Results on a-C tubes subjected to synchrotron irradiation

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OUTLINE

- Parameters of SR beam line and experimental set-up at BINP
  - Experimental program for HiLumi
  - First SR on
    - Comparison of Cu and C-α samples
- Options for future investigations
  - PEE at high magnetic field
In the framework of the HL-LHC project, the vacuum performance of new surface material needs to be studied in details. In particular, amorphous carbon (a-C) coating is proposed as an anti-multipactor surface with the objective to minimize the heat load deposed on the shielded beam screen and the background to the experiment due to proton scattering onto the residual gas. Since the protons in the HL-LHC Inner Triplets generates SR with ~ 10 eV critical energy and ~ 10^{16} ph/m/s flux, it is therefore of great importance to study the impact of such photons on a-C coating held at room and cryogenic temperature and compare the results against present LHC material.
Experimental program in frame of Collaboration R&D CERN – BINP (Addendum P110/A2)

- quantitative photon stimulated gas desorption by a calibrated residual gas analyzer (RGA);
- photo-electron yield; forward reflectivity in SR power and photon flux units; azimuthal distribution of photoelectrons and azimuthal distribution of diffusely scattered photons.

These measurements will be done for two CERN supplied samples: uncoated and a-C coated OFE-Cu tubes.

The experimental program:
- an accumulated photon dose > $10^{23}$ ph/m, a SR incident angle of 13 mrad, a SR critical energy in accumulated photon dose mode is in the range 40 ÷ 50 eV, a scanning over SR critical energy at 100, 200, 400, 800, 1300, 1700 eV at selected doses of $10^{21}$, $10^{22}$, $10^{23}$ ph/m, a total number of azimuthal collectors of 10.

BINP will repeat the measurements in the temperature range 60 ÷ 300 K for exchangeable Cu tube samples perforated with holes in order to simulate a distributed pumping.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>min</th>
<th>nominal</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>E [MeV]</td>
<td>193</td>
<td>390</td>
<td>899</td>
</tr>
<tr>
<td>Beam current [A]</td>
<td>0.2</td>
<td>0.5</td>
<td>0.05</td>
</tr>
<tr>
<td>Banding magnet radii [mm]</td>
<td></td>
<td>1280</td>
<td></td>
</tr>
<tr>
<td>SR critical energy [eV]</td>
<td>12.5</td>
<td>100</td>
<td>1250</td>
</tr>
<tr>
<td>SR flux [ph/mrad/s]</td>
<td>1.1E15</td>
<td>1.5E16</td>
<td>4.7E15</td>
</tr>
<tr>
<td>SR power [W/mrad]</td>
<td>0.009</td>
<td>0.045</td>
<td>3.6</td>
</tr>
<tr>
<td>SR vertical divergence [mrad] at Ec</td>
<td>2.5</td>
<td>1.7</td>
<td>0.56</td>
</tr>
</tbody>
</table>
First SR on

Conditions without SR: \( P = 5 \times 10^{-9} \text{ Torr} \) in measuring port. \( P = 1.7 \times 10^{-9} \text{ Torr} \) in vessel (NEG cartridge is not activated)

SR on: \( I_e = 70 \text{ mA} \), \( E_{e} = 390 \text{ MeV} \), \( E_{c} = 102 \text{ eV} \), \( \text{Ph flux} = 4.5 \times 10^{16} \text{ Ph/s} \) (SR angle 9 mrad), or \( 3 \times 10^{16} \text{ ph/m/s} \):
Pressure in measuring port \( 1.2 \times 10^{-7} \text{ Torr} \)

Before inlet to testing tube
\( W \approx 10 \text{ mm} \)

After outlet of testing tube
\( W \approx 30 \text{ mm} \)

Reflected from testing tube
First SR on, RGA spectra

**SR on:** \( I_e = 70 \text{ mA}, \ E_e = 390 \text{ MeV}, \ E_c = 102 \text{ eV}, \ \text{Ph flax} = 4.5 \times 10^{16} \text{ Ph/s} \) (SR angle 9 mrad):

- Pressure in measuring port: 1.2e-7 Torr
- Pressure in vessel: 2e-8 Torr at +60 V on end calorimeter and 4.2e-8 Torr at -60 V on end calorimeter, **Testing tube:** Cu HCP cleaned and passivated at CERN, ID=40.5 mm, L=1500 mm
First SR on, desorption yield

**SR on**: $I_e=70$ mA, $E_e=390$ MeV, $E_c=102$ eV, $Ph\ flax=4.5e16$ Ph/s (SR angle 9 mrad):
 Pressure in measuring port  1.2e-7 Torr
 Pressure in vessel 2e-8 Torr at +60 V on end calorimeter and 4.2e-8 Torr at -60 V on end calorimeter

$\eta=3.5e-3$ molecule/ph – nitrogen equivalent. Dose is small. Less than 1e19 ph/m.

