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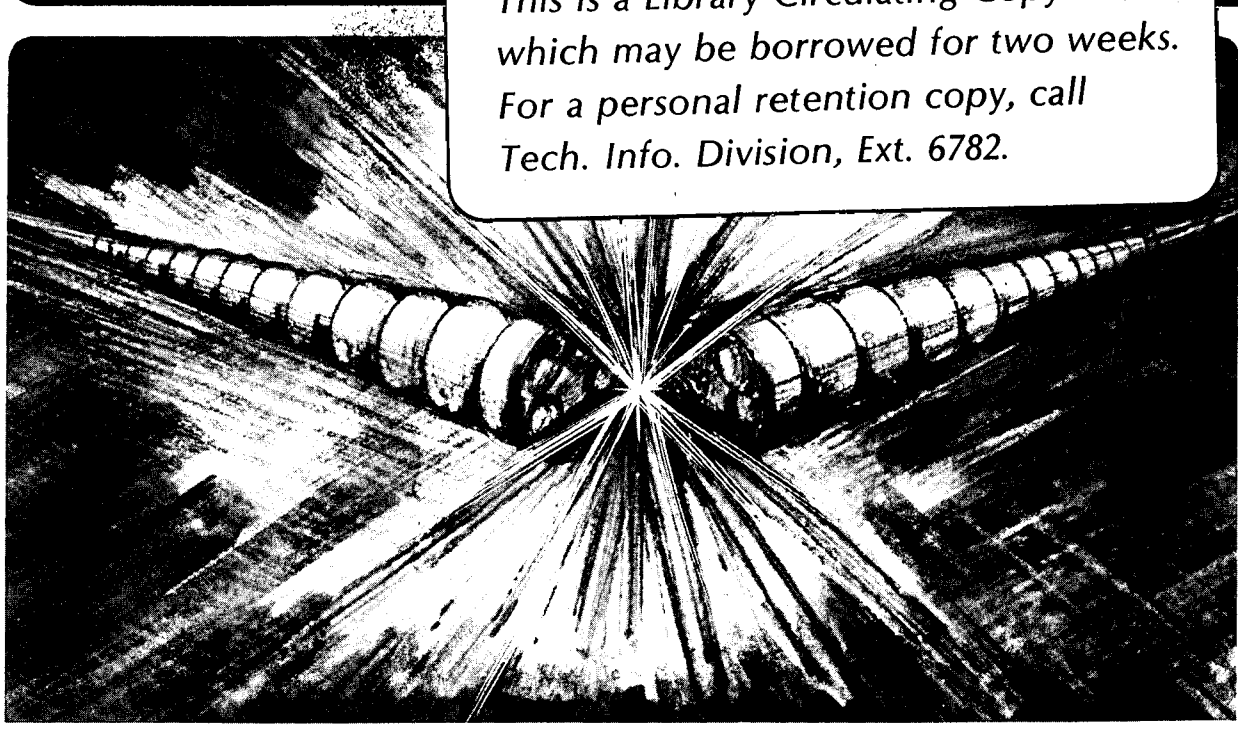

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A STUDY OF THE H- PRODUCTION ON POLY- AND MONOCRYSTALLINE CONVERTERS IN A SURFACE PLASMA SOURCE*

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A study of the H^- production on poly- and monocrystalline converters in a surface plasma source.

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ABSTRACT

Monocrystalline (110) and polycrystalline tungsten and molybdenum converter surfaces have been tested in a surface negative hydrogen ion source, both with and without cesium added to the plasma. With cesium added to the discharge, no significant difference in H^- yield is measured between the four converter surfaces. Energy spectra reveal that the contribution to the total H^- yield from the back-scattered hydrogen is negligible compared to the ion impact desorbed H^- ions. The converter voltage required for optimum H^- production increases with the amount of cesium added to the plasma. The measurements without cesium show roughly equal fractions of back-scattered and desorbed H^- ions in the self-extracted beam. The presence of oxygen on the surfaces enhances the ion impact desorbed (sputtered) H^- yield with respect to the reflected H^- yield. This is attributed to the formation of OH on the surfaces.

