INSTALLATION FOR MEASUREMENTS OF SECONDARY EMISSION YIELD AND ELECTRON CLOUD LIFETIME IN MAGNETIC FIELD

V.V. Anahsin, A.A. Krasnov, V.K. Ovchar, V.V. Smaluk, D.P. Sukhanov,
Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia

Abstract

An experimental setup for investigations of electron-surface interaction and electron cloud behaviour is under commissioning at BINP. The proposed method provides direct measurements of secondary emission yield and electron clouds lifetime in the presence of strong magnetic field. In principle, the experiments can be performed at cryogenic temperatures. The experimental data will help to figure out the process of reflection of low energy electrons from a metal surface and can be useful for improvement of computer codes developed for simulation of electron clouds behaviour in a cold beam pipe of particle accelerators. The structure and performance capabilities of the setup are described, first experimental results are presented.

INTRODUCTION

Last years, the electron cloud build-up conditions are under keen consideration of accelerator physics [1].

Initiation of the new method and experimental set-up [2] for electron cloud investigation is necessary for several reasons:

- absence of experimental data for electron-surface interaction in the presence of strong magnetic field.
- make simple electron cloud build-up and measurements of its parameters under laboratory conditions (including experiments at cryogenic temperatures).
- time resolution observation of surface double layer influence on SEY and charging/discharging of the oxide layers.

EXPERIMENTAL INSTALLATION

Method Conception

The method principle is based on two options: confinement of low energy electron cloud living in a well defined space and the use of synchronous time resolution current measurements (Figure 1). The thermo-cathode "C", fast modulator "M", diaphragm "D" and sample are placed inside a solenoid on its axis.

The modulator generates a short pulse (3÷10 ns) of primarily electron current I_P. The electron energy is determined by cathode potential (-50V ÷ 1500 V). When the primarily electrons reach sample its current is equal: $I_S=I_{TS}+R+R_d$ (true secondary + reflected + re-defused) - I_P. Note, the integral of $I_S(t)$ over the pulse time gives an additional charge ΔQ coming from the sample to vacuum space due to secondary electron emission phenomenon. The living space of the created electron cloud is confined by the magnetic field and by the drift space between sample and diaphragm "D". After reflection by electric field between "M" and "D" the secondary, reflected and re-diffused electrons return to the sample with different time (dependent of their velocity) and could be absorbed by the sample or reflected again. The curves $I_S(t)$, $I_{BM1}(t)$ and $I_{BM2}(t)$ give the electron cloud dynamic behaviour.

Gate valve (GV) port (SRP) and sample manipulator provides sample replacement without venting. Thermal screen protects liquid helium bath against heat load from thermo-cathode and sample heater.

Four coaxial electrical feedthrough and in-vacuum coaxial lines connected to "modulator", BM1, BM2 and "sample" are applied to provide time resolution measurement in nanosecond region.

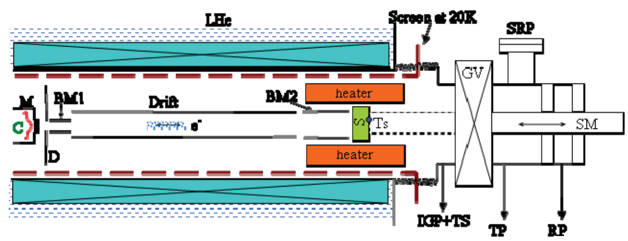

Figure 1: Experimental set-up. "SC" – superconducting coil, "C" – thermo-cathode, "M" – modulator, "D – diaphragm, "BM1, BM2" – beam monitor (coaxial cylinders), "LHe" – liquid helium, "S" – sample, "Ts" – thermo sensor, "GV" – all metal gate valve, "IGP+TS" – ion getter pump + titanium sublimation pump, "TP" – turbo-molecular pump, "RP" – rough pump, "SRP" – sample replacement port, "SM" – sample manipulator.

Installation Parameters

The main geometrical parameters are listed in Table 1.

