Observation of Nuclear Transmutation Reactions induced by D_2 Gas Permeation through Pd Complexes

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Features of the Present Method

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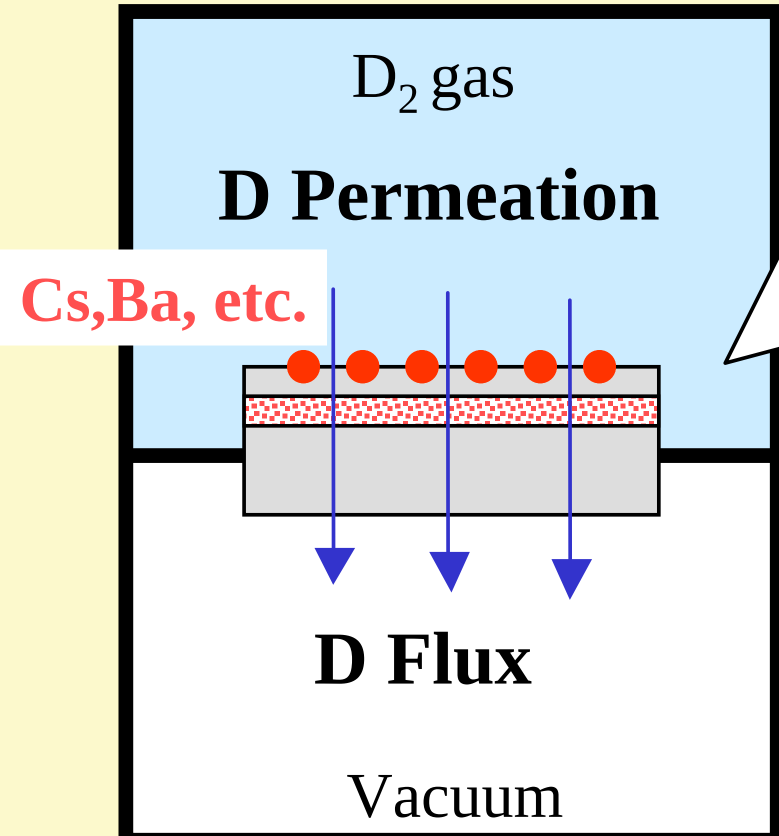
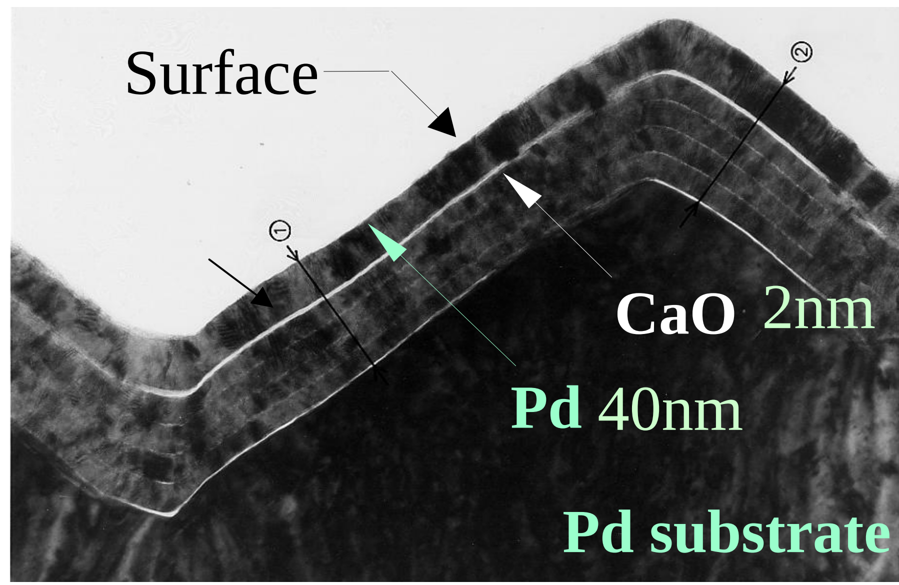
D_2 gas permeation through the Pd complex



Cross Section of Pd Complex



Fabrication of Pd Complex

Washing a Palladium Sample with Acetone

↓

900°C 10H Annealing under Vacuum Condition (< 10^{-7} Torr)

↓

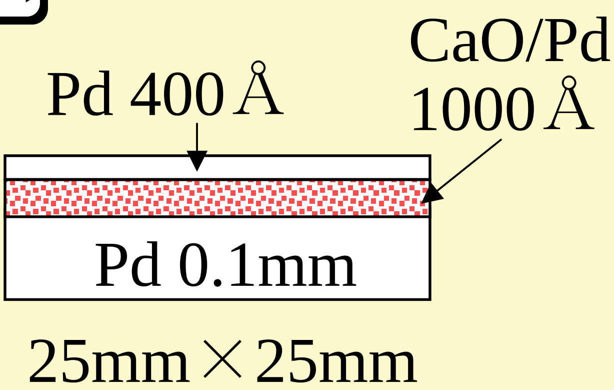
Washing the Sample with Aqua Regia (100sec)

↓

5 times Alternatingly Sputtering of CaO(20Å) and Pd(180Å)

↓

Ion Beam Sputtering of Pd only (400Å)



Schematic View of the Experimental Apparatus

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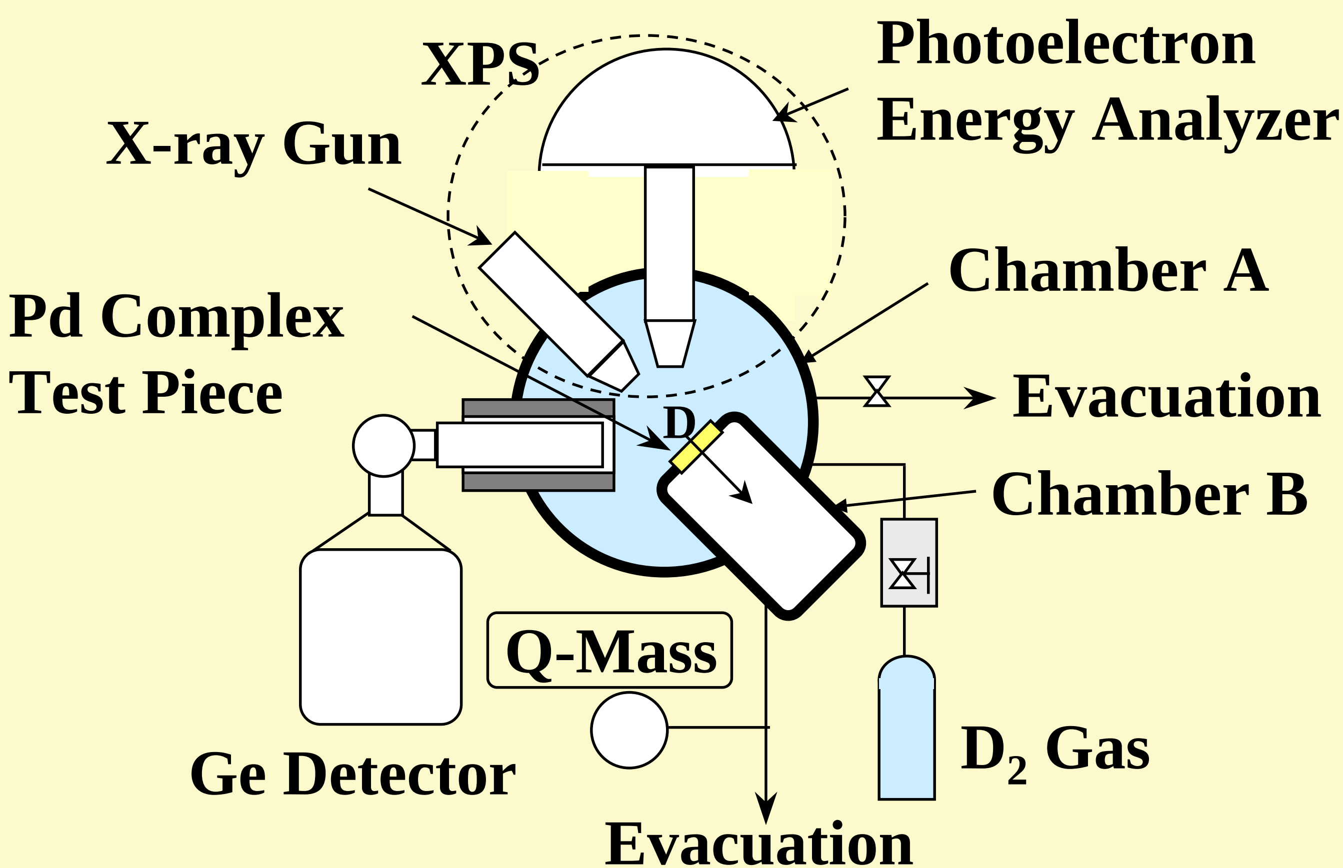

Photograph of the Experimental Setup

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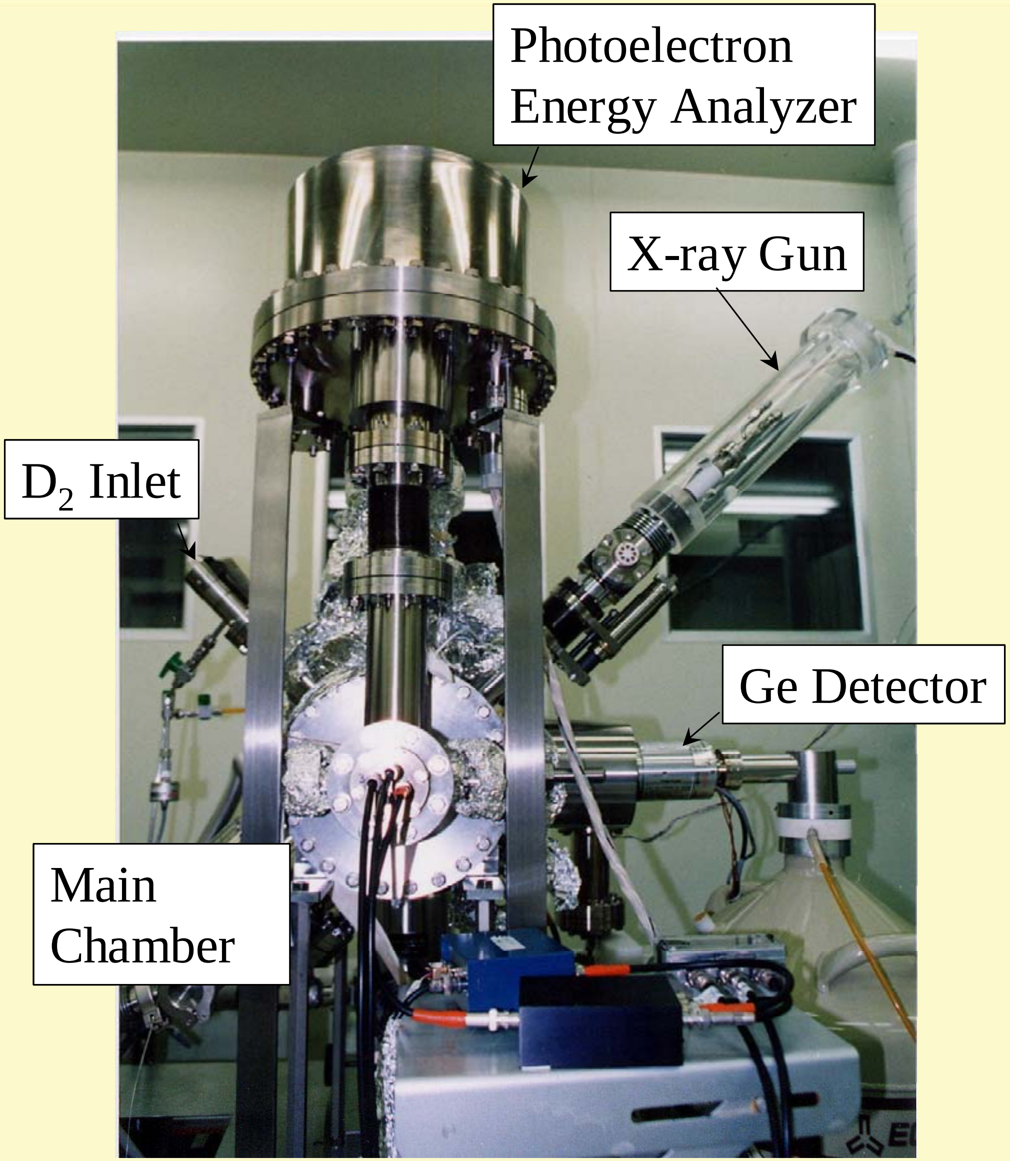

Decrease of Cs and Emergence of Pr

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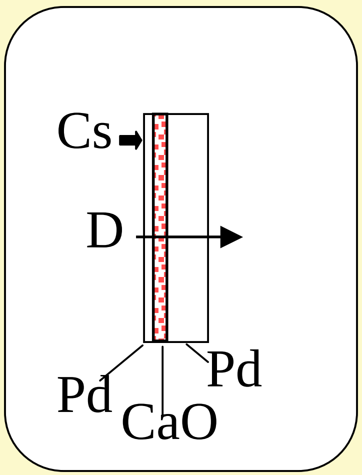

