First documented pressure bump in ISR
E. Fischer/O. Gröbner/E. Jones 18/11/1970

NON-THERMAL OUTGASSING
AIM OF THE TALK
– ATTEMPT TO SUMMARIZE THE ACTUAL KNOWLEDGE USEFUL TO DESIGN AND OPERATE ACCELERATORS

OUTLOOK OF THE TALK
– ION INDUCED DESORPTION
– ELECTRON INDUCED DESORPTION
– PHOTON INDUCED DESORPTION
– THE CASE OF COLD SYSTEMS

CONCLUSIONS

THANKS
– To my colleagues for their help and patience. Have specially suffered: V. Baglin, D. Brandt, E. Mahner, P. Strubin
NON-THERMAL OUTGASSING

• HISTORY

– BIBLIOGRAPHY:

• P.A. REDHEAD VACUUM 48, 585-596 (1997)
• D. MENZEL NIM B101, 1-10 (1995)
• T.E. MADEY SURFACE SCIENCE 299/300, 824-836 (1994)
NON-THERMAL OUTGASSING

• HISTORY

– THE START:

A new Method of Positive Ray Analysis

A. J. Dempster

*Ryerson Physical Laboratory, Chicago*

Phys. Rev. 11, 316-325 (1918)

---

**A NEW METHOD OF POSITIVE RAY ANALYSIS.**

By A. J. Dempster.

The analysis of positive rays is based on the determination of the ratio of the charge to the mass of various constituents. The correlation of positive rays with the elements is as follows:

- $H_1$, $H_2$, $Li$ (weak), $O_1$ (strong), Na (strong), $O_3$ (?) (weak), $M = 62$ (weak, possibly $Na_2O$), $M = 67$ (strong, possibly $H_3PO_2 = 66$), $M = 76$ (strong), $M = 86$ (weak, possibly $Rb = 85.5$), $M = 112$ (strong, possibly $P_2O_5 = 110$).

It was thought that the bombardment of salts by electrons might break up the chemical compounds and give rise to many positive ions. Although the aluminium phosphate was chemically pure, the rays obtained under the bombardment of 128 volt electrons were very complex; the following ions were observed besides a couple of unresolved groups:

- $H_1$, $H_2$, $Li$ (weak), $O_1$ (strong), Na (strong), $O_3$ (?) (weak), $M = 62$ (weak, possibly $Na_2O$), $M = 67$ (strong, possibly $H_3PO_2 = 66$), $M = 76$ (strong), $M = 86$ (weak, possibly $Rb = 85.5$), $M = 112$ (strong, possibly $P_2O_5 = 110$).

The experiments indicated the convenience of the method of obtaining positive rays and opened up an interesting field for investigation.

The experiments were however first directed...
NON-THERMAL OUTGASSING

• HISTORY

– THE TUBE INDUSTRY (1930)
  • EMPIRICAL STUDIES TO EXTEND CATHODES LIFETIME (“poisoning”)
  • ESD THRESHOLD ALREADY ANTICIPATED: “10V EFFECTS”

– STUDIES ON VACUUM GAUGE LIMITATIONS (1960) P. REDHEAD

– THE LARGE DEVICES (1960) (cf. F. DYLLA’S TALK)
  • $e^+e^-$ STORAGE RINGS
    Fischer and Mack, Bernardini and Malter (JVSTA 1965), Garwin (1968)
  • FUSION DEVICES (McCracken (1967) (ESD and ISD)
  • PROTON STORAGE RINGS ISR (1970) ISD
NON-THERMAL OUTGASSING

• HISTORY

– THE MODELS FOR ESD

• THE “MGR” MODEL (1964)
  – TWO INDEPENDENT TEAMS: P. REDHEAD, B. GOMER AND D. MENZEL
  – EXCITATION TO AN ANTI-BOUNDING STATE

• THE KNOTEK-FEIBELMAN MODEL (1978)
  – AUGER EFFECT

• ACTUAL EVOLUTION

• SURFACE PHYSICS ISSUE

• MAINLY MODELS FOR ESD OF IONS
NON-THERMAL OUTGASSING

• APPLICATION FOR ESD:
  - SURFACE CHARACTERISATION
    • K.J. Middleman, J.D. Herbert, R.J. Reid Vacuum in Press (2006)

• BIOLOGY
  • ANALYTICAL TOOL (COUPLING ESD+SEM F. DYLLA)
  • STUDIES OF DAMAGE INDUCED TO DNA BY LOW ENERGY e⁻
NON-THERMAL OUTGASSING

