Accelerator Systems Division

Seminar Announcement

Title: Diamond Cathodes

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Date: Wednesday, Dec. 10, 2014

Time: 11:00 a.m.

Location: Conf. Rm. A1100

Abstract

Ultrananocrystalline diamond (UNCD) emerges as an excellent platform to create high efficiency and stable electron emitters for accelerator applications. We fabricated and tested two emitter prototypes.

Field emission cathode. Field emission is a process of liberation of electrons from solid-state materials into vacuum. A strong electric field induces tunneling propagation through the surface barrier. Thus, the field emission cathode (FEC) is an electron source alternative to photo-/thermionic cathode with no need of additional laser/heater. In the RF injector, electron bunches could be generated and phased by the electric RF field itself every time its positive part peaks on the FEC's surface, and a repetition rate equal to an RF frequency is supported automatically. Hence, the FEC may simplify RF electron guns. A case performance study of a FEC based on nitrogen-incorporated UNCD, (N)UNCD, was carried out in an RF 1.3 GHz electron gun. The FEC was a 100 nm (N)UNCD film grown on a 20 mm cathode plug. At surface gradients 45-65 MV/m, peak currents of 1-80 mA (0.3-25 mA/cm2) were achieved. Imaging with two YAG screens confirmed emission from the planar (N)UNCD surface with (1) the beam emittance of 1.5 mm×mrad/mm-rms and (2) longitudinal FWHM energy spread of 0.7% at 2 MeV. Current stability was tested over 36×103 RF pulses (equivalent to 288×106 GHz oscillations). See Ref.[1] for details.

Photocathode. Activation of p-Si or p-GaAs with alkali Cs has led to a special photocathode type with negative electron affinity (NEA) – one of brightest electron sources. NEA is a unique circumstance, when electrons injected to the conduction band can be emitted directly into the vacuum. Nevertheless, the main drawback remains - they require vacuum <10-10 Torr for synthesis, handling, and operation. Wide bandgap (>5 eV) semiconductors are another class of NEA materials. This includes natural and synthetic diamonds. We report results of QE measurements carried out on a 150 nm thick nitrogen-incorporated UNCD terminated with hydrogen; abbreviated as (N)UNCD:H. (N)UNCD:H demonstrated a QE of ~10-3 (~0.1%) at 254 nm. (N)UNCD:H was also sensitive in visible light with a QE of ~5×10-8 at 405 nm. Importantly, after growth and prior to QE measurements, samples were exposed to air for about 2 h for transfer and loading. Such design takes advantage of a key combination: (1) H-termination proven to induce NEA on the (N)UNCD and to stabilize its surface against air exposure; and (2) N-incorporation inducing n-type conductivity in intrinsically insulating UNCD. See Ref.[2] for details.

[1] S.V. Baryshev, S.P. Antipov, J. Shao, C. Jing, K.J. Pérez Quintero, J. Qiu, W. Liu, W. Gai, A.D. Kanareykin, A.V. Sumant. Planar Ultrananocrystalline Diamond Field Emitter in Accelerator RF Electron Injector: Performance Metrics. Appl. Phys. Lett. 105, 203505 (2014)

[2] K.J. Pérez Quintero, S. Antipov, A.V. Sumant, C. Jing, S.V. Baryshev. High Quantum Efficiency Ultrananocrystalline Diamond Photocathode for Photoinjector Applications. Appl. Phys. Lett. 105, 123103 (2014)