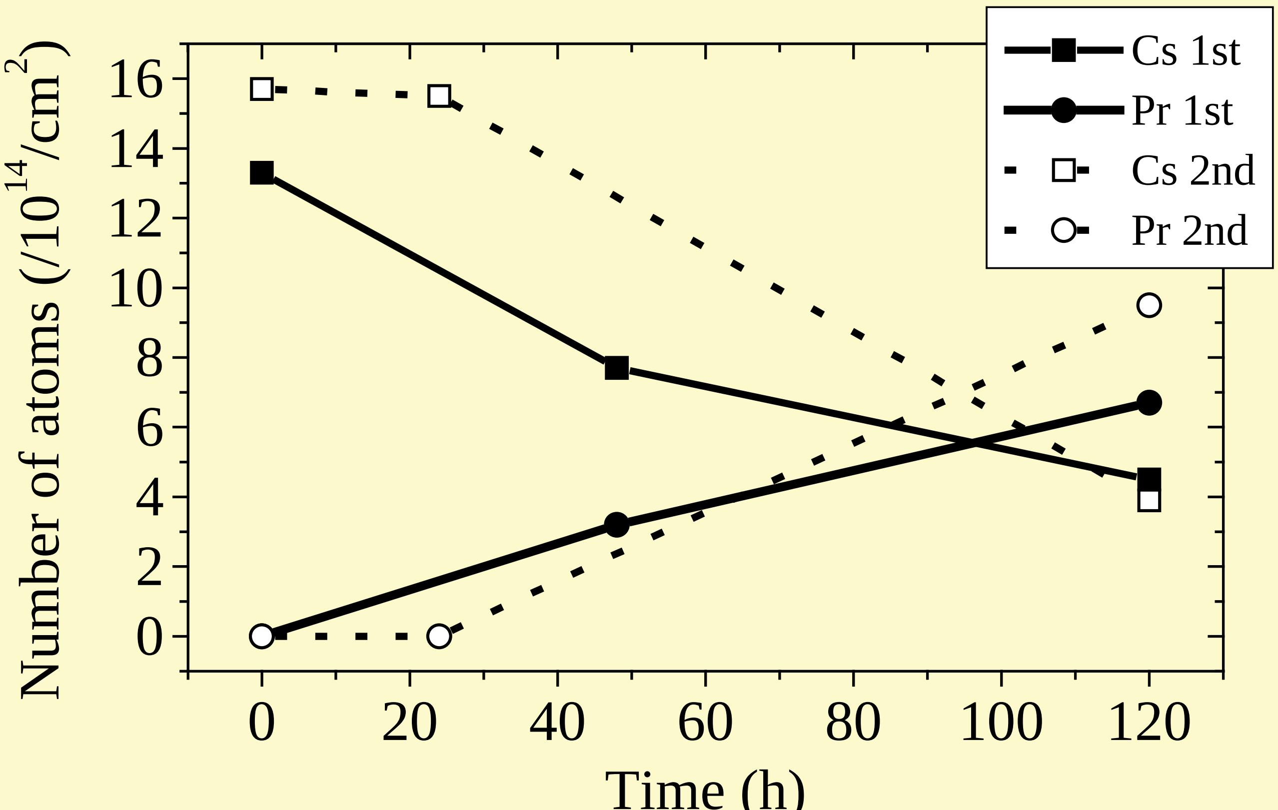

Identification of Pr by TOF-SIMS

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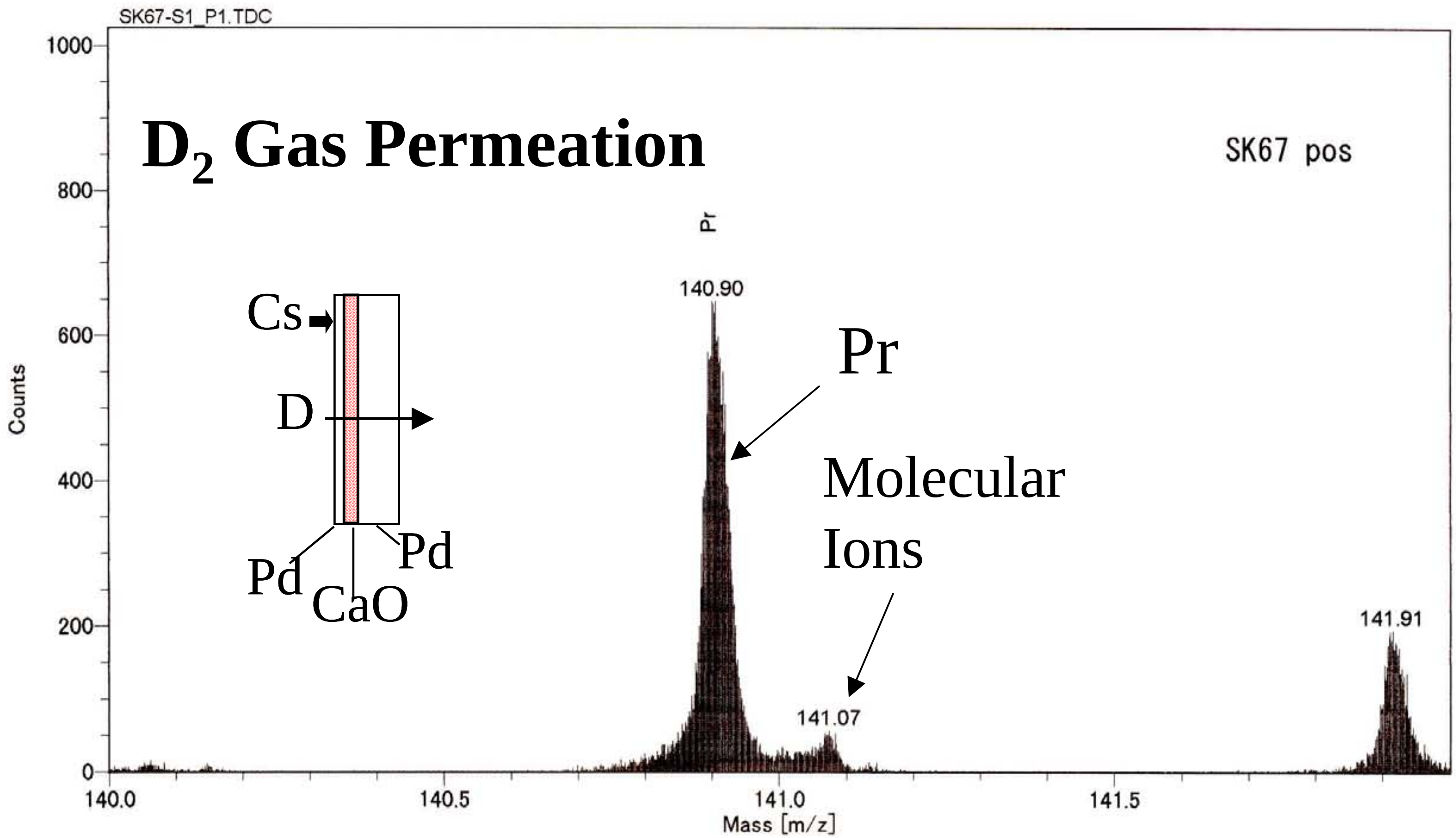

TOF-SIMS device (TRIFT™ II ;ULVAC-PHI)

Decrease of Sr and Emergence of Mo

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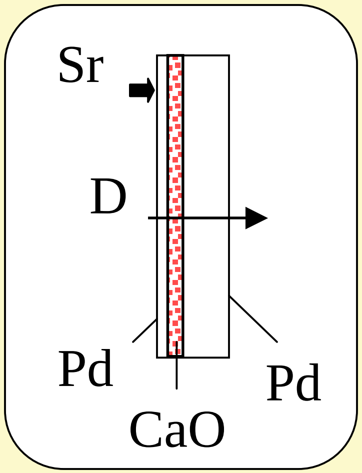

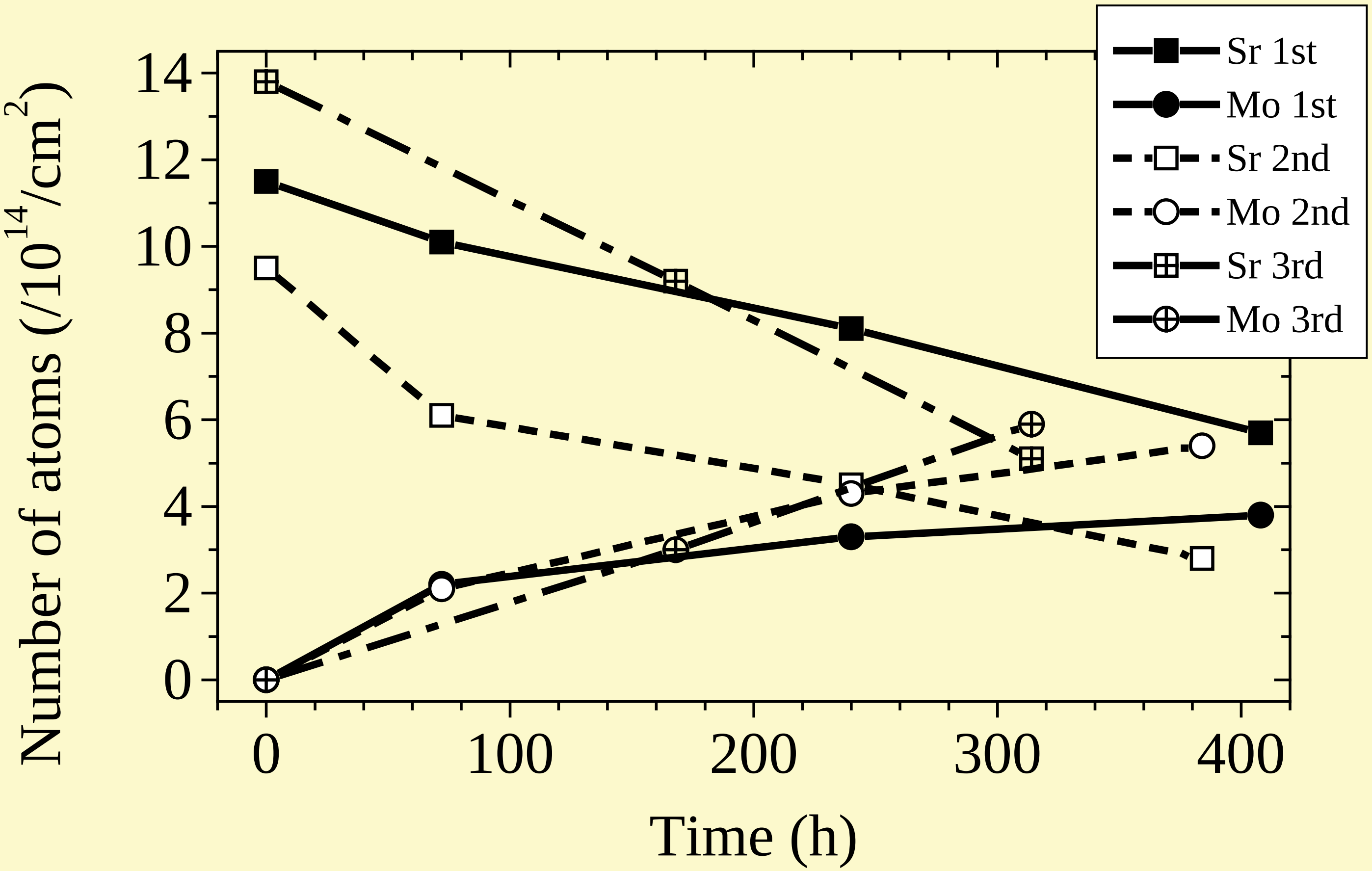

Relation of Isotopic Composition between Sr and Mo

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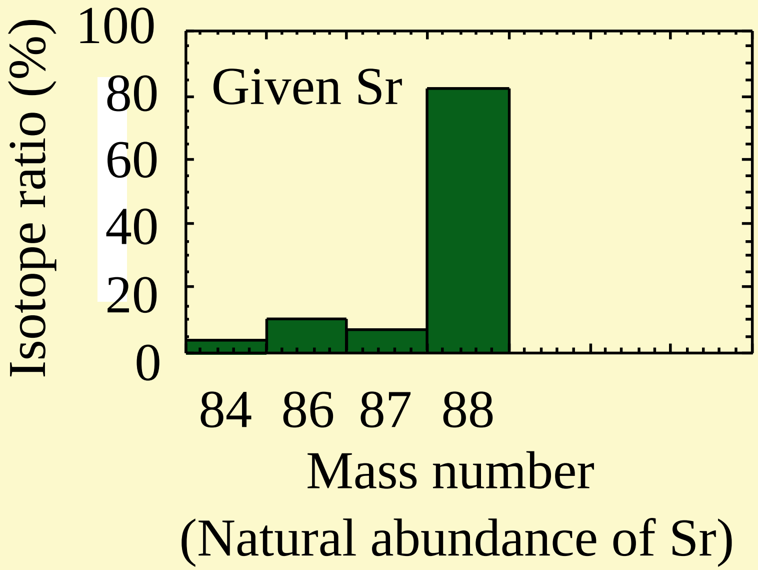