- APPLICATION FOR ESD:
  STM LITHOGRAPHY
  (nm range) Si/H


Fig. 8. A comparison of the desorption area written by the same tip. The top line is written with e-irradiation of 7 V, 0.1 nA and line dose $1 \times 10^{-4}$ C cm$^{-1}$. The bottom line is written with 4 V, 4 nA and $4 \times 10^{-3}$ C cm$^{-1}$.
NON-THERMAL OUTGASSING

- BEAM DEPENDENT PRESSURE VARIATION
- STIMULATED DESORPTION

- IONS/ ELECTRONS HADRON MACHINES
- PHOTONS/ ELECTRONS LEPTON MACHINES

INCIDENT PARTICLE

ENERGY eV->MeV

DESORPTION ELECTRON EMISSION

STIMULATION OF DIFFUSION, CREATION OF DEFECTS
NON-THERMAL OUTGASSING

• ION INDUCED DESORPTION
  – PROTON MACHINES
  – DEPENDS MORE ON TREATMENTS THAN MATERIALS
  – TYPICAL DESORPTION YIELDS (COPPER):
    0.1->2 AFTER BAKING (300ºC)
  – VARY WITH ION MASS/NATURE, ENERGY

DESORBED MOLECULES
H₂, CO, CO₂, ....

ION INDUCED DESORPTION YIELD VERSUS ION ENERGY FOR AS RECEIVED COPPER

M.P. LOZANO-BERNAL 2001
NON-THERMAL OUTGASSING

• ION INDUCED DESORPTION

– YIELDS FOR STAINLESS STEEL

\[ \eta_{\text{mach}} = \eta_{\text{lab}}^{-1} \]
NON-THERMAL OUTGASSING

• Proton machines: The ion induced instability

\[ P(I) = P_0 \left(1 - \frac{I}{I_c}\right)^\sigma \eta S \] 

\[ I \rightarrow e \ast S \sigma \eta = I_c \] 

\[ P \rightarrow \infty \]
NON-THERMAL OUTGASSING

- THE ION INDUCED INSTABILITY

- EFFECT OF THE ION MASS

\[ P(I) = \frac{P_0}{1 - I \frac{\sigma}{e^*} \frac{\eta}{S}} \implies I \rightarrow \frac{e^* S}{\sigma \eta} = I_c \quad P \rightarrow \infty \]

Effect of the mass:

- \( \sigma, \eta \)
- \( C \) => \( S \)
- ENRICHMENT IN HEAVY GASES
- HEAVY GASES MORE DANGEROUS

**IONISATION CROSS SECTIONS**

- **H2**, **He**, **CH4**, **CO**, **Ar**, **CO2**
- **26GeV**
- **7TeV**

**D.E.**

\[ D.E. = \frac{\eta_{i^+}}{\eta_{H_2^+}} \]
Non-thermal outgassing

- THE ION INDUCED INSTABILITY
- EFFECT OF THE ION MASS
  \[ \rightarrow \text{Long term drifts} \]
  \[ \rightarrow \text{Change in gas composition: more heavy gases} \]

**EVOLUTION OF THE GAS COMPOSITION DURING A PRESSURE BUMP**

(A. Mathewson-P. Strubin 1981)

<table>
<thead>
<tr>
<th>MASS</th>
<th>INITIAL</th>
<th>AFTER 100 mn (constant current)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (H2)</td>
<td>80%</td>
<td>30%</td>
</tr>
<tr>
<td>28 (CO + CxHy)</td>
<td>10%</td>
<td>40%</td>
</tr>
<tr>
<td>44 (CO2)</td>
<td>5%</td>
<td>20%</td>
</tr>
<tr>
<td>15 (CH4)</td>
<td>10%</td>
<td>5%</td>
</tr>
</tbody>
</table>

(time on x-axis, mass on y-axis)
NON-THERMAL OUTGASSING

• OTHER TYPES OF PRESSURE VARIATION
  – BEAM PUMPING:

\[ P(I) = \frac{P_0}{1 - I^* \frac{\sigma}{\kappa} \frac{e}{E}} \]

\( S_{beam} = \frac{\sigma \kappa}{e} I \left( m^2 s^{-1} \right) \)

\( \sigma \): Ionisation C.S. (m²)
\( \kappa \): Trapping probability
\( I \): Beam intensity (A)
\( E \): Electron charge (C)

\( \eta_{LAB} < 1 \Rightarrow \eta_{ACC} < 0 \Rightarrow P(I) < P_0 \)