Table 1: Geometrical Parameters

Element (from left to right)	**ID** [mm]	**Length** [mm]	**Gap with right element** [mm]
Cathode	-		0.25
Modulator	0.5	2	3
Diaphragm	4.5	1	1
BM1	4	10	0
Drift tube	7	325	1
BM2	7	59	2÷3 (to sample)

Other parameters of interest are:

- Maximum sample diameter is 13mm.
- Energy of primarily electrons: 50 ÷ 1500eV.
- Primarily beam pulse current: up to 0.2mA.
- Primarily electron beam pulse duration: 1 ÷ 10ns.

- Beam diameter: 0.5 ÷ 2mm (RT operation), 0.5mm (cryogenic operation).
- Maximum magnetic field: 0.1T (RT operation), 10T (cryogenic operation).
- BM1, Drift tube, BM2 independed bias: -600 ÷ +600V.
- sample temperature range: RT ÷ +250°C (RT operation), -253°C ÷ +250°C (cryogenic operation).
- preamplifiers frequency range: 0 ÷ 1.8 GHz.

FIRST EXPERIMENTS

At present time the installation is under commissioning at Room Temperature. Figure 2 shows typical signals recoded from BM1, BM2 and "sample (I_S). The bias on BM1, drift tube and BM2 is same and equal +40V. Left part of Figure 5 shows propagation of primary electron beam and firs turn of secondary electrons. Right part of Figure 2 shows relatively long time electron cloud behaviour – multiple reflections of secondary electrons.

Secondary electron yield (SEY) can be interpreted as relation of electron cloud charge after interaction with sample to primarily electron beam change and can be calculated from recorded curves with different ways. The use two of them is shown on Figure 3. 'BM2 only" means SEY calculated with following relation:

$$SEY_{BM2\,only} = \frac{\int\limits_{over\ first\ positive\ pulse} I_{BM2}(t)dt}{\int\limits_{over\ first\ negative\ pulse} I_{BM2}(t)dt}$$

"BM2+I_S" means SEY calculated with next relation:

$$SEY_{BM2+Is} = \frac{\int\limits_{over\ first\ positive\ pulse} I_{BM2}(t)dt}{\int\limits_{over\ first\ positive\ pulse} I_{BM2}(t)dt - \int\limits_{over\ first\ pulse} I_S(t)dt}$$

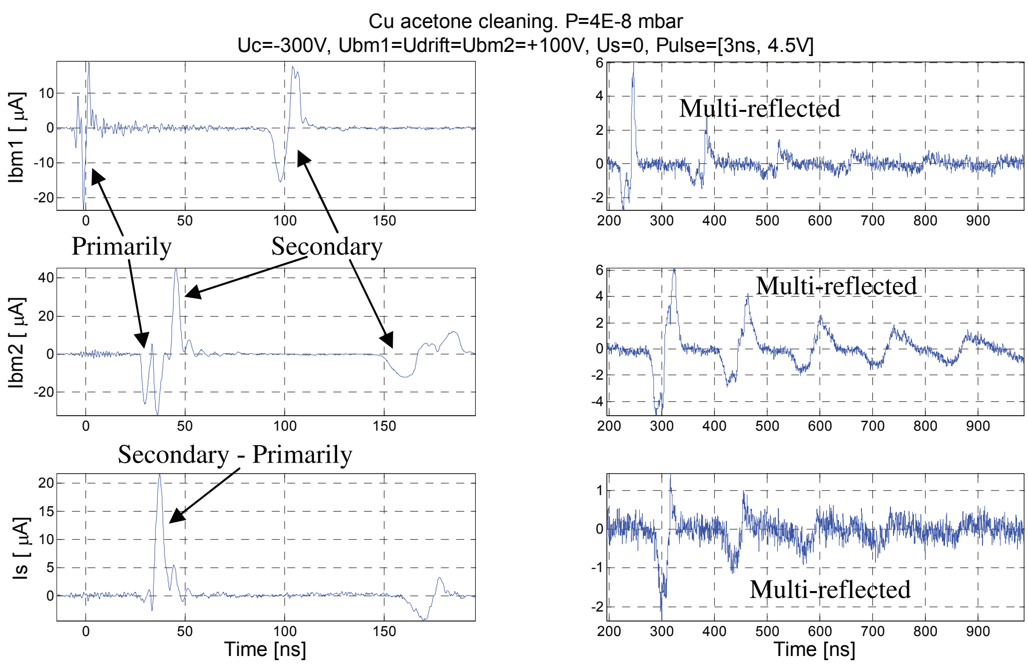

Figure 2: Typical current signals recoded from BM1, BM2 and "Sample".

