PRELIMINARY MEASUREMENTS ON SINGLE AND MULTI-CRYSTAL DIAMOND ELECTRON CATHODES

Eisuke J. Minehara

FEL laboratory at Tokai, APRC, Kansai, JAERI

2-4 Shirakata-Shirane Tokai, Naka, Ibaraki, Japan 319-1195

Abstract

The next generation high brightness and high current electron source like a photo cathode, a thermionic cathode, a crystal Diamond electron cathode and others would be expected to realize the next generation ERL (energy recovery linac) based light source and SASE X-Ray free-electron laser. The JAERI FEL group has recently started to develop a new crystal Diamond electron cathode technology for high current, high brightness, and long life electron source. In the presentation, we plan to explain and to discuss our strategy and a preliminary experimental measurements of the crystal Diamond cathode, and related Diamond cathode evaluation system.

1 INTRODUCTION

The next generation high brightness and high current electron source like a photo cathode, a thermionic cathode, a crystal Diamond electron cathode and others would be expected to realize the next generation ERL (energy recovery linac) based light source and SASE X-Ray free-electron laser. The JAERI FEL group has recently started to develop a new crystal Diamond electron cathode technology for high current, high brightness, and long life electron source. In the presentation, we plan to explain and to discuss our strategy and a preliminary experimental work of the crystal Diamond cathode, and related extreme high vacuum evacuation system.

Diamond secondary emission cathode will be discussed here as Diamond electron cathode using primary electron as the exciting quanta to produce many electron hole pairs instead of the laser photon. In the scheme, we can expect very high quantum efficiency, say 10% quantum efficiency means 10 photons need to produce one electron, on the other hand, 2.6keV primary electron can produce about 200 electrons in principle. Multiplication factor should be estimated below where we define several delimeters used here in the following.

$N=E/ Eeh =E/(2.2 \cdot \Delta +Nr \cdot Ephonon)$

N: Mutliplication Factor(is proportional to E.), E : Primary Electron Kinetic Energy, Eeh:Energy needed for producing single electron hole pair=~13eV, Δ : Gap Energy of Diamond=~5.5eV, Nr: Averaged Number of Primary Electron Excited Phonon、Ephonon: Dissipated Phonon Energy ~several tens meV.

2 ELECTRON MULTIPLICATION MECHANISM

2.1 Evaluation

After the 1st step of the material preparation,and in the 2nd step, Diamond and Diamond like Carbon secondary electron multiplication (SEM) material evaluation have been performed to make quick decision on their potential using electron microscope in the Fig.1. I could see some differences and impressions on the Carbon SEM performance, and evaluate them by using electron microscope image brightness. Another evaluation of the 2nd steps is the energy dependence of the multiplication factor N, and the dependence directly show the most important performance parameter as explained in Fig.2.
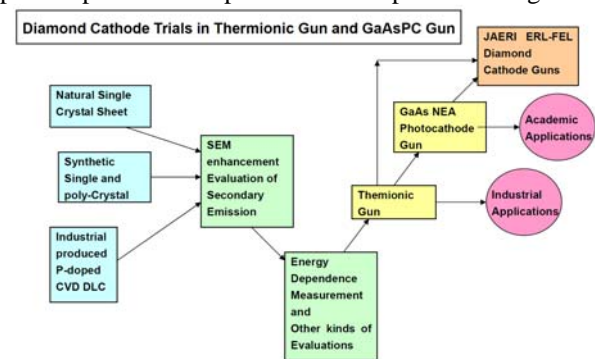

Figure 1: Developmental steps of Diamond cathodes.

Figure2: Band structures of NEA layered secondary electron Diamond cathode and primary electron photo
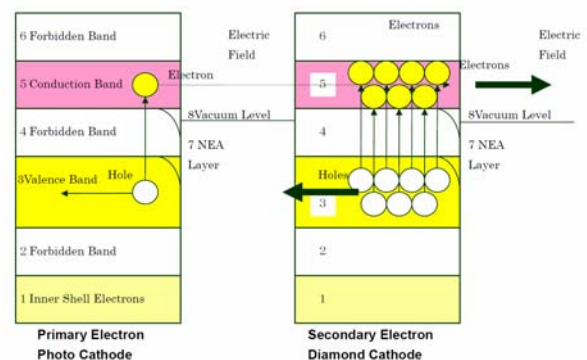
cathode.