BEAM PUMPING IN ISR 13-03-1980

148.0 + 12

47.8 A

1.2 pTorr
NON-THERMAL OUTGASSING

• OTHER TYPES OF PRESSURE VARIATION

  – Beam losses
    • Sudden increase, pressure decay with time constant

  – Radiation burst
    • Sudden increase, immediate recovery (ionisation in the gauge collector cable)

  – This case:
    • Beam pumping

  – Simultaneity of several types
NON-THERMAL OUTGASSING

- SWIFT HEAVY IONS
  - DESORPTION AND BEAM CLEANING
  - HIGH YIELDS $>10^4$ measured at CERN


- DESPITE HIGH PENETRATION (30$\mu$) SENSITIVE TO SURFACE (2$\mu$ Ag)

- ELECTRONIC STOPPING PREDOMINANT

N. HILLERET  Non-thermal outgassing  CAS Platja d’Aro 16-24/05/06
NON-THERMAL OUTGASSING

• SWIFT HEAVY IONS
  – SIMILAR YIELDS FOUND IN GSI: Pb$^{27+}$, Cr$^{7+}$, C$^{2+}$ 1.4 MeV/u

  AND BNL

  P. Thieberger et al. PRST AB 7 093201 2004

  M. Toulemonde et al. NIM B212 346 2003

• cf SPUTTERING YIELDS OF INSULATORS

  • LiF > $10^4$ Au$^{29+}$, 230 MeV, 20º incidence

  R. Behrisch et al. NIM B118,262 1996

-H$_2$ DESORPTION FROM C: $7 \times 10^6$

  700 MeV I$^+$


H. Reich-Sprenger et al. pp1657-1659 EPAC 2004
NON-THERMAL OUTGASSING

• INFLUENCE ON OPERATION

• AT MODERATE ENERGY (MeV/ U) HIGHLY CHARGED IONS VERY SENSITIVE TO CHARGE EXCHANGE

• => BEAM LOSS => DESORPTION => CHARGE EXCHANGE


\[ n^+ \rightarrow \text{Electron capture} \rightarrow n^{-1}^+ \rightarrow \text{molecule} \rightarrow \text{Lost ion} \rightarrow n^+ \rightarrow \text{DESORPTION} \]
NON-THERMAL OUTGASSING

• REMEDIES
  • WHEN CRITICAL PLACES FOR BEAM LOSSES Known
  • INSTALL STOPPERS
  • PERPENDICULAR INCIDENCE
  • ADEQUATE COATING
  • LOCAL PUMPING

STOPPER

N. HILLERET  Non-thermal outgassing
CAS Platja d’Aro 16-24/05/06
NON-THERMAL OUTGASSING

ELECTRON INDUCED DESORPTION

- Important where/when resonant multiplication of electrons (e-cloud, RF devices (couplers)
- Many similarities with PSD
- Decrease with $\eta = \eta_0 D^{-n}$
- Beam cleaning

| GAS | $H_2$ | $CH_4$ | CO | $C_2H_6$ | CO$_2$
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta(&gt;10^{15})$</td>
<td>-0.489</td>
<td>-0.643</td>
<td>-0.489</td>
<td>-0.584</td>
<td>-0.561</td>
</tr>
<tr>
<td>$\eta_0(&gt;10^{15})$</td>
<td>$2.68 \times 10^6$</td>
<td>$2.67 \times 10^7$</td>
<td>$3.36 \times 10^5$</td>
<td>$2.02 \times 10^6$</td>
<td>$7.36 \times 10^6$</td>
</tr>
</tbody>
</table>
NON-THERMAL OUTGASSING

- ELECTRON INDUCED DESORPTION
  - INFLUENCE OF THE MATERIAL (Baked 150°C+300°C 2h)

NON-THERMAL OUTGASSING

ELECTRON INDUCED DESORPTION
- Variation of ESD with electron energy
- Threshold close to 10 eV

\[
\eta(E) = \eta_{300} \times \left( \frac{E - E_c}{300 - E_c} \right)^{0.85}
\]