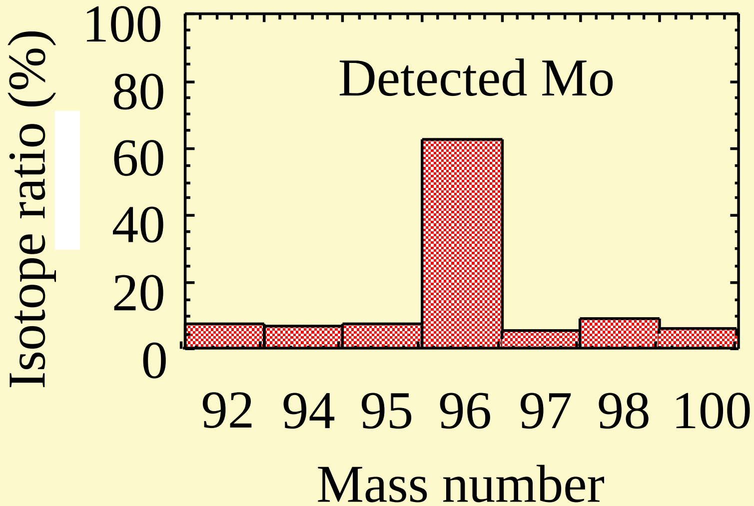

Mass N. +8 Mass N. +8

$${}^{88}_{38}Sr \rightarrow {}^{96}_{42}Mo \quad \Leftrightarrow \quad {}^{133}_{55}Cs \rightarrow {}^{141}_{59}\mathrm{Pr}$$

Atomic N. +4 Atomic N. +4

Recent Results; Part 1

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Transmutation of ^{138}Ba into ^{150}Sm and ^{137}Ba into ^{149}Sm

Transmutation of Ba into Sm; Natural Ba

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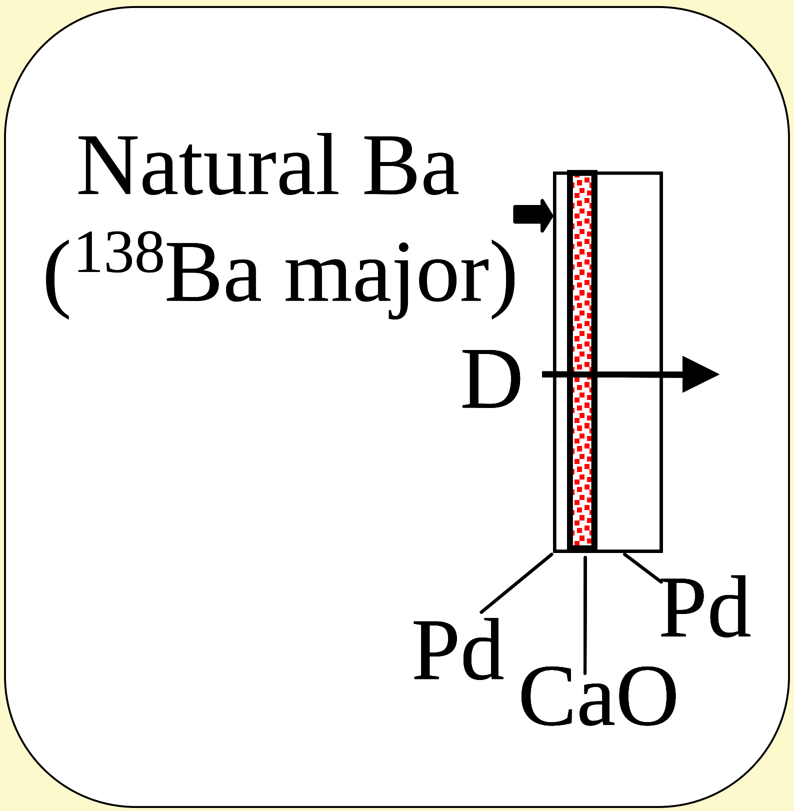

^{150}Sm was detected after D permeation on the Pd complex

Schematic View of the Ex-situ Measurement Apparatus

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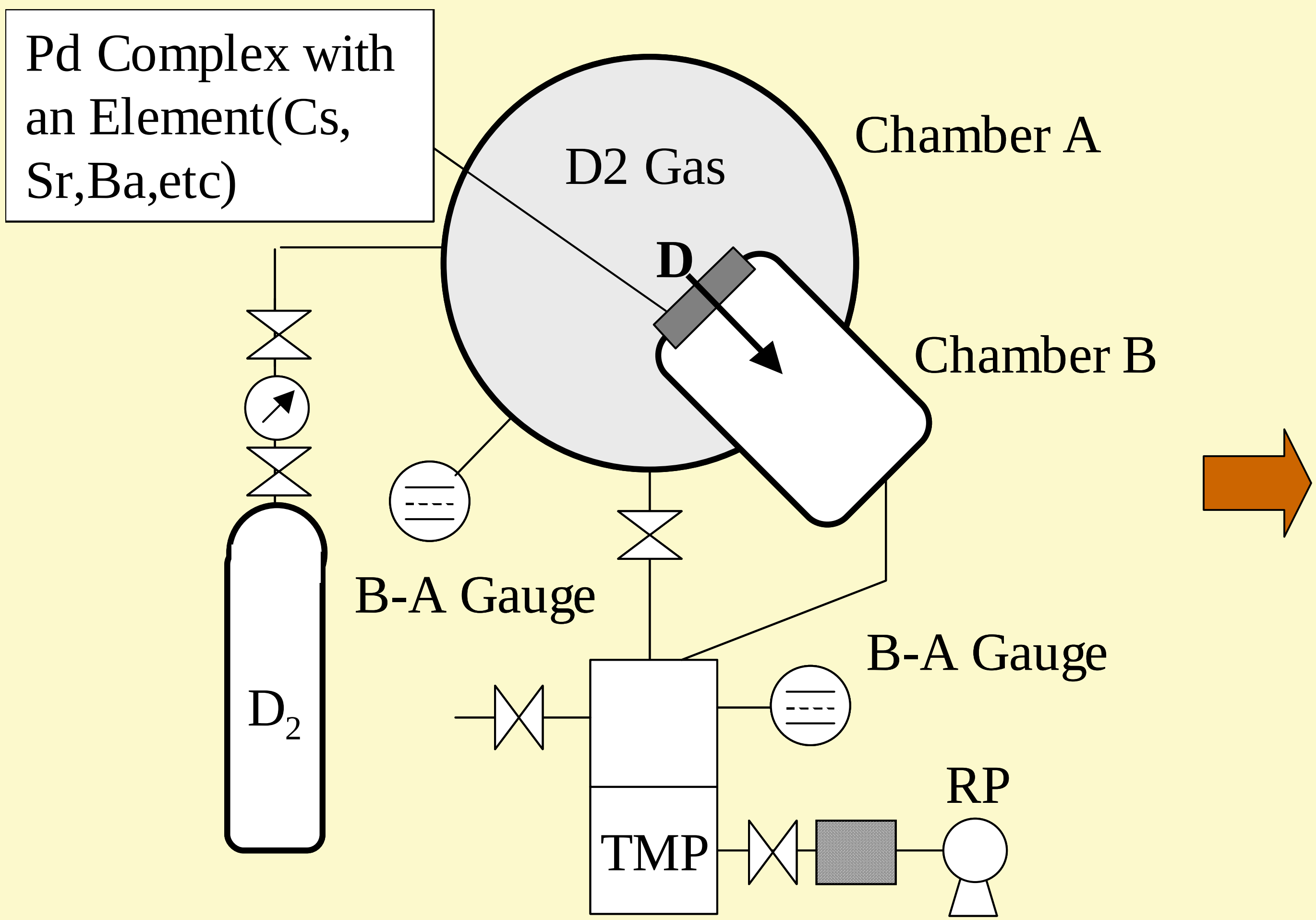

Ex-situ Measurement;

XPS, SIMS, ICP-MS, etc.

XPS Spectra for detected Sm

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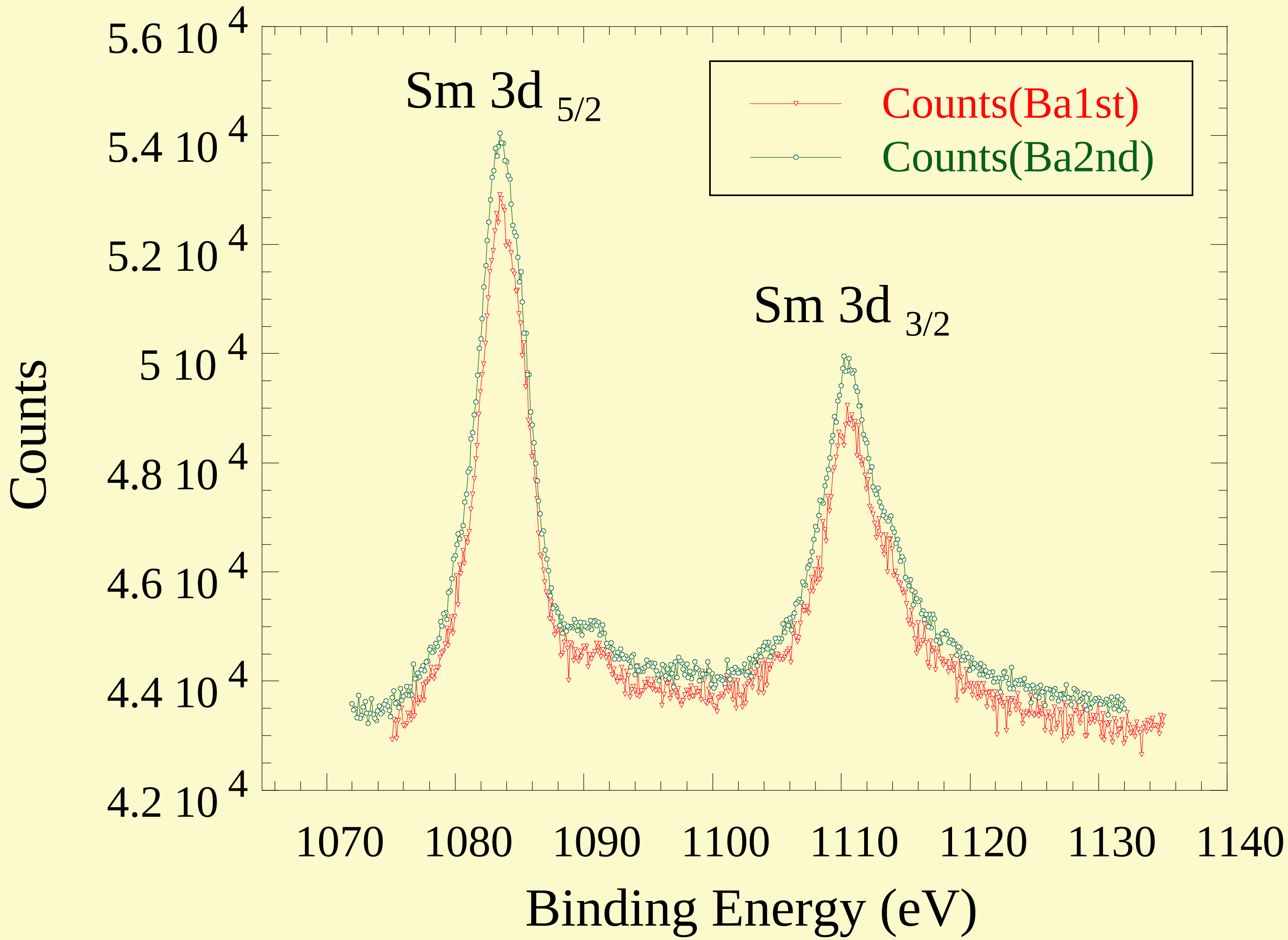