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1 INTRODUCTION

Neutral beam injection has proven to be an effective way to heat plasmas in fusion devices to thermonuclear temperatures [1,2]. In future fusion reactor schemes, the required neutral beam energy will be greater than 150 keV [3]. Because of the high neutralization efficiency at these energies (> 60 %) the use of H^- or D^- ions is desired [4,5].

There are several approaches for the production of negative ions [4,6,7]. H^- ions can be extracted directly from a hydrogen discharge plasma [7,8,9]. Low energy (≈ 1 keV) positive hydrogen or deuterium ions can be converted into negative ions by double charge exchange in a sodium or cesium cell [10,11]. H^- ions can also be produced in a conversion process where positive ions are reflected specularly from a surface with a low work function [12,13,14]. At present the most evolved H^- ion sources are those based on plasma surface interactions [15,16,17,18]. In this latter type of source, an auxiliary electrode, the so-called converter, is introduced into the hydrogen discharge. This converter is biased negatively with respect to the source chamber wall (anode) and therefore to the plasma. Cesium is introduced into the discharge. As a result, the converter surface is partially covered by cesium. In general this results in a lowering of the work function. Positive hydrogen and cesium ions are accelerated towards the converter across the plasma sheath. Hydrogen atoms are either desorbed by ion impact or reflected from the surface. Part of these atoms are negatively charged because of the low work function of the cesiated converter. Any negative ions formed at or near the surface are accelerated back across the sheath. Subsequently these negative ions

pass through the plasma and the extraction slit. No external extraction field is present; this is called "self-extraction" [19].

Measurements have shown that when positive hydrogen ions reflect specularly from cesiated monocrystalline (110) tungsten, a factor of 3 higher H^- yield is found as compared with polycrystalline tungsten surfaces [20]. This difference is partly due to a reduced reflectivity in the case of polycrystalline tungsten and partly due to an enhancement of the negative ion formation probability by a factor of 2 for the monocrystals. It is found that the optimum H^+ to H^- conversion efficiency is reached at velocities perpendicular to the surface of around 7×10^4 m/s [12,13]. These velocities correspond to "perpendicular" energies of about 5 eV. Hydrogen particles desorbed through ion impact from the converter present in surface plasma sources, are believed to leave the surface with energies of the same magnitude [21].

Because of the differences in H^- yield mentioned above, it is worthwhile to do a comparative test on polycrystalline and monocrystalline (110) tungsten converter surfaces in a surface conversion H^- source. The results of such a test are shown in section 4. Poly- and monocrystalline (110) molybdenum surfaces are included in the test because traditionally this material is most extensively used in these types of sources [18].

Regarding the origin of the hydrogen that emerges as a negative ion, two opposing views are stated in literature [6,9]. Data obtained in surface plasma sources strongly indicates a mechanism where the hydrogen is sputtered or desorbed from surfaces by ion impact [15,17]. However, single particle experiments [13,14,20] clearly demonstrate the possibility of reflection or back-scattering of hydrogen from surfaces. Therefore

the question arises to what degree each of these processes contributes to H^- formation in surface plasma sources. Our measurements indicate that the relative contribution of both processes strongly depends on the surface conditions. Two extreme cases are distinguished: cesiated surfaces yielding maximum H^- currents, such as the ones discussed in section 4, and "clean" surfaces in discharges with cesium absent. The latter situation is treated in section 3. This study was also performed to test the procedure for cleaning the surfaces. Cleaning is done by adding argon or xenon to the hydrogen plasma. Oxygen plays an important role in the ion impact desorption of H^- from the Cs-free converter, because it enhances the adsorption of hydrogen on the converter surface.

2 APPARATUS

A schematic diagram of the experimental arrangement is shown in Figure 1. The device is a cylindrical ion source [9,22] of the bucket type, with a diameter of 20 cm and a length of 18 cm. The stainless steel chamber of this bucket source is surrounded externally by 10 columns of cobalt-samarium magnets (B ≈ 3.6 kG) to form a linecusp configuration for confinement of primary electrons and plasma [22]. The end flange of the chamber is also equipped with magnets. These magnets, mounted in 4 rows, are connected to the ones on the cylindrical wall. The extraction side of the chamber is closed by the plasma electrode. The extraction slit in this plasma electrode has an area of $0.5 \times 11\ mm^2$.