Table 1: Fit parameters

<table>
<thead>
<tr>
<th>Compound</th>
<th>(\eta_0) / (molec./e(^{-}))</th>
<th>(E_c) / eV</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(_2)H(_6)</td>
<td>1.1 \times 10^{-1}</td>
<td>11.4</td>
</tr>
<tr>
<td>CH(_4)</td>
<td>2.1 \times 10^{-2}</td>
<td>7.5</td>
</tr>
<tr>
<td>CO</td>
<td>5.8 \times 10^{-2}</td>
<td>7.2</td>
</tr>
<tr>
<td>CO(_2)</td>
<td>2.7 \times 10^{-1}</td>
<td>9.1</td>
</tr>
<tr>
<td>H(_2)</td>
<td>1.9 \times 10^{0}</td>
<td>12.7</td>
</tr>
</tbody>
</table>
NON-THERMAL OUTGASSING

- ELECTRON INDUCED DESORPTION
  - INFLUENCE OF BAKE-OUT

N. HILLERET  Non-thermal outgassing  CAS Platja d'Aro 16-24/05/06
NON- THERMAL OUTGASSING

- ELECTRON INDUCED DESORPTION
- TOTAL NUMBER OF RELEASED MOLECULES

\[ \times 100 \text{ Monolayers desorbed } \iff \eta/100 \]

(AS RECEIVED COPPER)

TOTAL NUMBER OF DESORBED MOLECULES PER UNIT AREA (cm\(^{-2}\))

- H\(_2\)
- CO
- CO\(_2\)
- CH\(_4\)
- C\(_2\)H\(_6\)

UNBAKED COPPER
G.Vorlaufer
NON-THERMAL OUTGASSING

- PHOTON STIMULATED DESORPTION

- LEPTON MACHINES
  DESORPTION:

  PHOTONS => PHOTOELECTRONS

  STATIC
  => DYNAMIC PRESSURE

N. HILLERET
Non-thermal outgassing

CAS Platja d’Aro 16-24/05/06
NON-THERMAL OUTGASSING

PHOTON STIMULATED DESORPTION

\[ \frac{dN}{ds} = 1.28 \times 10^{17} \times I \times \frac{E}{R} \]

DYNAMIC PRESSURE

\[ \frac{\Delta P}{I} = K \times \frac{E}{R} \times \frac{\eta}{S} \]
NON-THERMAL OUTGASSING

• PHOTON STIMULATED DESORPTION

– Synchrotron light

\[ P(W) = 88.6 \times E^4 \times \frac{I}{R} \]

\[ \varepsilon_c (eV) = 2.2 \times 10^3 \times \frac{E^3}{R} \]
## NON-THERMAL OUTGASSING

### PHOTON STIMULATED DESORPTION

Synchrotron light

<table>
<thead>
<tr>
<th>MACHINE</th>
<th>ENERGY (GeV)</th>
<th>CRITICAL ENERGY (keV)</th>
<th>POWER W/m</th>
<th>PHOTONS/m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>KEK-LER</td>
<td>3.5</td>
<td>5.9</td>
<td>2.15x10^4</td>
<td>7.2x10^19</td>
</tr>
<tr>
<td>PEP II-LER</td>
<td>3.1</td>
<td>4.8</td>
<td>1.5x10^4</td>
<td>6.2x10^19</td>
</tr>
<tr>
<td>LEP</td>
<td>100</td>
<td>711</td>
<td>9x10^2</td>
<td>2.5x10^16</td>
</tr>
<tr>
<td>ESRF</td>
<td>5</td>
<td>2.2</td>
<td>56</td>
<td>5.3x10^17</td>
</tr>
<tr>
<td>LHC (protons)</td>
<td>7000</td>
<td>0.044</td>
<td>0.22</td>
<td>1x10^17</td>
</tr>
</tbody>
</table>
NON-THERMAL OUTGASSING

- PHOTON STIMULATED DESORPTION
  - MATERIAL DEPENDENCE

Fig. 3 Molecular desorption yields for aluminium alloy.

Fig. 4 Molecular desorption yields for stainless steel.

O. GROBNER CAS 1999
NON-THERMAL OUTGASSING

- PHOTON INDUCED DESORPTION
- MATERIAL DEPENDENCE
- $3.75 \text{ keV photons} / \text{Cu (unbaked)}$

VARIATION OF THE PHOTON INDUCED DESORPTION
THE NUMBER OF MOLECULES DESORBED
(BAKED COPPER)

$O. Grbner et al., J.V.S.T. A 12(3), 84$
NON-THERMAL OUTGASSING

- PHOTON INDUCED DESORPTION
- ENERGY DEPENDANCE (CRITICAL ENERGY)
- CONSTANT IN THE keV/100 keV RANGE SCALES WITH POWER ABOVE

NON-THERMAL OUTGASSING

- PHOTON INDUCED DESORPTION
  - Energy dependence (Compton)