Full Spectrum

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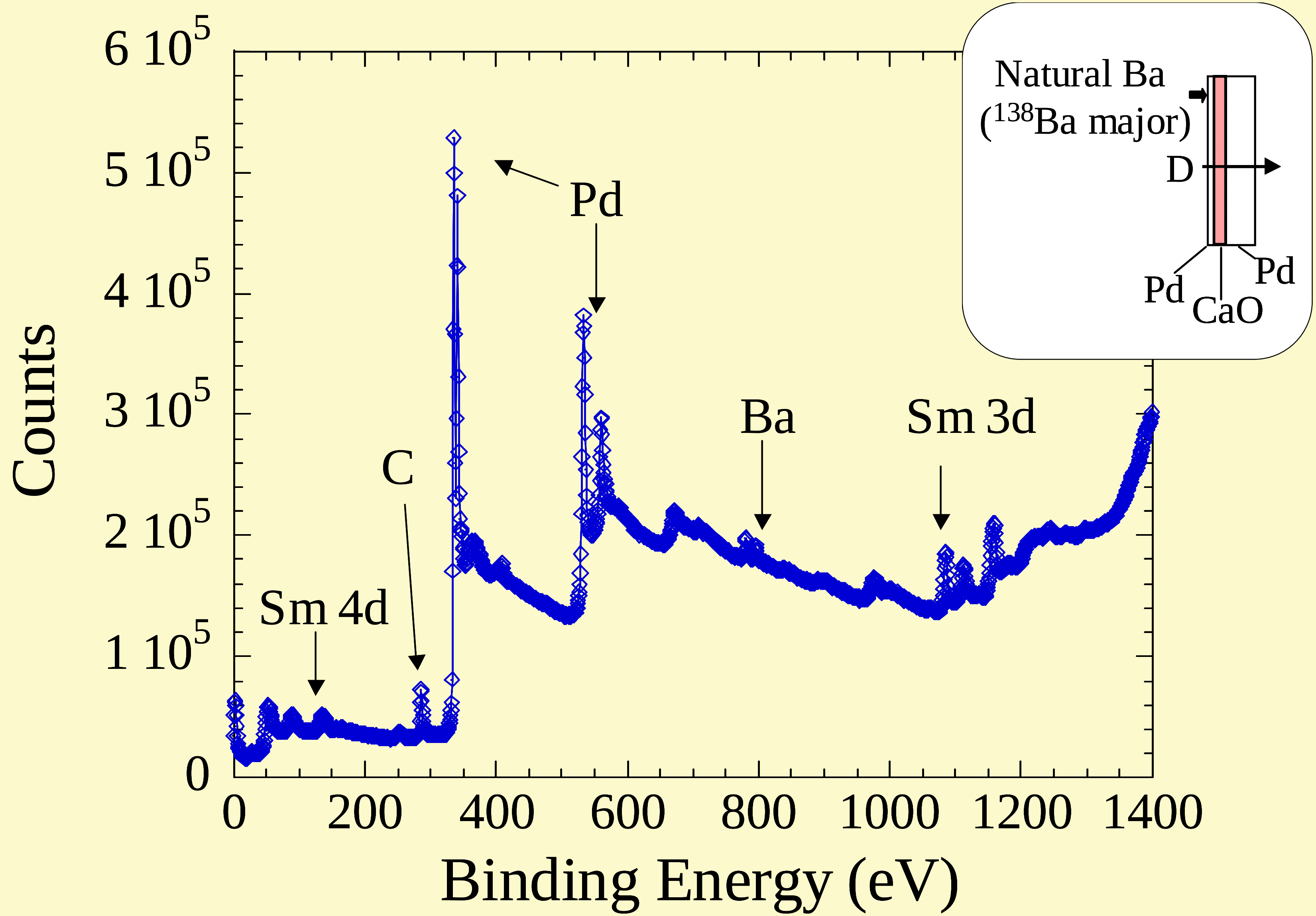

Sm Natural Abundance

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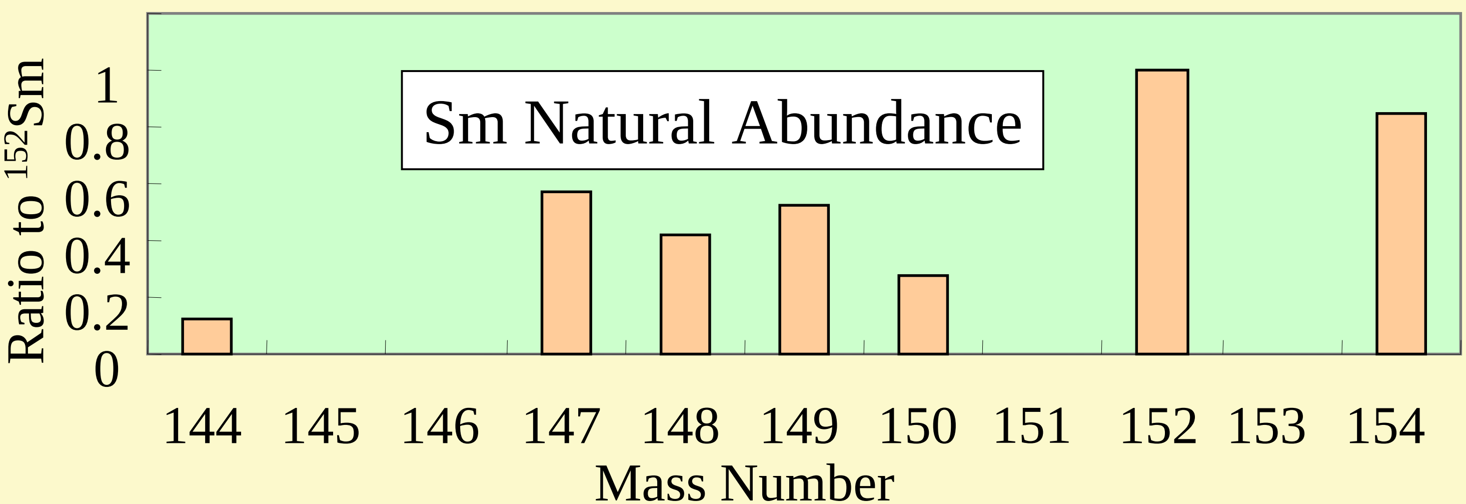
^{144}Sm	^{147}Sm	^{148}Sm	^{149}Sm	^{150}Sm	^{152}Sm	^{154}Sm
3.2%	15.1%	11.3%	13.8%	7.5%	26.6%	22.5%



SIMS Spectra for Given and Detected Elements

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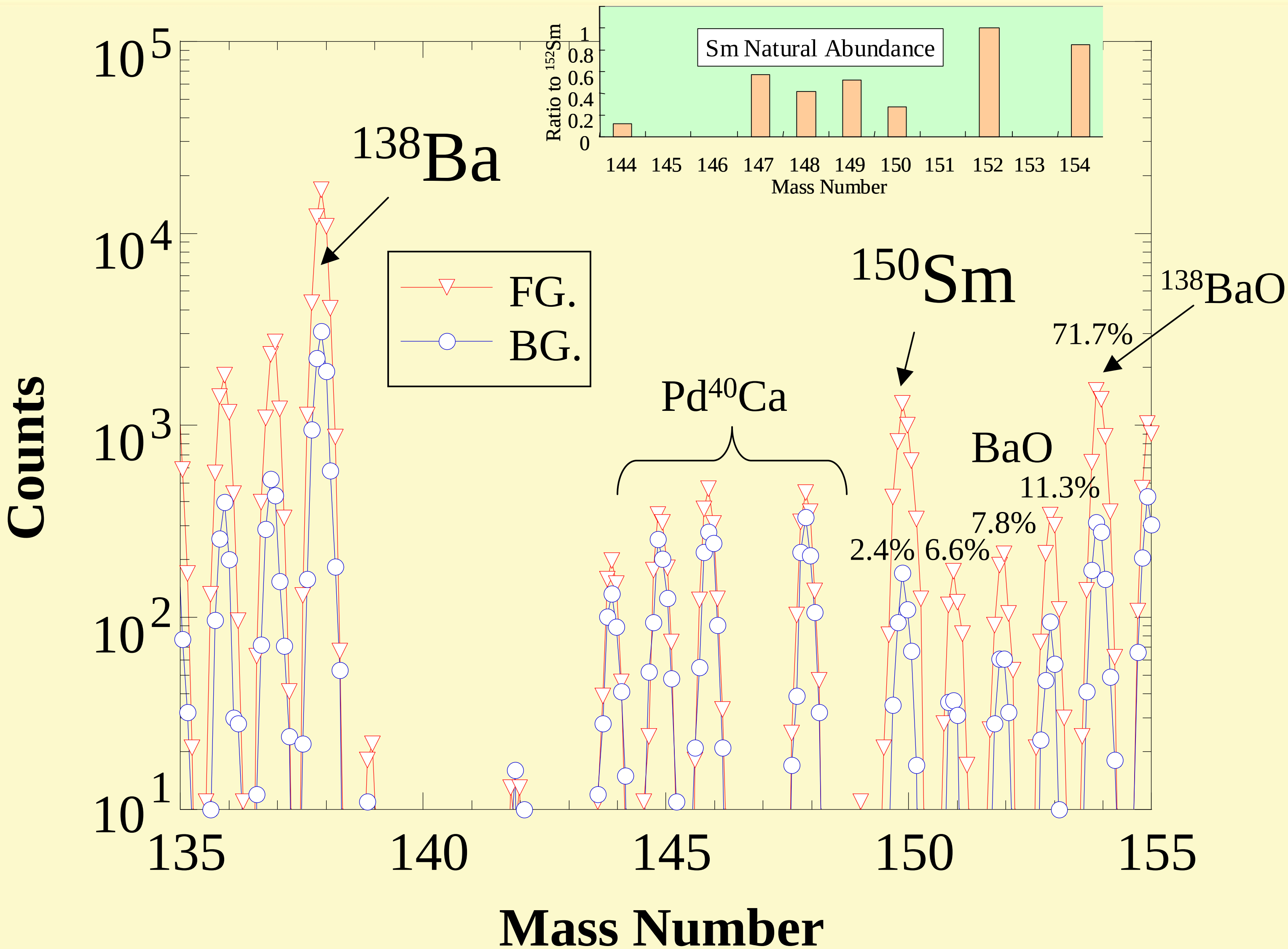

Examination of Molecular Ions

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Pd	$Pd^{40}Ca$
102(1%)	142
104 (11%)	144
105 (22%)	145
106 (27%)	146
108 (26%)	148
110 (12%)	150

Ba	$Ba^{16}O$
130(0.1%)	146
132(0.1%)	148
134(2.4%)	150
135(6.6%)	151
136(7.8%)	152
137(11.3%)	153
138(71.7%)	154

No Molecular Ions for 149.

^{110}Pd(12%)Ca and ^{134}Ba(2.4%)O for mass150, however their effects should be lower than ^{106}Pd(27%)Ca and ^{138}Ba(71.7%)O

Transmutation of Natural Ba into Sm

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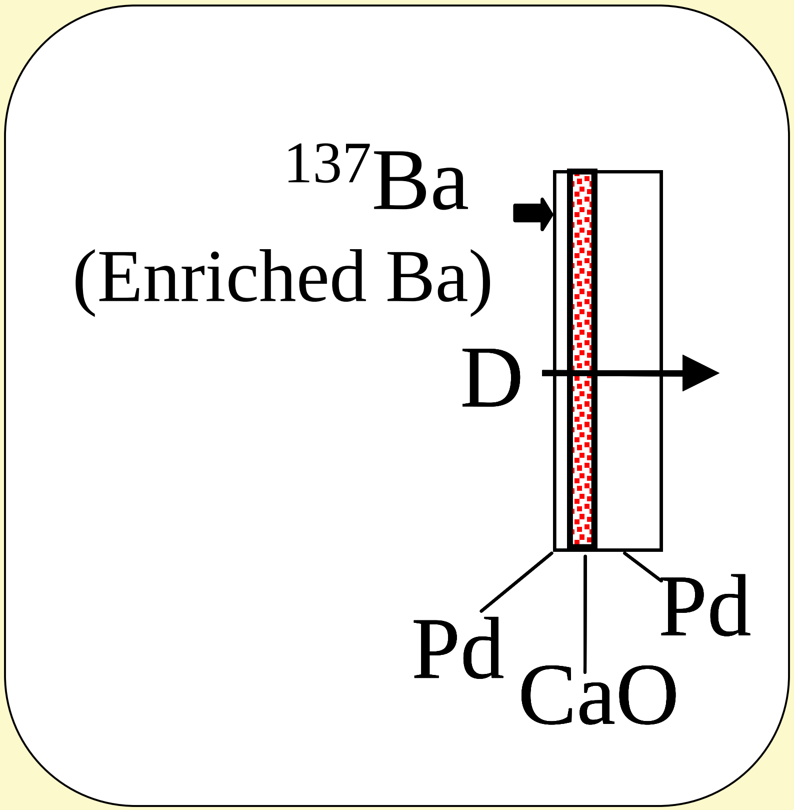
- XPS analysis showed Sm signal.
- SIMS analysis showed the increase of mass 150.
- Natural Sm isotopic distribution did not match with SIMS mass data.
- These facts strongly suggests that ^{150}Sm exists on the Pd complex after D_2 gas permeation.

