nitrogen-vacancy (NV) center in diamond has been intensively studied for years. Despite favorable properties such as remarkable coherence times, an application of ensembles of NV centers to perform quantum computing raises some technical issues. Since a direct coupling of NV centers via spin-spin dipolar interaction requires the NV centers to be separated by less than a few nanometers, this proximity limits the addressability of a single center. To overcome this problem, enhancement of coherent interaction between NV centers and a microwave field recently has been demonstrated using spin waves propagating in an yttrium iron garnet (YIG) film [1]. We analyze the optically detected magnetic resonance (ODMR) spectra by combining the occurring resonances and the orientation of the external magnetic field in the YIG. In that way, the crystal orientation of the NV centers is identified, which, in turn, nicely links to applications of NV centers for sensing. In order to explain the coupling mechanism and to estimate the enhancement of the coupling strength, we theoretically calculate the amplitude of the spin waves in the YIG.

[1] P. Andrich *et al.* Long-range spin wave mediated control of defect qubits in nanodiamonds. *npj Quantum Information* **3**, 28 (2017).

20 min. break

Invited Talk KFM 13.5 Wed 11:20 E 020

CVD diamond for high power electronic devices — •Verena Zürbig — Fraunhofer-Institut für Angewandte Festkörperphysik IAF, Freiburg, Germany

CVD single-crystalline diamond is a promising wide band gap semiconductor for the fabrication of high power, high frequency and high temperature electronic devices due to its outstanding physical properties such as high breakdown electric field, high thermal conductivity and high electron and hole mobilities. Diamond high power devices have been intensively investigated for several years and are a promising alternative to SiC- and GaN-based high power electronic devices. The realization of uni- and bipolar devices requires the ability to grow high quality phosphorous- and boron-doped single-crystalline diamond layers on (100) and (111) oriented crystals along with the ability of 3D-technology to manufacture high power electronic devices. In this talk, a detailed presentation of phosphorous- and boron-doped diamond layer-growths regarding their crystalline quality and its influence on electronic properties will be given. In addition, recently diamond-based power electronic devices will be summarized.

KFM 13.6 Wed 11:50 E 020

Electrical characterization of diamond-based Schottky-diodes for high power electronics — •Lucas Pinti[1], Philipp Reinke[1], Fouad Benkhelifa[1], Lutz Kirste[1], Christian Giese[1], Tobias Erlbacher[2], Andreas Schletz[2], Volker Cimalla[1], Christoph E. Nebel[1], Oliver Ambacher[3], and Verena Zuerbig[1] — [1]Fraunhofer IAF, Freiburg, Germany — [2]Fraunhofer IISB, Erlangen, Germany — [3]INATECH, Freiburg, Germany

In power electronics, the enhancement of energy efficiency and reduction of module volume are major points for innovative voltage converter system. Switching and conduction losses in common Si-based power electronic devices and the consequential need of cooling systems to guarantee reliable operation of such systems reduce the overall efficiency and therefore represent additional costs. Diamond as a new wide-band-gap semiconductor material is a promising extension in terms of voltage and heat dissipation in comparison to Si-based power electronic devices. With its outstanding physical properties like high breakdown electric field, high carrier mobilities and high thermal conductivity diamond has the best requirements to enable semiconductor power devices with low losses and minimized cooling efforts. In our presentation, we will report on the electrical characterization of vertical single-crystalline diamond Schottky diodes, which are fabricated by a CVD process. Temperature dependent IV characteristics as well as a detailed analysis of important device parameters like blocking voltage and specific on-resistance of the diodes will be given and compared to state of the art power diodes suitable for power converter modules.

KFM 13.7 Wed 12:10 E 020

Messverfahren zur Bestimmung der Wärmeleitfähigkeit an dünnen Diamantschichten an Hand von Beispielen — •Mario Bähr, Indira Käpplinger, Alexander Lawerenz und Thomas Ortlepp — CiS Forschungsinstitut für Mikrosensorik GmbH, Konrad-Zuse-Str. 14, 99099 Erfurt, Germany

Diamant besitzt in seiner einkristallinen Form einen der höchsten Wärmeleitfähigkeitskoeffizienten (>2000 W/mK). Diese wird nur bei Diamant gepaart mit einem über mehrere Größenordnungen einstellbaren elektrischen Widerstand von 10^4-10^{14} Ohmcm. Daher ist eine technische Nutzung von höchstem Interesse im Bereich der Aufbau- und Verbindungstechnologie temperaturkritischer Bauelemente, die einem effektiven Wärmemanagement bedürfen. Diese sind bspw. Leuchtdioden oder (opto-) elektronische Hochleistungsbauelemente. Kosteneffizient könnten Diamantschichten als Wärmespreizer auch als dünne Schichten mit Dicken von <50 um eingesetzt werden. Dazu wird die Diamantschicht auf einem Träger (=Wärmesenke) synthetisiert und strukturiert. Dieser Ansatz wurde verfolgt und Siliziumträger mit einer wärmespreizenden synthetischen Diamantschicht simuliert, hergestellt und mit verschiedenen Verfahren charakterisiert. Besonderes Augenmerk liegt auf der Bestimmung der Wärmeleitfähigkeit der dünnen Diamantschichten. Gegenübergestellt werden die 3-Omega-Methode angewendet an unterschiedlichen Probenkonfigurationen und das Laser-Flash-Verfahren in verschiedenen Konfigurationen. Da für die Anwendung relevant, wird auf die Unterscheidung der transversalen und der lateralen Wärmeleitfähigkeit hingearbeitet.

KFM 13.8 Wed 12:30 E 020

Holonomic Quantum Control of the state of an NV-center in Diamond — •Vlad Shkolnikov[1], Brian Zhou[2], Paul Jerger[2], Joseph Heremans[2,3], Guido Burkard[1], and David Awschalom[2,3] — [1]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany — [2]Institute for Molecular Engineering, University of Chicago, Chicago, Illinois 60637, USA — [3]Materials Science Division, Argonne National Laboratory, Argonne, Illinois 60439, USA

Geometric phases arising from cyclic evolution of quantum systems open new strategies for constructing robust quantum technologies. Here, we demonstrate arbitrary single qubit holonomic gates from a single cycle of nonadiabatic evolution of the electron spin of an NV-center [1]. Our method varies the amplitude, phase, and detuning of a two-tone optical field to gain full control over the state of the qubit with arbitrary rotation axes and angles. We analyze the robustness of detuned gates using the Lindblad formalism and show the gate fidelity to be mostly defined by the lifetime of the excited state of the NV. We experimentally and theoretically prove that single cycle gates are better than those consisting of two concatenated cycles.

[1] Brian B. Zhou, Paul C. Jerger, V.O. Shkolnikov, F. Joseph Heremans, Guido Burkard, and David D. Awschalom Phys. Rev. Lett. 119, 140503