LEP SYNCHROTRON RADIATION

Photon ENERGY (MeV)

Mass Attenuation (cm²/g)

100 GeV
80 GeV
45 GeV
22 GeV
- AL COMPTON
- AL PHOTEL.

N. HILLERET  Non-thermal outgassing  CAS Platja d’Aro 16-24/05/06
NON- THERMAL OUTGASSING

- ANGULAR DEPENDENCE
- SATURATION AT GLANCING ANGLE
  (FLATNESS/ SMOOTHNESS OF TECHNOLOGICAL SURFACES)

O Gröbner et al. Vacuum 33,7,397-406 (1983)
NON-THERMAL OUTGASSING

• PHOTON INDUCED DESORPTION

– THE CASE OF NEG

V. BAGLIN et al. CERN IVC 15 San Francisco (2001)

BAKED Cu (H₂, CO)

INCIDENCE: CERN 90º
NOVOSIBIRSK 10 mrad

DESORBED GAS

H₂ CH₄ CO C₂H₆ CO₂

NEG AS REC
NEG 200C
NEG AS REC
NEG ACT

CERN
NOVOSIBIRSK

BAKED Cu (H₂, CO)
NON-THERMAL OUTGASSING

• PHOTON INDUCED DESORPTION – BEAM CLEANING

VARIATION OF THE PHOTON INDUCED DESORPTION
THE NUMBER OF MOLECULES DESORBED
(BAKED COPPER)

C. Herbeaux et al. JVSTA 17(2) 635-643 (1999)
NON-THERMAL OUTGASSING

- PHOTON INDUCED DESORPTION
- BEAM CLEANING: GAS COMPOSITION VARIATION

ELECTRODE CORROSION ANISOTROPY

37
NON-THERMAL OUTGASSING

• BEAM CLEANING
  - Important effect in lepton machines (synch radiation)
    - Gas load reduced by ~ 300 during 1st year in LEP (1 A.h)
  - Consequences for design
    - Pumping speed tailored to reduced desorption:
      => Pump budget / Cleaning time
    - Cleaning partly lost in absence of operation (quick recovery)
  - Also valid for photoelectron/electron emission (δ decrease 2->1.3)
NON-THERMAL OUTGASSING

• PHOTON INDUCED DESORPTION
  
  on st. steel: limited capacity: $10^{-4}$ monolayer
  on getter: limited to CO (?) re-saturate quickly in absence of synch. rad.

CO: 300 l/s/m $10^{23}$ phot/m
ST STEEL

C. Herbeaux et al. JVSTA 17(2) 635-643 (1999)
NON-THERMAL OUTGASSING

• COMPARISON ION/PHOTON DESORPTION
  - IMPLICATIONS FOR ACCELERATORS

• ION

\[ P(I) = \frac{P_0}{1 - I \cdot \frac{\sigma \cdot \eta}{e \cdot S}} \Rightarrow I \rightarrow \frac{e \cdot S}{\sigma \cdot \eta} \quad P \rightarrow \infty \]

• PHOTON

\[ \frac{\Delta P}{I} = K \cdot \frac{1}{\rho} \cdot \frac{E \cdot \eta}{S} \]

- Runaway process if \( I_c \) exceeded
  - \( \Rightarrow \) FAST PRESSURE INCREASE WHEN \( I_c \) APPROACHED
  - \( \Rightarrow \) NO BEAM CLEANING

- Elaborated surface treatments
  - \( \Rightarrow \) ION BOMBARDMENT CLEANING
  - \( \Rightarrow \) BAKE OUT MANDATORY IN STORAGE RINGS

- Baked machine => longer repair time

- Pressure increases linearly with current => stability
  - \( \Rightarrow \) BEAM CLEANING

- Simpler preparation procedure
  - (BAKE-OUT OPTIONAL)

- Shorter interventions
- Heavy power load on surfaces (synchrotron radiation)

N. HILLERET  Non-thermal outgassing  CAS Platja d’Aro 16-24/05/06
NON-THERMAL OUTGASSING

• COLD SYSTEMS (cf. V. Baglin)
  –DIFFERENCE WITH WARM SYSTEMS
    • SMALL HEAT LOADS DANGEROUS (HIGH PRESSURE => QUENCH SC MAGNETS)
    • POSSIBILITY OF THICK CONDENSED LAYER (VAPOUR PRESSURE, DESORPTION)
      ENERGETIC PARTICLES: PHOTONS, ELECTRONS, IONS
    • TWO SOURCES OF DESORPTION:
      –CHEMISORBED GAS (AS FOR WARM SYSTEMS)
      –PHYSISORBED GAS (INITIALLY NOT PRESENT)