<table>
<thead>
<tr>
<th>Gas</th>
<th>$\Delta P$ [Torr]</th>
<th>$\eta$ [mol/ph]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_2$</td>
<td>2.9e-8</td>
<td>5.1e-3</td>
</tr>
<tr>
<td>$CH_4$</td>
<td>3.7e-9</td>
<td>2.2e-4</td>
</tr>
<tr>
<td>$H_2O$</td>
<td>1.1e-8</td>
<td>6.5e-4</td>
</tr>
<tr>
<td>CO</td>
<td>3.8e-8</td>
<td>1.8e-3</td>
</tr>
<tr>
<td>$C_2H_6$</td>
<td>3.7e-9</td>
<td>1.7e-4</td>
</tr>
<tr>
<td>$CO_2$</td>
<td>1.8e-8</td>
<td>6.6e-4</td>
</tr>
</tbody>
</table>

Estimated sensitivity – 2e-6 molecule/ph at $I_e=500$ mA
Sample with α-C coating

Installation of the sample with α-C coating
Desorption yield for α-C and Cu vs SR critical energy

Dose: 1E21 Ph/m
Ee=193….900 MeV
Ec=12,5… 1250 eV

<table>
<thead>
<tr>
<th>Ec eV</th>
<th>α-C η [mol/ph]</th>
<th>Cu η [mol/ph]</th>
</tr>
</thead>
<tbody>
<tr>
<td>12,5</td>
<td>2E-4 ?</td>
<td>1,6E-4</td>
</tr>
<tr>
<td>25</td>
<td>2,2E-4 ?</td>
<td>3,3E-4</td>
</tr>
<tr>
<td>50</td>
<td>1,8E-4</td>
<td>4,2E-4</td>
</tr>
<tr>
<td>100</td>
<td>4,5E-4</td>
<td>7,7E-4</td>
</tr>
<tr>
<td>200</td>
<td>4,6E-4</td>
<td>1,4E-3</td>
</tr>
<tr>
<td>400</td>
<td>1,1E-3</td>
<td>2,5E-3</td>
</tr>
<tr>
<td>800</td>
<td>2,3E-3</td>
<td>4,3E-3</td>
</tr>
<tr>
<td>1250</td>
<td>3,7E-3</td>
<td>4,6E-3</td>
</tr>
</tbody>
</table>
Desorption yield for α-C vs SR critical energy

Photo-desorption vs SR critical energy

Dose: 1E21 Ph/m

SR critical energy [eV]

- H2
- CH4
- H2O
- CO
- CO2

y = 1E-05x^{0.6251}

y = 6E-08x^{0.5603}
Desorption yield for α-C vs SR critical energy

Dose: 7E22 Ph/m

Photo-desorption vs SR critical energy

SR critical energy [eV]
**Forward reflectivity**

**BEP**: $I_e$ up to 650 mA, $E_e=193....900$ MeV, $E_c=12,5...1250$ eV

<table>
<thead>
<tr>
<th>$E_c$ eV</th>
<th>$\alpha$-C R forward</th>
<th>Cu1 R forward</th>
</tr>
</thead>
<tbody>
<tr>
<td>12,5</td>
<td>0,013</td>
<td>$&gt;$0,75</td>
</tr>
<tr>
<td>25</td>
<td>-</td>
<td>$&gt;$0,75</td>
</tr>
<tr>
<td>50</td>
<td>-</td>
<td>$&gt;$0,7</td>
</tr>
<tr>
<td>100</td>
<td>0,027</td>
<td>0,6...0,75</td>
</tr>
<tr>
<td>200</td>
<td>0,018</td>
<td>-</td>
</tr>
<tr>
<td>400</td>
<td>0,028</td>
<td>-</td>
</tr>
<tr>
<td>800</td>
<td>0,021</td>
<td>-</td>
</tr>
<tr>
<td>1250</td>
<td>0,015</td>
<td>-</td>
</tr>
</tbody>
</table>

* Calibration and more experiments are needed to check the result
Conclusion

Desorption less than from Cu
Effective suppression of photoelectrons and diffusely scattered photons

Interesting to measure C-alpha with Ti sub-layer
Thanks for your attention
Future possible experiments on the BEP SR Beam Line
- **Photoelectron emission (PEE) from cold surface in presence of strong magnetic field (up to 10T)**
- **SEE in situ**
- **XPS (Auger) in situ (surface element analysis)**
- **Ion desorption under SR**
- RF stimulated electron cloud build-up in presence SR – experimental simulation of phenomena in LHC arc beam pipe
- **Behavior of NEG coating at Low temperatures**
Options for future investigation

PEE from cold surface in presence of strong magnetic field

Main question:
does PEE depend on magnetic field at cryogenic temperatures?

![Diagram of experimental setup]

Experimental set-up for PEE measurements

Based on the new SR beam line and 14T SC solenoid of VEPP2000


Measurement options:
- PEY in strong magnetic field (up to 10 Tesla). DC and time resolution modes.
- TOF measurements of energy distribution of photoelectrons. Pulse repetition is 73.3 nS.
Conclusion

- Experimental program for C-α sample at RT is complete

- Experiments at cryogenic temperature are planned in Q1-Q2 2019

- A set of proposed investigations with the use the new SR beam line are under consideration