Transmutation of Ba into Sm; mass 137 Enriched Ba



^{149}Sm were possibly detected after D permeation on the Pd complex

SIMS Spectra for #1Experiment

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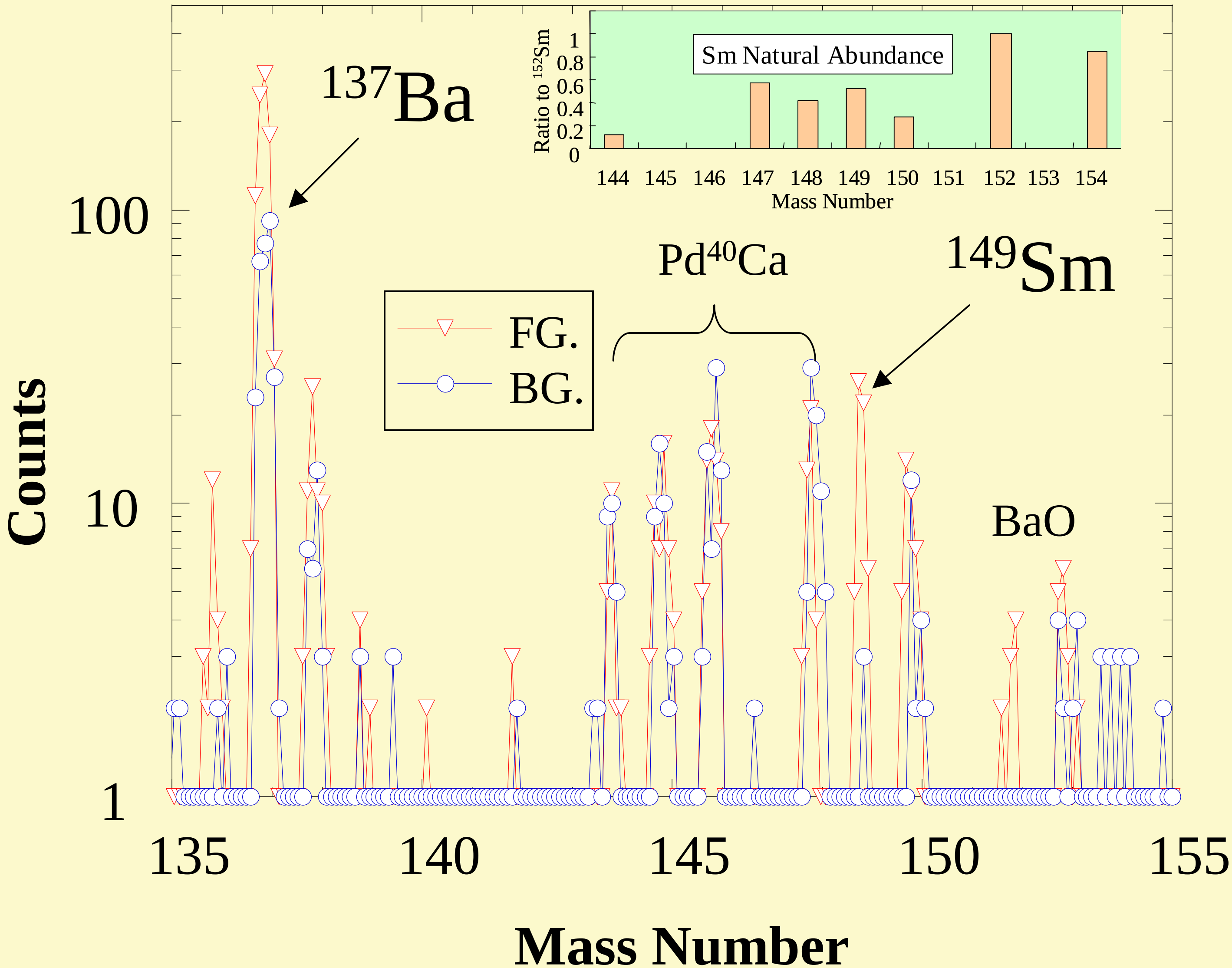

SIMS Spectra for #2 Experiment

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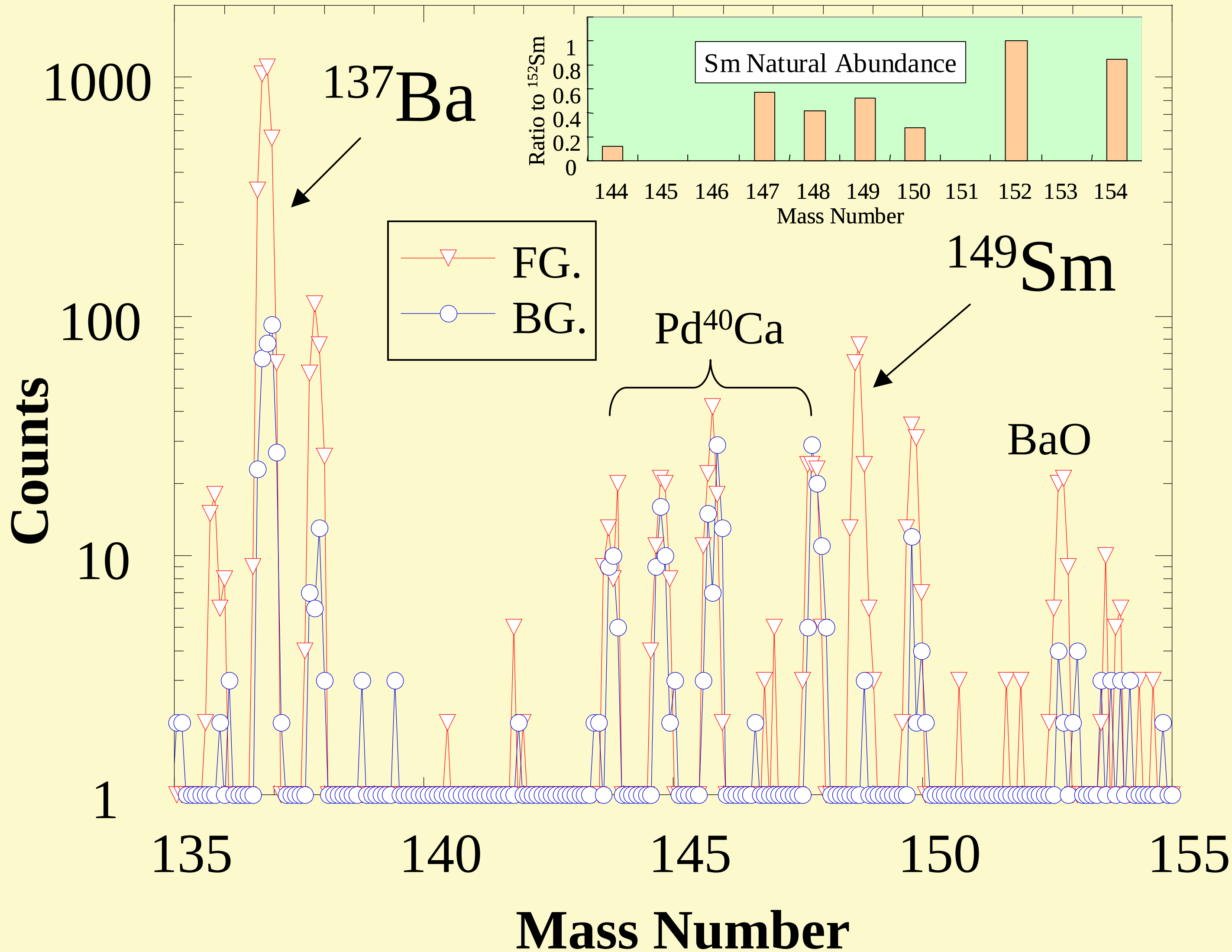

Transmutation of ^{137}Ba into Sm

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- SIMS analysis showed the increase of mass 149.
- Natural Sm isotopic distribution did not match with SIMS mass data.
- XPS analysis showed very weak Sm spectra. Now we are trying to obtain clear XPS signals.
- These facts suggests that ^{149}Sm exists on the Pd complex if we consider that Sm spectra were obtained by XPS using natural Ba.

Mass Correlation between Given and Detected Elements

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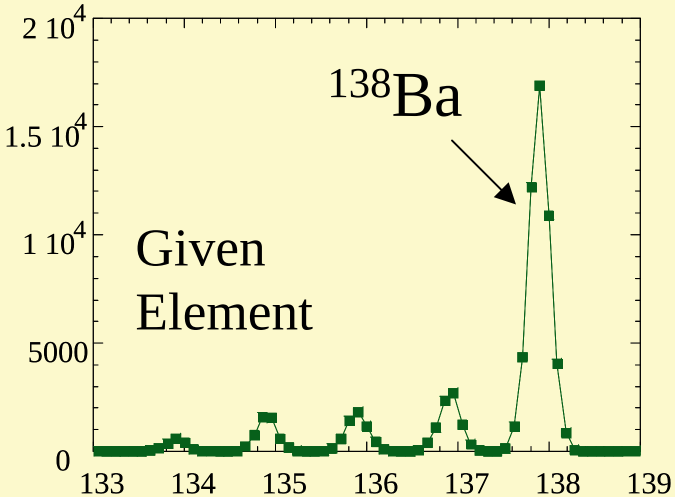
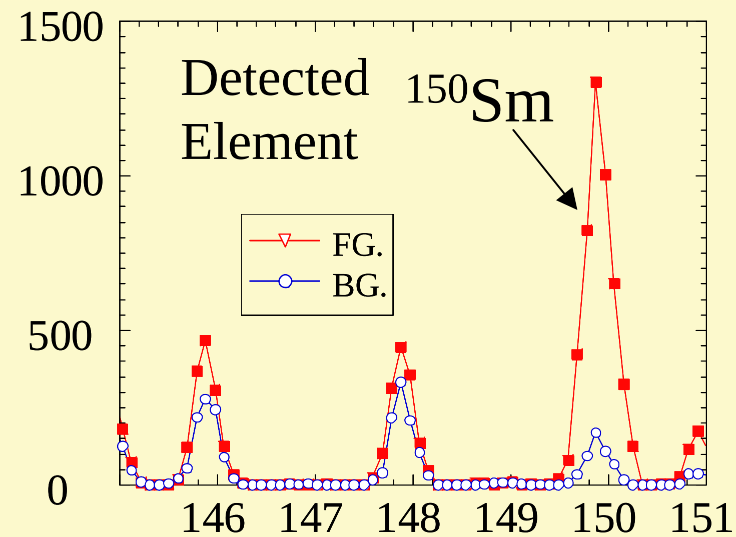
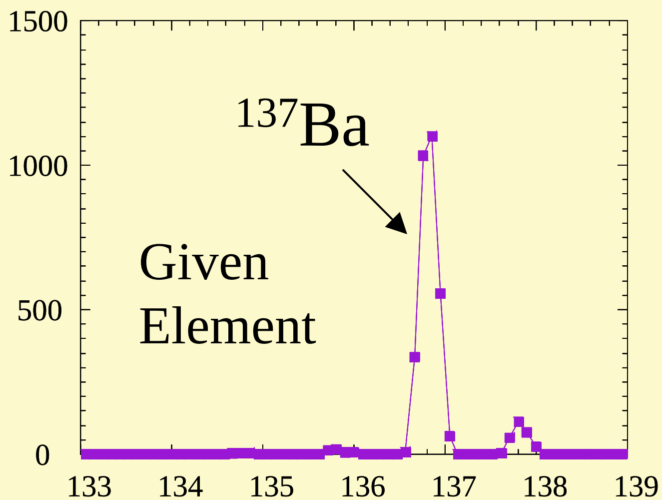


$$^{138}_{56}Ba \xrightarrow{6d} {}^{150}_{62}Sm$$

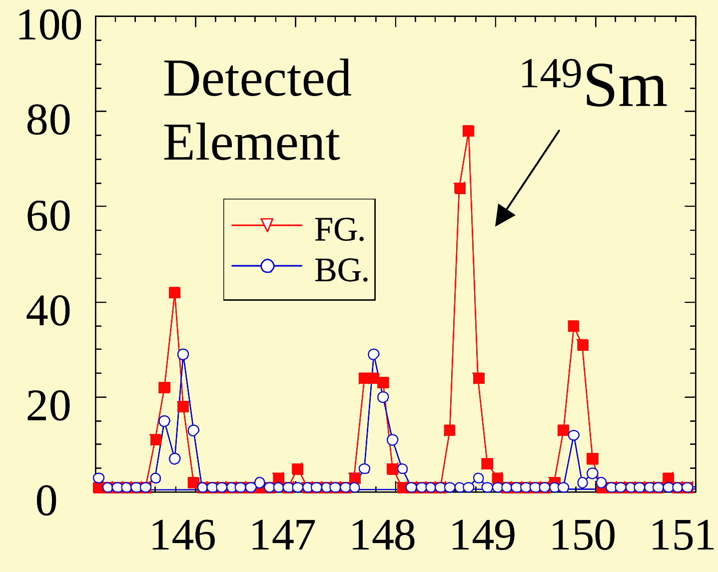
M +12
Z +6





$$^{137}_{56}Ba \xrightarrow{6d} {}^{149}_{62}Sm$$

M +12
Z +6



The Aim of Ba Transmutation Experiments

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$$^{137}_{56}Ba \xrightarrow{6d\,(3\alpha)} {}^{149}_{62}Sm$$

Experimental Results

^{149}Sm is a Mossbauer Isotope

Excitation Energy: 22.5keV

If we measure the Mossbauer effect of ^{149}Sm, we will obtain clear evidence of generation of ^{149}Sm. And the information on the ultra fine structure relating to the electronic state and phonon of the generated ^{149}Sm will be obtain.