The actual pressure in the source is not measured. However, in normal operation, the pressure indicated by a gauge located downstream of the mass spectrometer is 1×10^{-4} torr. Calculations, based on the conductance of the holes in the plasma electrode, indicate that the pressure in the source is ≈ 1.5×10^{-3} torr. The base pressure of the vacuum system is 1×10^{-6} torr. During operation a continous flow of hydrogen is maintained.

A steady-state hydrogen plasma is generated by electrons emitted from two tungsten filaments (diameter 0.5 mm). These filaments are biased at -70 V with respect to the source chamber wall (anode). Normal operation included an arc current of 4 A, a hydrogen pressure of 1.5×10^{-3} torr and a converter voltage of -200 V. Langmuir probe measurements indicate a plasma density of $3 \times 10^{10}\ cm^{-3}$ and an electron temperature of 0.7 eV. They further show that the plasma potential is

≈ 2.5 V positive with respect to the anode potential. At a discharge current of 4 A and a pressure of the order of 1×10^{-3} torr the species ratio in this source was measured to be

$$H^+ : H_2^+ : H_3^+ = 4 : 35 : 61.$$

A circular water-cooled converter is inserted into the source chamber through a high-voltage insulator mounted on the end flange. Figure 2 shows a photograph of the converter. The converter consists of an oxygen free copper plate with a diameter of 5.7 cm and a thickness of 1 cm. On this copper plate, a polycrystalline molybdenum foil (thickness 0.25 mm) is brazed with Au-Ni brazing material. A tungsten polycrystal, a tungsten monocrystal (110) and a molybdenum monocrystal (110) are brazed directly onto the copper through holes in the molybdenum foil. The dimensions of the crystals are 16 x 19 x 1 mm^3. The crystals were mechanically polished to a grain size of 1µm. Subsequently the crystals are electrolytically polished.

The converter can be rotated about its center. The extraction slit in the plasma electrode is situated off center. Only one type of converter material at a time is seen by the viewing system formed by the extraction slit and the entrance slit of the mass spectrometer. The latter is situated 3.8 mm behind the extraction slit. The distance from the converter to the extraction slit is approximately 9 cm. Typically the converter is biased at -200 V with respect to the source chamber wall.

The noble gases xenon or argon are introduced into the hydrogen discharge for cleaning of the converter surfaces. The surfaces are cleaned by sputtering with Ar^+ and Xe^+ ions, accelerated across the

plasma sheath. Directly after sputter cleaning the converter, the mass spectrum of the negative ions leaving the converter shows a distict (factor 5) decrease of the impurity peaks. Continued cleaning does not further reduce the impurity peak amplitudes.

Cesium is introduced into the discharge either via SAES Getters dispensers [23] or via a molybdenum pipe connected to a cesium oven. The dispensers or the hole in the molybdenum pipe are placed such that a large part of the cesium vapour is directed toward the converter surface. In normal operation, with cesium added to the discharge, the Langmuir probe measurements indicate that the plasma density is 7×10^{9} cm^{-3}. The electron temperature is 0.8 eV.

The mass spectrometer, consisting of an electromagnet and a Faraday cup, has an entrance slit width of 0.12 mm. The maximum mass number that can be detected is about 100. The half opening angle of the system formed by the extraction and the entrance slit is 2.8^{o}. The mass spectrometer is operated at the same potential as the source chamber wall and the plasma electrode. For negative ions with the same mass over charge ratio, the mass spectrometer acts as an energy analyzer.

3 RESULTS FOR A DISCHARGE WITHOUT CESIUM

The source was first operated without cesium, with an arc voltage of 70 V, an arc current of 4 A and a source pressure of $\approx 1.5\times10^{-3}$ torr. The converter voltage was -200 V and the converter current was about 80 mA.

Figure 3 shows the mass spectrum of negative ions emerging from the source. All these negative ions were created at the converter surface, as we will show.