1. ENERGETIC PARTICLES
2. PRIMARY DESORPTION
3. RECONDENSED MOLECULES
4. ENERGETIC PARTICLES
5. SECONDARY DESORPTION
6. SURFACE OXYDE
NON-THERMAL OUTGASSING

• THE GAS SOURCES

–LHC CIRCULATING CURRENT .56 A: SPACE CHARGE
• => ION INDUCED DESORPTION

–SYNCHROTRON RADIATION: $10^{17}$ PHOTONS/s/m,
Ec = 45 eV, 0.2 W/m
• => PHOTON INDUCED DESORPTION

ELECTRON MULTIPLICATION BY PARTICLE BUNCHES (cf: O. Gröbner talk)
• => ELECTRON INDUCED DESORPTION

N. HILLERET Non-thermal outgassing
NON-THERMAL OUTGASSING

- ESD OF CONDENSED GASES
- LARGE YIELDS VARYING WITH COVERAGE
- PEAK AT LOW COVERAGE
- FLAT MAXIMUM ABOVE 300 eV
- DEPENDS ON THE SUBLIMATION ENERGY

Large amount of data for higher $\eta$ energy and higher coverages in:

J. Schou  Risø-R-591 (EN) Risø National Laboratory, Roskilde, Denmark

$\sigma = \frac{\eta}{\theta}$
NON-THERMAL OUTGASSING

- PSD OF CONDENSED GASES


PRIMARY DESORPTION

PHYSISORBED GAS DESORPTION (recycling)

N. HILLERET  Non-thermal outgassing

CAS Platja d’Aro 16-24/05/06
NON-THERMAL OUTGASSING

- COLD SYSTEMS

- PRIMARY DESORPTION => COVERAGE INCREASE => SECONDARY DESORPTION => PRESSURE => GAS FLOW TO COLD BORE

EQUILIBRIUM: PRIMARY DESORPTION ~ FLOW TO COLD BORE
NON-THERMAL OUTGASSING

- COLD SYSTEMS

EVOLUTION DURING OPERATION

DESORPTION YIELDS

BEAM SCREEN COVERAGE VERSUS ELECTRON DOSAGE

E moy (eV): 300.0
P (W/m²/ap.): 1.0

H₂ COV
CO COV
CO₂ COV
CH₄ COV
CO₂ EQ COV
CO₂ EQ COV
CH₂ EQ COV

ELECTRON DOSE (e⁻/cm²)

H₂ PHYS
CO PHYS
CO₂ PHYS
CH₄ PHYS
H₂ PRIM
CO PRIM
CO₂ PRIM
CH₄ PRIM

H₂ TOT
CO TOT
CO₂ TOT
CH₄ TOT

ELECTRON DOSE (e⁻/cm²)

E moy (eV): 300.0
P (W/m²/ap.): 1.0
NON-THERMAL OUTGASSING

- COLD SYSTEMS

EVOLUTION DURING OPERATION

DESORPTION YIELDS

E moy (eV): 300.0
P (W/m/ap.): 1.0

BEAM SCREEN COVERAGE VERSUS ELECTRON Dose

E moy (eV): 300.0
P (W/m/ap.): 1.0
NON-THERMAL OUTGASSING

• COLD SYSTEMS

– EVOLUTION DURING OPERATION

GAS DENSITY VERSUS ELECTRON DOSE

E moy (eV): 300.0
P (W/m²/ap.): 1.0

H2
CO
CO2
CH4
H2 EQ
CO EQ
CO2 EQ
CH4 EQ
CONCLUSIONS

- Non-thermal outgassing is the predominant gas load during operation of an accelerator.
- Produced by the impact of photons, electrons, and ions generated/accelerated by the beam.
- The desorption coefficient $\eta$ is surface (more than material) dependent.
- Strongly influenced by surface treatments.
- Oxide layer is suspect of playing a determinant detrimental role.
- Equivalent of $\sim n \times 10$ monolayers to be removed to reduce $\eta$ by a factor 100 (PSD).
CONCLUSIONS

- DETERMINES THE PREPARATION PROCEDURES TO ACHIEVE NOMINAL CONDITIONS
- MAKE THE VACUUM SYSTEM OF ACCELERATORS ALIVE

...............AND THE LIFE OF THE DESIGNER / OPERATOR

EXCITING !!!