Recent Results; Part 2

Pr Confirmation by XRF
and Experiments for
in-situ Measurement at SPring-8

Identification of Pr by X-ray Fluorescence

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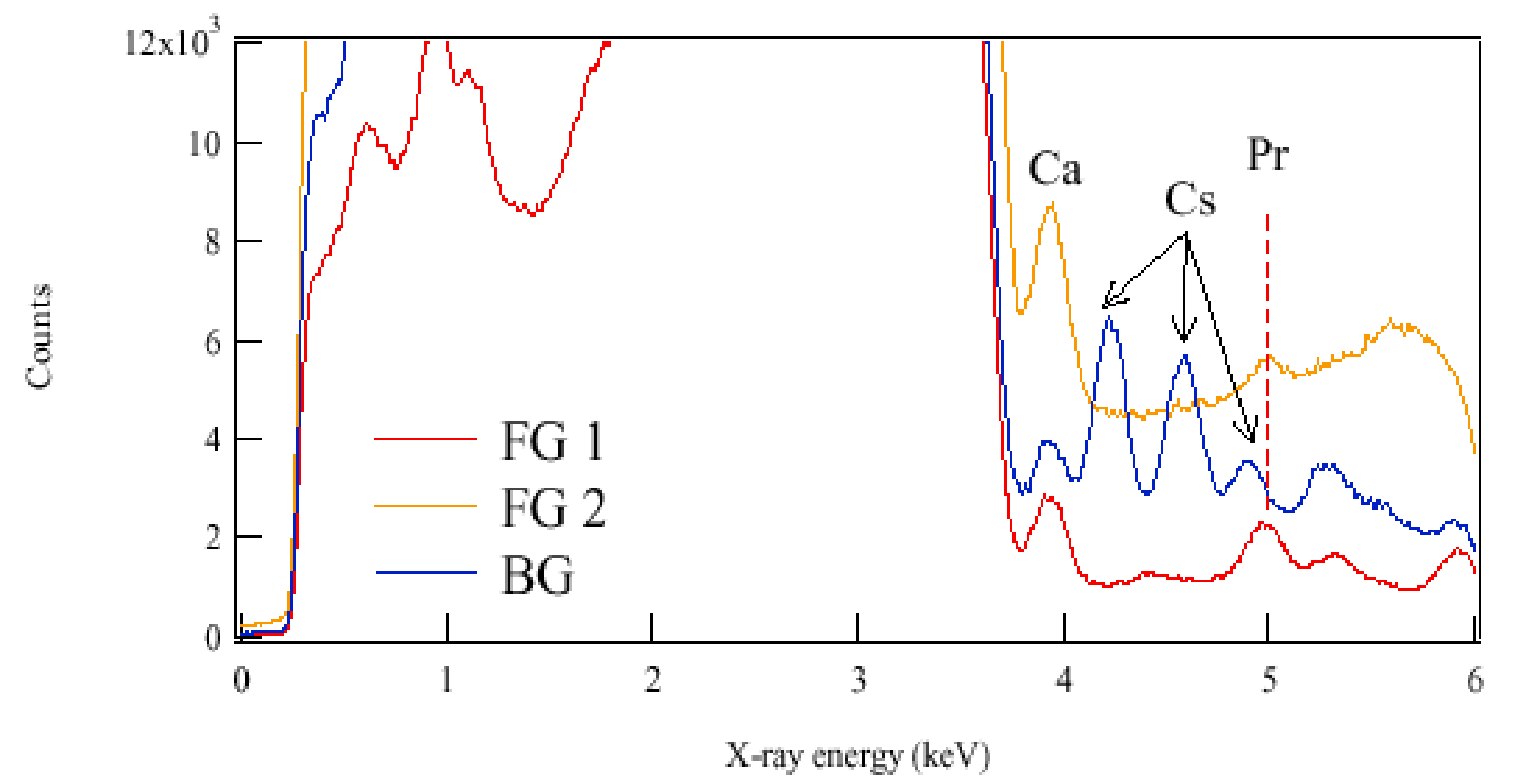

Detection of Pr using SOR X-ray at Spring-8, Harima, Japan
(FG1,FG2:Signals from Samples after D2 Permeation
BG:Signals from the sample before Permeation)

Experimental Set-up for *in-situ* Measurement located at SPring-8

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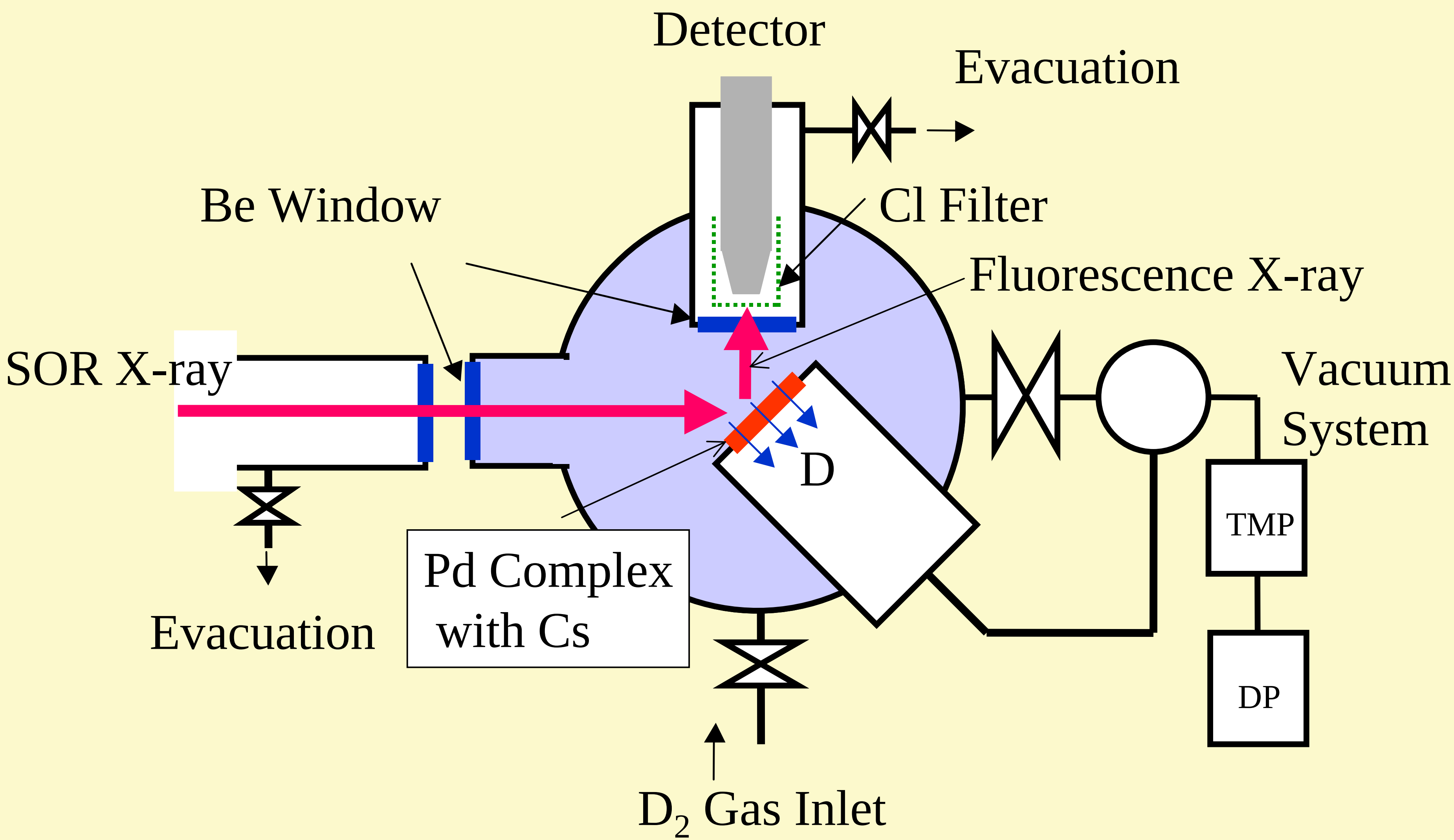

Photograph of the Experimental Set-up

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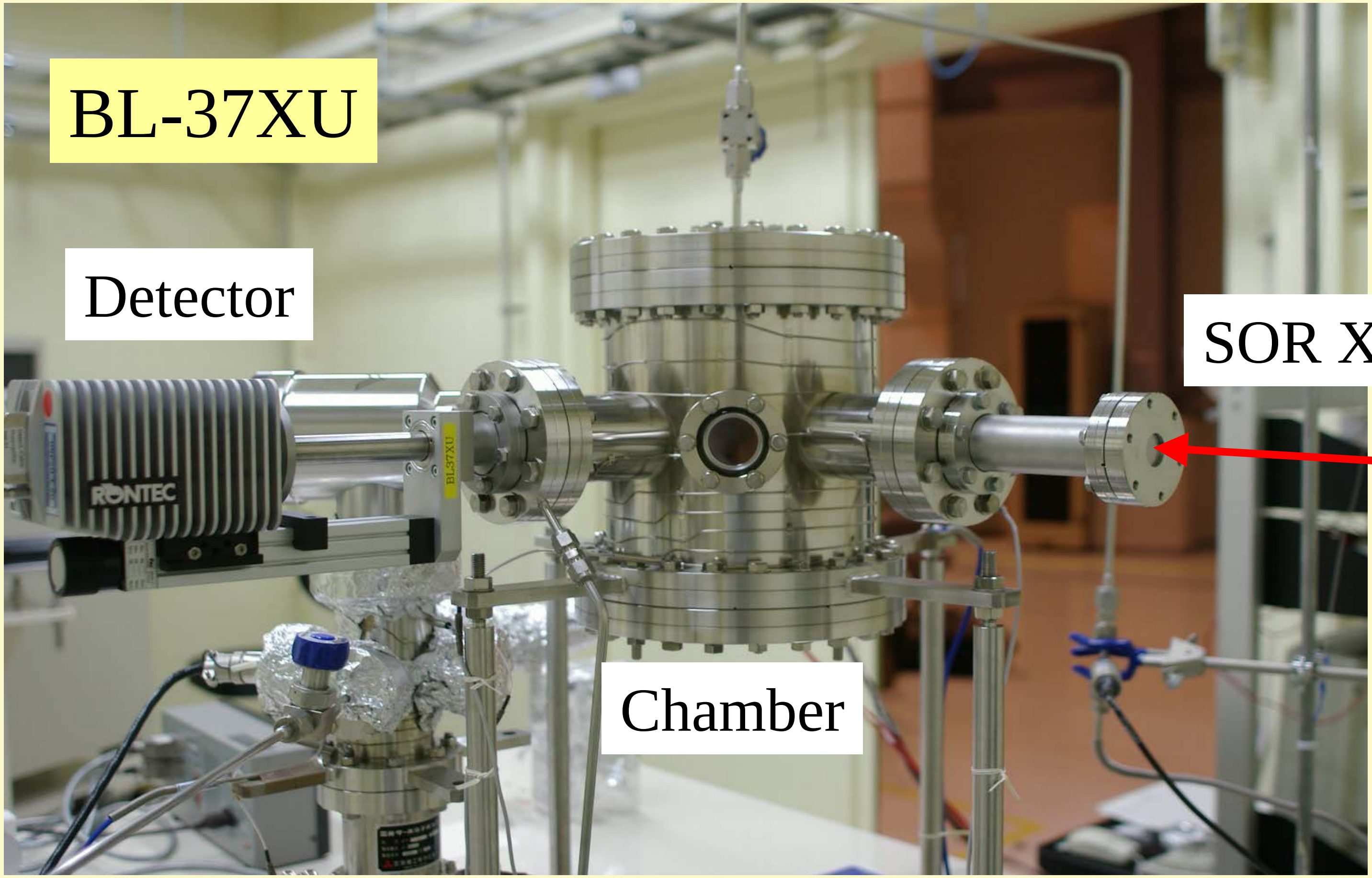
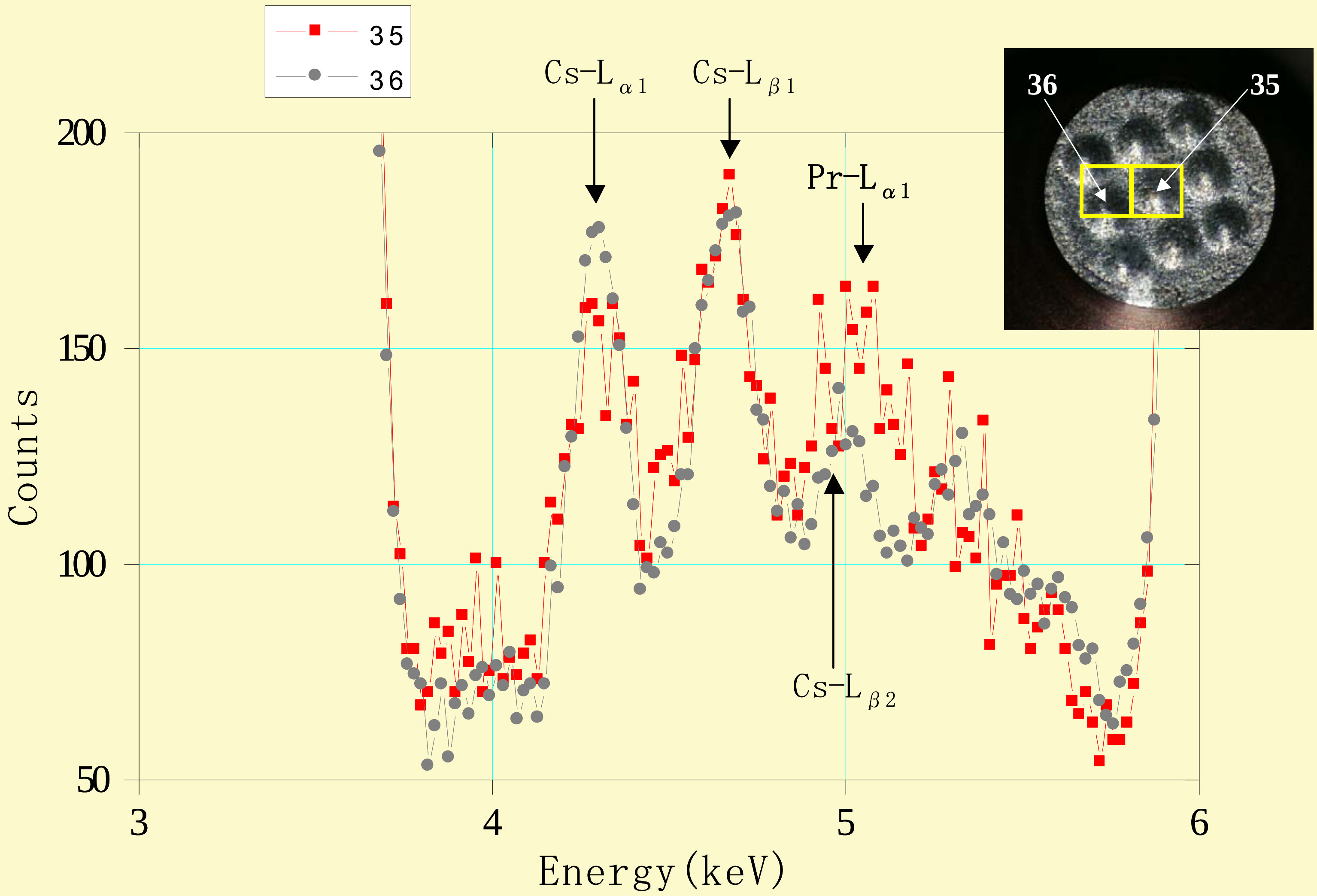