The thickness of the plasma sheath in front of the converter is small (≈ 3 mm) compared to the distance the particles that leave the converter must travel through the plasma (≈ 9 cm). Negative ions produced in the main plasma (through the so-called "volume" production processes) are not accelerated across the sheath and consequently have a much lower energy than those generated on the converter. It is therefore easy to discriminate against them with the mass spectrometer. Energetic negative ions can in principle also be created via radiative attachment of fast neutrals leaving the converter surface, while they travel through the plasma. However, the cross section for radiative attachment is 7×10^{-23} cm^2 at an electron temperature of around 0.8 eV [24]. This means that the mean free path length is much larger than the dimensions of the source chamber. Therefore no energetic H^- ions are formed in the plasma, and all negative ions detected by the mass spectrometer are generated on the converter surface.

The main peaks in figure 3 correspond with the masses 1(H^-) 16(O^-), 17(OH^-) and 32(O_2^-). The measurement is done 10 minutes after cleaning of the converter surface by sputtering with Ar^+ ions. During

these 10 minutes it is observed that the oxygen related peaks reappear in the mass spectra, which indicates that the surfaces are covered with oxygen again. The oxygen signals are higher for the molybdenum surfaces than for the tungsten ones, indicating that the oxygen coverage of the molybdenum surface is higher than that of the tungsten surface.

Figure 4 shows the measured H^- yield as a function of the energy of the H^- ions for the four converter surfaces. These H^- peaks are measured with a higher sensitivity of the detection system compared to the spectra in figure 3. Both the H^- energy spectra from contaminated and clean surfaces are shown. The discharge conditions are the same as mentioned above. The energy of the detected H^- ions ranges roughly from eV_c, where V_c is the converter voltage, to $2eV_c$. The energy spectra are mainly composed of two peaks, indicating two different populations of H^- ions.

The high energy part of the peak is explained by reflection (back-scattering) of the hydrogen ions from the converter. Plasma ions (H^+, H_2^+ and H_3^+) are accelerated across the sheath with the molecular ions H_2^+ and H_3^+ dissociating at the converter surface [25,26]. On leaving the surface, some of the hydrogen particles become negatively charged. These H^- ions are then accelerated back into the plasma across the sheath. Thus, at a converter voltage V_c, the detected H^- ions can have energies of $2eV_c$ in case of incident H^+ ions, $1.5eV_c$ in case of H_2^+ ions and $1.33eV_c$ in case of H_3^+ ions. Consequently, due to this species effect, the high energy part of the H^- energy spectrum should consist of three superimposed groups. Because of the positive ion species ratio, combined with the energy dependence of H^- formation on back-scattering, the peak resulting from H_3^+ reflection is the highest. The H^+ reflection peak is

not visible.

The low energy part of the H^- energy spectrum shows a peak at an energy slightly higher than eV_c. This peak is due to ion impact desorption of negative hydrogen ions from the surfaces [27].

Comparison of the peak height of the low and the high energy H^- peaks of the four contaminated converter surfaces (figure 4) show that they are different for tungsten and molybdenum. The low energy desorption peak is 40 % smaller in the case of tungsten, compared to molybdenum. The high energy back-scattering peak is 25 % smaller in the case of tungsten. The differences between the energy spectra of the polycrystals and the monocrystals are negligible.

To test the effect of oxygen adsorbed on the converter surface, H^- energy spectra were measured while introducing oxygen into the plasma. Figure 5 shows the energy spectra of the H^- ions leaving the polycrystalline molybdenum surface with different amounts of oxygen present in the discharge. When the amount of oxygen increases, the character of the discharge changes and the total yield of H^- ions decreases. However, it can be seen that the ratio of the height of the back-scattering peak to that of the ion impact desorption peak decreases. Consequently ion impact desorption is relatively enhanced.

The right hand side of figure 4 shows the energy spectra of the H^- ions leaving clean converter surfaces. The spectra are taken directly after cleaning of the surfaces by adding argon or xenon to the hydrogen discharge. The discharge parameters are the same as for the energy spectra shown in the left hand side of figure 4, except for the arc current which is reduced to 3 A. During this cleaning procedure, the ion impact desorption peak of the H^- energy spectrum is observed to

increase. After a while, typically 5 minutes (depending on the amount of noble gas introduced), the desorption peak decreases again. It returns rapidly after the argon inlet is stopped. In about 10 minutes, the H^- energy spectra again look like the ones shown in the left hand side of figure 4.