.

Right Angle Extracted secondary electrons Diamond Source Excited by Photoelectron

1.Primary Electron Generating Photo Cathode, 2. High Energy Quanta for Exciting Secondary Electrons, 3. Diamond Semiconductor and InsulatorMultiplying Film, 4.Many Excited Electron Hole Pairs, 5. Negative Electron Affinity Surface, 6.Secondary Electrons Extraction to Vacuum,
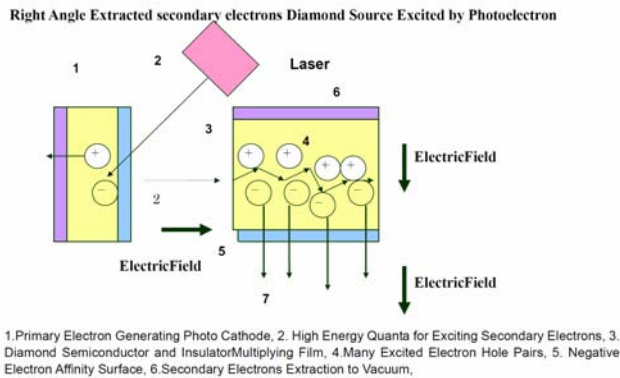
Figure 3: Forward angle extracted secondary electrons Diamond source excited by photoelectron.

As illustrated in Fig.3, one typical example of the Diamond secondary electron multiplication cathode configuration or construction and working mechanism are clearly explained here.

30kV E-Gun **XYsteerer, Focus Lens, Several tens microns diameter beam spot**

Figure 4: 30kV E-Gun XYsteerer, focus lens, several tens microns diameter beam spot.

2.2 Experimental Apparatus

.As shown in Figs.4, 5 and 6, we continue our developmental program on high current and high brightness electron gun. As illustrated in Figs 4, and 5, a small e-gun for crystal analyzer has been used to measure primary electron energy dependency and the natural IIa Diamond crystal sample. Figure 6 shows one

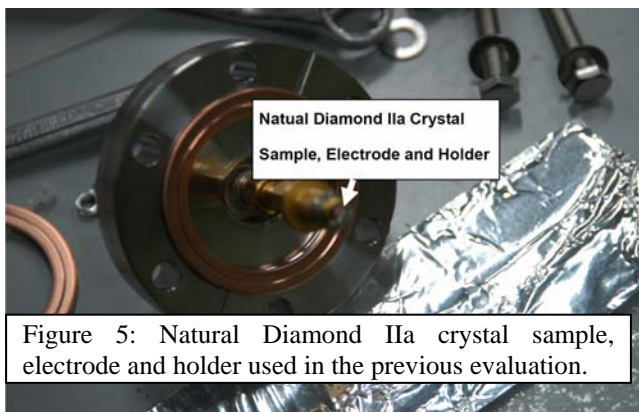**Natual Diamond IIa Crystal Sample, Electrode and Holder**

Figure 5: Natural Diamond IIa crystal sample, electrode and holder used in the previous evaluation.

candidate of the vacuum wall material for the high brightness high current electron gun for future ERL light source and ERL industrial machines.

. 3 SUMMARY

Current Status of JAERI Diamond Electron Cathode Development was discussed. Thermionic DC Gun and GaAs NEA DC Gun as the primary electron source are planned to realize the JAERI Diamond Electron Cathode for ERL-LS and ERL-FEL. A Simple and Emperical Multiplication factor is estimated to be proportional to primary electron kinetic energy in ideal case. Diamond Material Evaluation by SEM , Multiplication Factor and Others Now under way. XHV(Extreme High Vacuum) Ti alloy chamber as a future Gun chamber candidate is shown as one of our Gun activities.

REFERENCES

[1] A.N. Other, "A Very Interesting Paper", EPAC'96, Sitges, June 1996

KS120 Ti-Alloy Test Chamber for Future JAERI-EGUN 5x10^{-13}Torr Achieved

Figure 6: KS120 Ti-alloy test chamber for future JAERI e-gun. Ultimate lowest pressure 5 x 10^{-13} torr achieved by tandem-type magnetically levitated turbo-molecular pumps.