An Example of Pr Detection by the Experiments at SPring-8



Recent Results; Part 3

Measurement and Experiments

relating to the role of CaO

TEM Photograph of the Pd Complex

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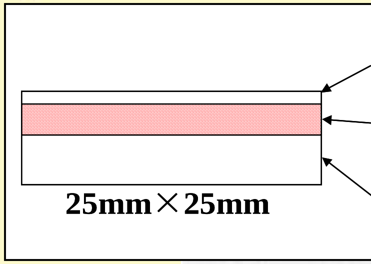

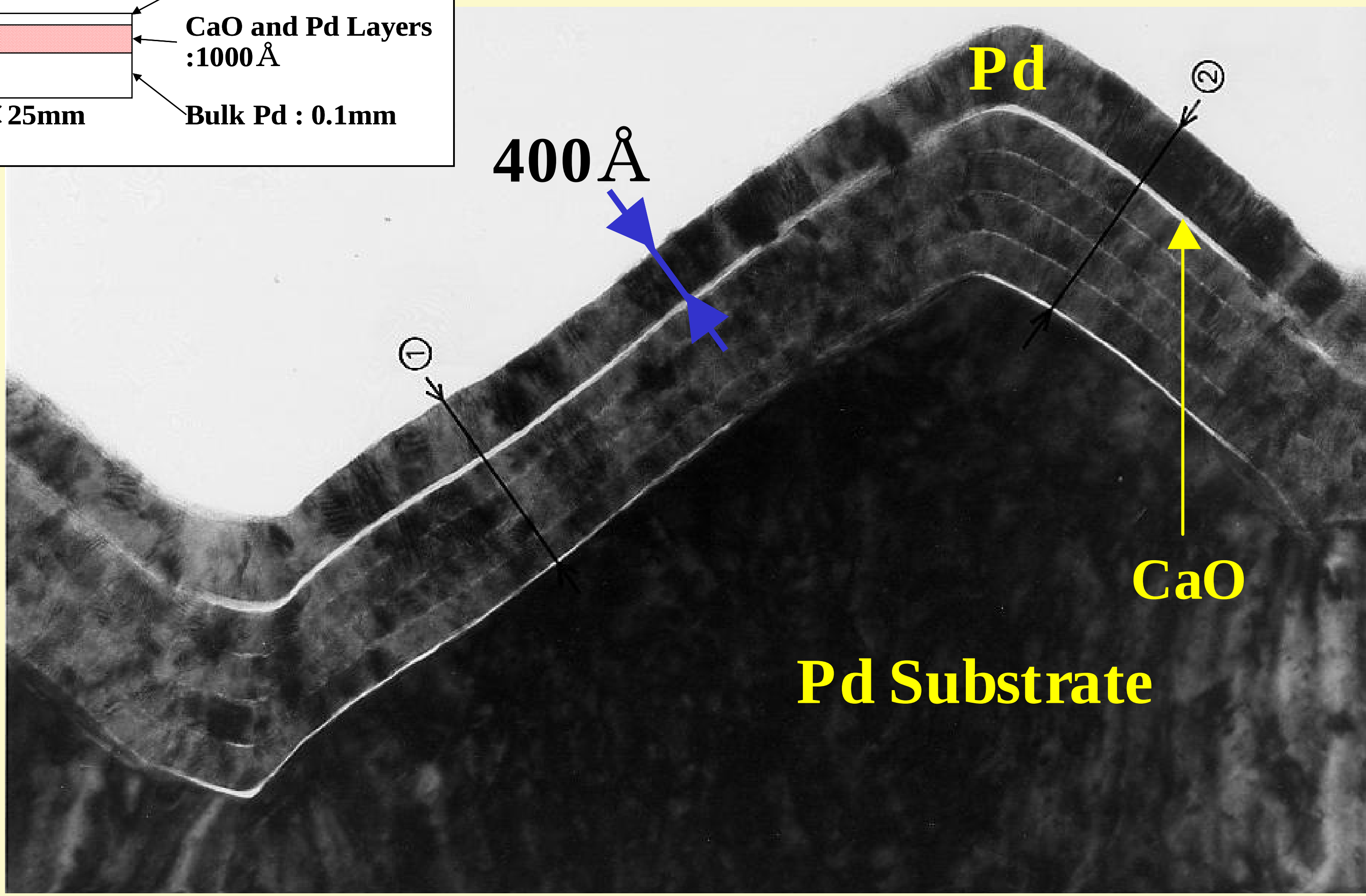

Depth Profile of Cs and Pr by TOF-SIMS

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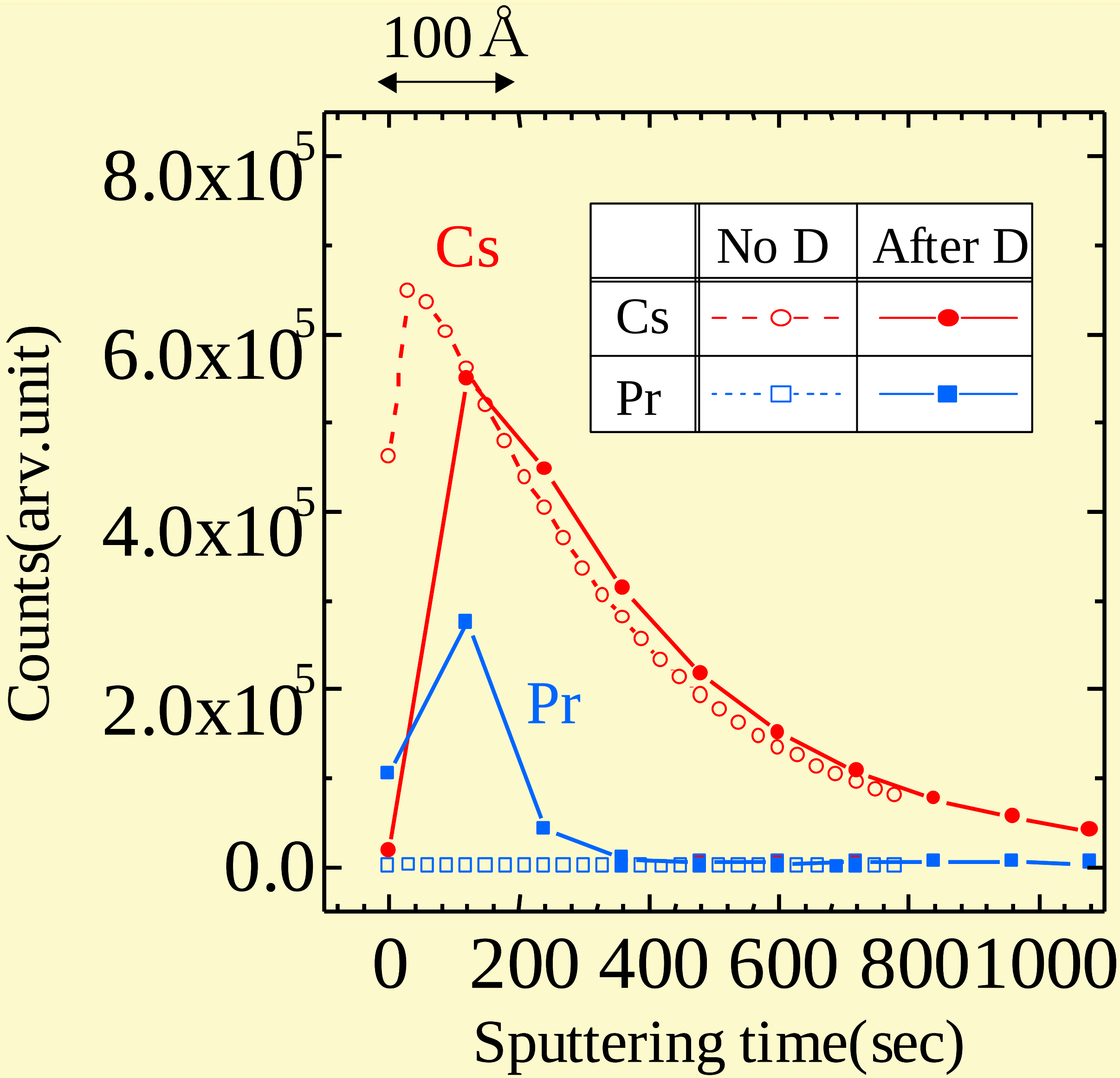

Depth Profile of Cs and Pr by XPS(1)