The height differences between the ion impact desorption peaks from molybdenum and tungsten, are explained by the difference in oxygen coverage between these surface materials (figure 3). It is reported that in the presence of surface oxides pronounced chemical trapping effects occur [28]. Almost certainly they result from the formation of OH bonds [28] and vanish after cleaning of the surface. The amount of adsorbed hydrogen atoms depends strongly on the form of oxygen adsorbed on the surface, e.g. O_2 adsorbed on the surface will not produce H^-. Under the influence of positive ion bombardment more hydrogen is desorbed from the surface with the higher OH coverage, i.e. molybdenum.

The difference in peak height of the back-scattering peaks in the energy spectra of the H^- ions leaving the contaminated surfaces, cannot be explained by by a difference in reflection coefficient between tungsten and molybdenum. According to Hiskes and Schneider [26], the reflection coefficients of tungsten and molybdenum are about equal for deuterium incident normally at energies between 50 eV and 300 eV. The difference in peak height cannot be explained by oxygen induced work function differences either, because these surfaces have a higher work function than clean surfaces [21,29]. However, refractory metals contain small concentrations of alkalis (mainly sodium) as impurity. Small fractions of a monolayer (< 0.01) will have measurable influences on the H^- production on "clean" surfaces. Differences in peak height can be

attributed to the influence of these dilute alkali impurities.

Some measurements (not shown) have been carried out at various converter voltages. Although the shape of the energy spectra did not change much, the total H^- yield increased with increasing (absolute) converter potential. This can be explained by taking into account two effects. First the sputtering yield of H^- increases with impact energy. Secondly the trajectories of the H^- ions have to be taken into account. In the case of a higher converter potential the H^- ions leaving the converter are accelerated to higher velocities. Then the velocity vector of these H^- ions will tend to have a more perpendicular angle with the surface. Therefore more ions will enter the mass spectrometer compared to the case of low converter potential.

Also some H^- energy spectra have been taken at arc currents between 1 and 4 A. No significant changes of the shape of the spectra are observed. The total H^- yield increases with increasing arc current.

4 RESULTS FOR A DISCHARGE WITH CESIUM

After the measurements with pure hydrogen, cesium was introduced into the discharge. Figure 6 shows energy spectra of H^- ions leaving the four converter surfaces, in the presence of cesium. The arc voltage is 70 V, the arc current 4 A and the hydrogen pressure ≈ 1.5×10^{-3} torr. The converter voltage is -200 V with respect to the anode and the converter current approximately 100 mA.

With cesium added to the discharge, the H^- peak height increased a factor of 1000 compared to the case without cesium. Cesium adsorption on tungsten or molybdenum surfaces lowers the work function of the surface [6,13,20,29] and hence increases the negative ionization probability. It can be seen from figure 6 that for that particular cesium pressure in the source, the monocrystalline (110) molybdenum converter surface yields a higher H^- production than the other surfaces. The H^- energy spectra in figure 6 also show that the H^- ions are mainly desorbed (sputtered) from the surfaces. This is in agreement with the interpretation of their experimental data by Bel'chenko et al. [17] and Wieseman [15]. The back-scattered fraction is small, less than 5 %, compared to the desorbed fraction.

The desorbed H^- fraction probably is high in the presence of cesium on the surface because of the large amount of hydrogen bound to the converter by the cesium. We observed a strong pumping effect when cesium was introduced into the discharge. This is also measured by Hellier [23], on dispenser generated alkaline films. Possibly the hydrogen reacts with cesium to form CsH [30], or the hydrogen is trapped between the cesium and the tungsten or molybdenum substrate [31].

A significant difference in H^- yield between the monocrystals and the polycrystals is not observed. Apparently, besides the negative ionization process, another process is important. This process could be related to surface roughness. On a microscopic scale the polycrystals are rougher than the monocrystals and therefore their effective area for hydrogen adsorption is larger. Consequently more hydrogen atoms are adsorbed on the polycrystals than on the monocrystals. Furthermore, the incoming positive ions have a larger probability of impinging on the polycrystalline surface under an angle smaller than normal. At smaller angles, the desorption coefficient is known to be larger [21]. The factor of 2 difference in negative ionization probability between mono- and polycrystals could be compensated by these effects.