As can be seen from Figure 3, the two calculations when combined provide a good fit.

OPTIONS FOR FUTURE INVESTIGATIONS

The installation has wide range of possible application. Most interest of them, from author's point of view, are written below:

- velocity distribution of the secondary electrons along magnetic field lines. That can be done by analyse of first positive pulse of BM2 or second pulse of BM1 at low bias on the monitors and drift tube (see Figure 4).
- measurements of secondary emission parameters at cryogenic temperature and strong magnetic field to obtain new data for electron cloud simulation in accelerators cryogenic beam pipe.
- check options for secondary electron suppression suitable for LHC upgrade. That could be a coating (sputtered carbon [2] or an aquadag for example) or a surface electron trapping [3,4].

- Measurements of SEY parameters as a function of space charge and primary beam duration (charging/discharging of oxide layers).

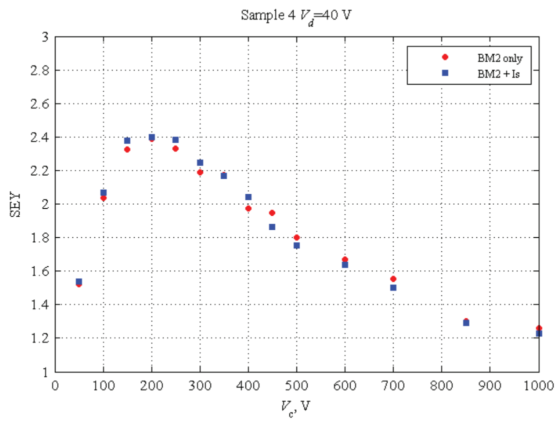

Figure 3: SEY of copper sample at residual gas pressure $4{\cdot}10^{-8}$ mbar.

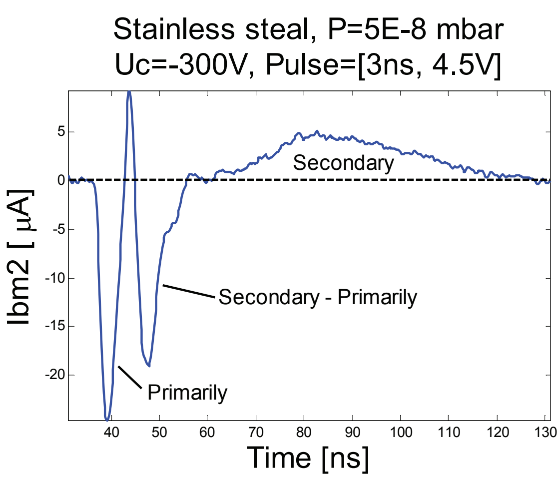

Figure 4: Dynamic of BM2 current at 5V potential of drift space (Ubm1=Udrift=Ubm2=5V).

POSSIBLE IMPROVEMENTS

Primarily beam parameters are limited in presence design:

- 1ns time resolution is limited by capacity of electrodes (modulator).
- beam diameter is limited by possible thermo-cathode power (load on cryogenic system).
- maximum pulse current (and measurements accuracy as result) is limited by space charge effect.

The mentioned characteristics could be improved by a simple photocathode application instead of thermo-cathode.

Photocathode will give additional options:

- simple control of electron beam diameter/profile.
- scanning of sample surface.

CONCLUSION

The installation for investigation of secondary electron emission and electron cloud behaviour in presence of magnetic field is under commissioning at Room Temperature. First results prove its wide potential range application especially in frame of obtaining new experimental data for electron cloud simulation at cryogenic temperatures and strong magnetic field.

ACKNOWLEDGMENTS

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