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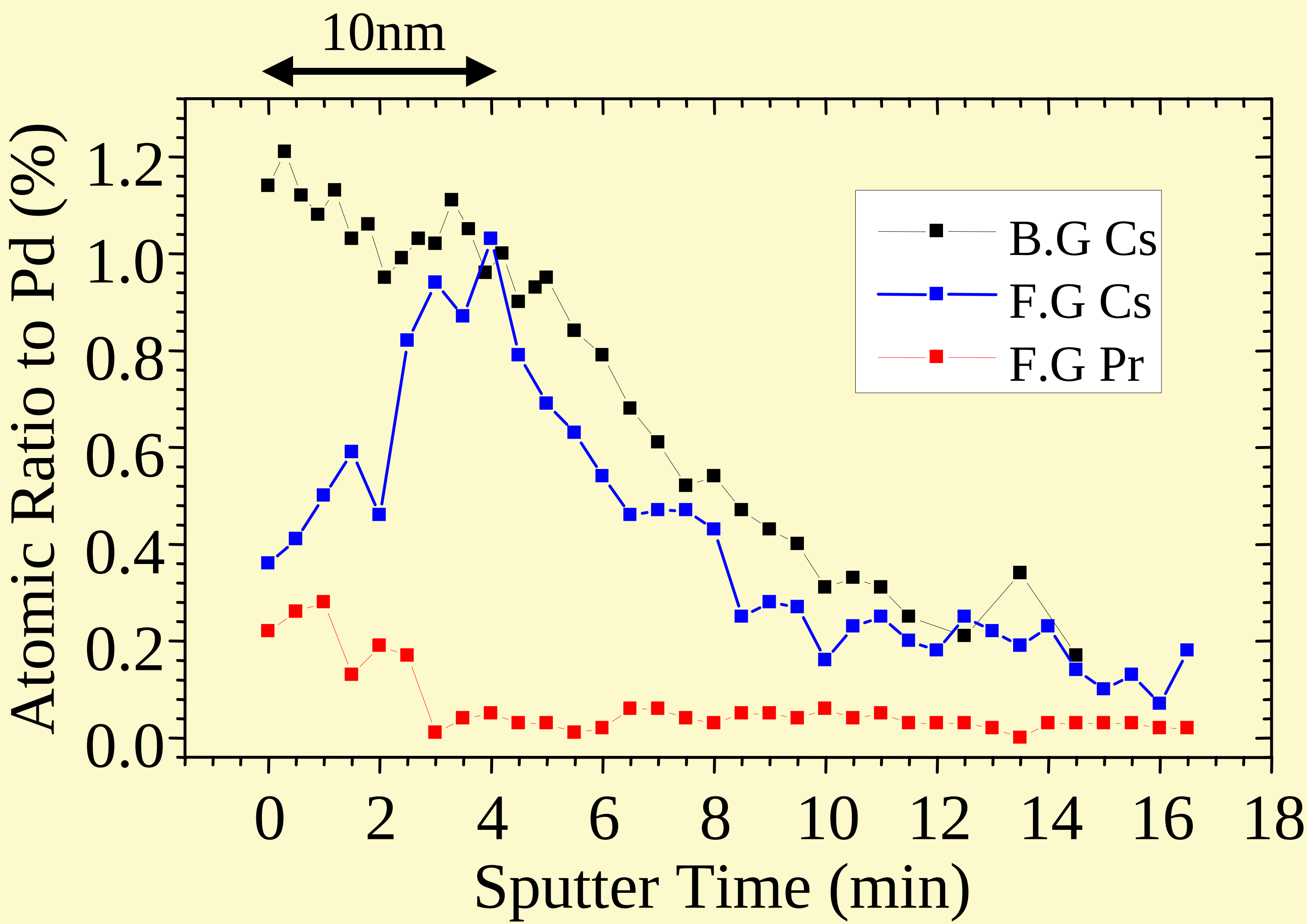
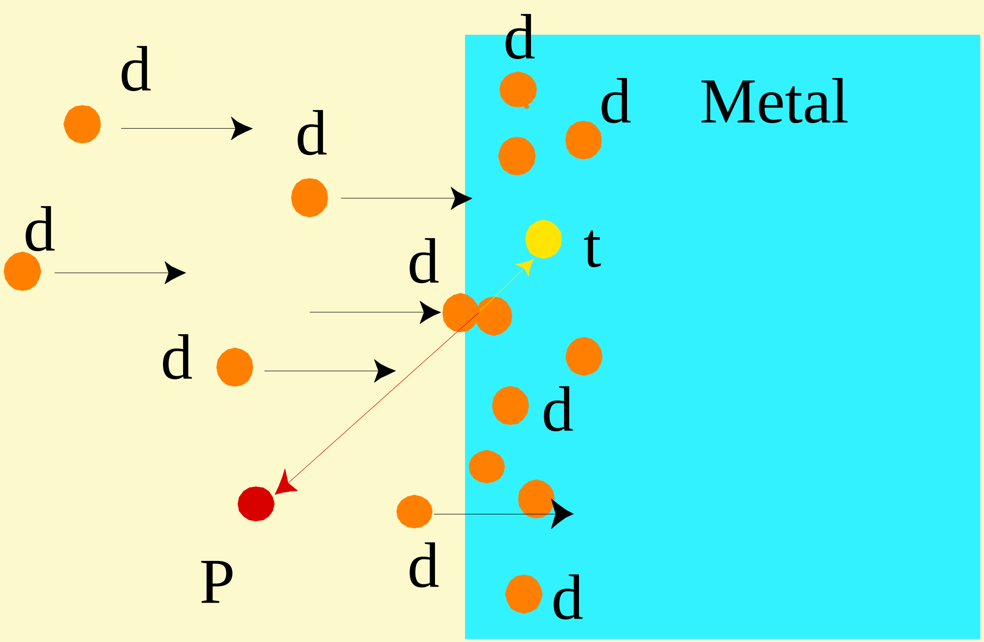
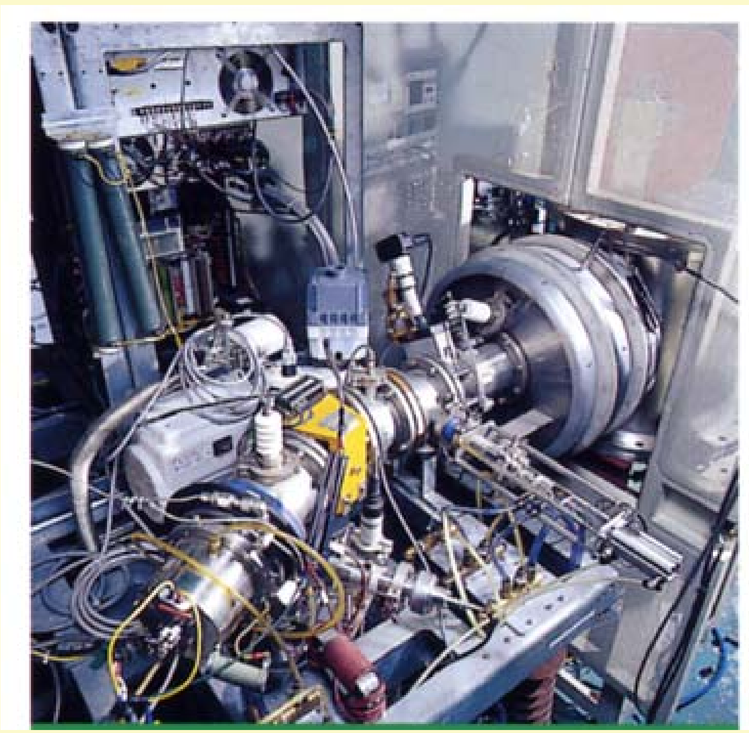


D^+ Ion Bombardment Experiment Performed at Tohoku Univ.

D+ Ion beam bombardment on metal target



Experimental Apparatus



Deuterium Density measured by D^+ Ion Bombardment Experiment

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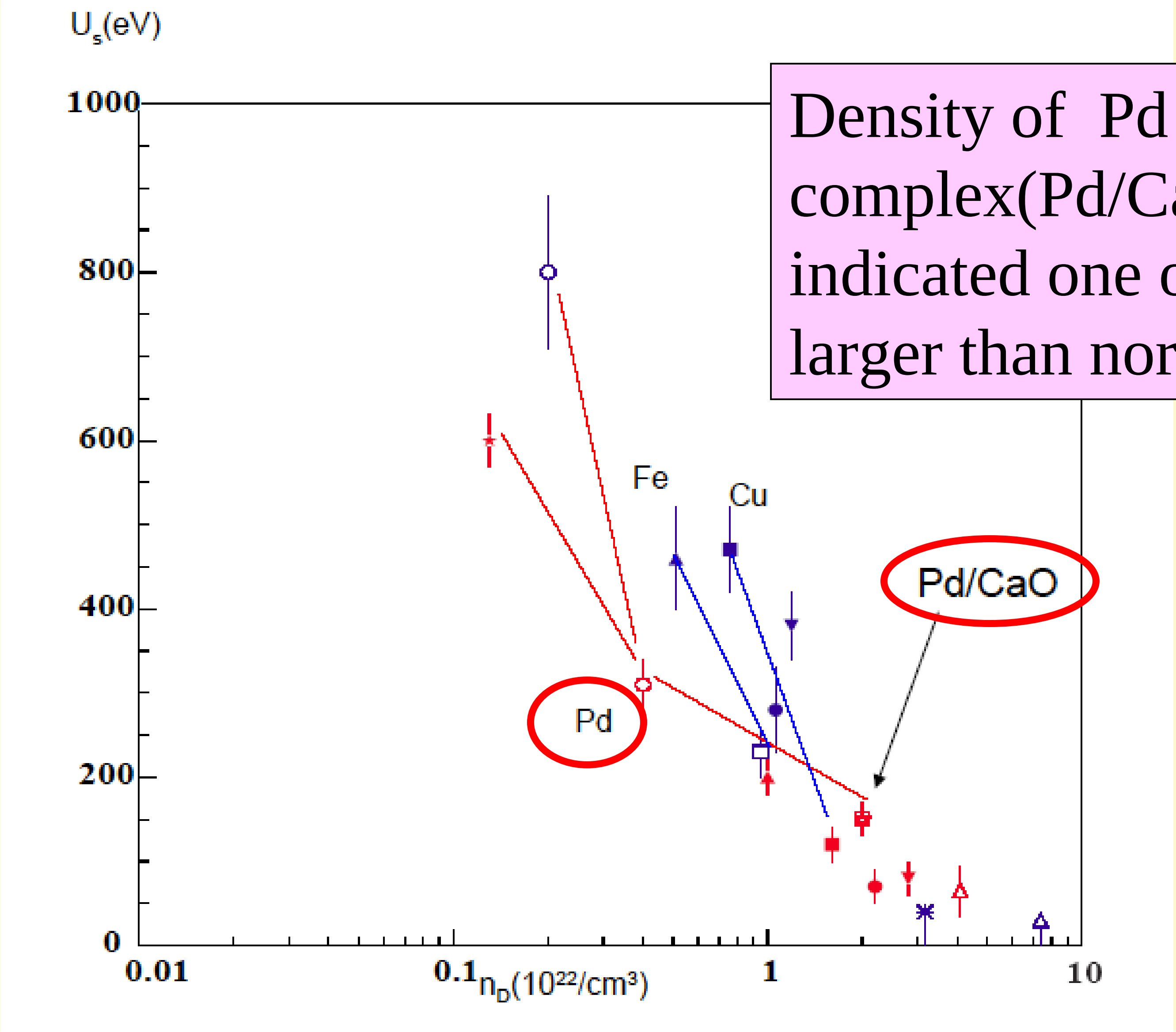

Density of Pd complex(Pd/CaO) indicated one order larger than normal Pd

MgO cannot work instead of CaO

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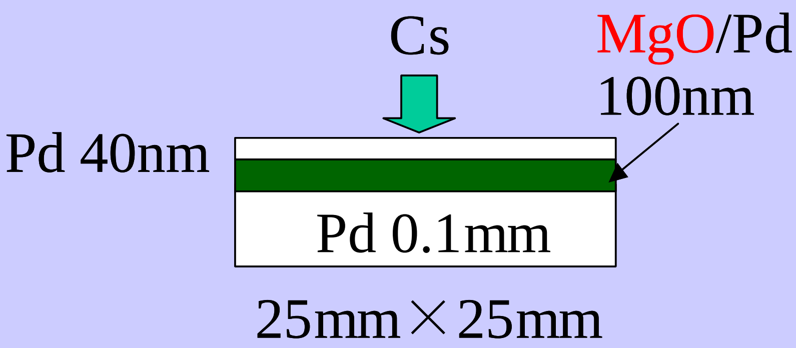
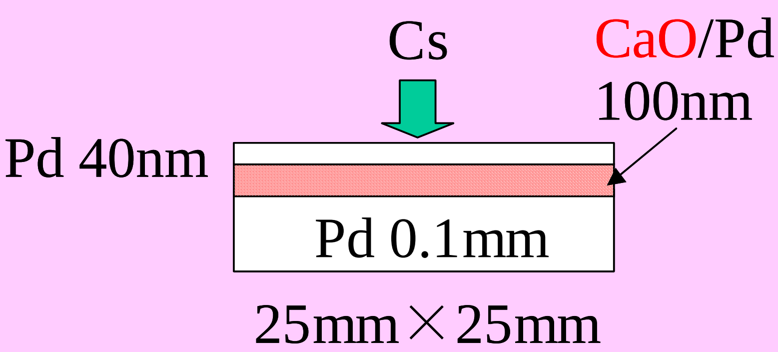


No Pr; Two cases out of two experiments.

ICP-MS measurements show no Pr(<0.01ng).

D_2 gas Flow rate enough(2-3sccm)



Almost every time Pr were detected.

More than 60 cases.

Consideration on the Role of CaO

- Increase of Deuterium Density ?
- Modify the Electronic State of Surface Pd?

Depth Profile Measurement of D
By a Resonance Nuclear Reaction

$$ {}^{7}_{3}Li({}^{2}_{1}d,\gamma){}^{9}_{4}Be $$

Concluding Remarks

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1. **Transmutations of Ba into Sm were observed both for the case of giving natural Ba on Pd complex samples and for the case of giving mass 137 enriched Ba.**
   It means that we obtained mass distribution of Sm depending on given isotopic distribution of Ba by our experimental method.

2. **One of our experimental apparatus was carried to SPring-8 for the purpose of in-situ measurement and we obtained some Pr signals by the X-ray Fluorescence method.**

3. **According to a D^+ ion beam bombardment experiment performed at Tohoku University, deuterium density of our Pd complex indicated one order larger than normal Pd.**