Figure 7 shows the heights of the H^- peaks as a function of the converter voltage, for one particular cesium inlet. The optimum H^- yield is found at a converter voltage of about -300 V, except for the polycrystalline molybdenum surface where the optimum is about -400 V, independent of the arc current. It is observed that these optima shift to higher (absolute) converter voltages when the amount of cesium added to the discharge increases. The highest optimum voltage we measured was -600 V. This is in contradiction with earlier measurements [5,16] where an optimum converter voltage of between -150 V and -200 V was measured.

An explanation can be found in the enhanced sputtering yield when the incident Cs^+ ion energy is increased. When the cesium pressure rises, more cesium is adsorbed. Therefore, to maintain an optimum coverage of a partial monolayer [12,13,20], also the sputtering rate must increase, which is done by raising the converter voltage. Thus maximum H^- yield is expected when the converter voltage at the particular value

of the cesium pressure, is such that the cesium sputtering and the cesium adsorption dynamically establish a coverage of about half a monolayer.

5 CONCLUSIONS

The negative hydrogen ion production in a discharge with no cesium present strongly depends on the oxygen coverage of the surface. For the case of clean surfaces, i.e. no oxygen on the surface, the heights of the ion impact desorption peak and the reflection peak are about equal. When oxygen is present on the converter surface, then the peak in the H^- energy spectrum due to ion impact desorption dominates the peak due to reflection of positive hydrogen ions. Consequently, the higher oxygen coverage on a Mo (110) converter results in a higher H^- yield than a W (110) converter. This effect is explained by bonding of hydrogen to oxygen.

When cesium is added to the plasma, the H^- yield increases roughly a factor 1000. This is due to the higher negative ionization probability, caused by the lowering of the work function of the cesiated surface. The dominant process for the H^- production is found to be ion impact desorption. The reflection peak height is below 5 % of the desorption peak. No appreciable difference between mono- and polycrystals was observed. The higher H^- yield of monocrystals is probably counterbalanced by the higher surface roughness of polycrystals.

For H^- production, the optimum converter voltage with respect to the anode increases with the amount of cesium added to the plasma. This result is different than those obtained in earlier measurements of the H^- yield of surface plasma sources.

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REFERENCES

1 F.H. Coensgen, W.F. Cummins, C. Gormenzano, B.G. Logan, A.W. Molvik, W.E. Nexsen, T.C. Simonen, B.W. Stallard and W.C. Turner, Phys. Rev. Lett. 37, 143 (1976)

2 ASDEX team (F. Wagner, K. Behringer, G. Becker, D. Campbell, A. Eberhagen, W. Engelhardt, G. Fussmann, O. Gehre, G. v. Gierke, G. Haas, F. Karger, M. Keilhacker, O. Klueber, M. Kornherr, K. Lackner, G. Lisitano, H.-M. Mayer, D. Meisel, R. Mueller, H. Murmann, H. Niedermeyer, W. Poschenrieder, H. Rapp, H. Roehr, F. Schneider, G. Siller, K.-H. Steuer and G. Venus) and Neutral-Injection Team (A. Staebler, E. Speth, R.C. Kunze, G.G. Lister, H. Lohnert, S. Succi and O. Vollmer), Proc. 3rd Joint Varenna - Grenoble Int. Symp. on Heating in Toroidal Plasmas, Grenoble, France, p. 35 (1982)

3 J.H. Fink, J. Vac. Sci. Technol. 20, 1191 (1982)

4 G.I. Dimov, Proc. 10th Eur. Conf. Contr. Fusion and Plasma Phys., Moscou, USSR (1981)

5 K.W. Ehlers, J. Vac. Sci. Technol. A 1, 974 (1983)

6 J.R. Hiskes, Proc. 14th Int. Conf. on Phenomena in Ionized Gases, Grenoble, France (1979); J. Phys. (Paris) 40, C7-179 (1979)

7 K.N. Leung, K.W. Ehlers and M. Bacal, Rev. Sci. Instrum. 54, 56 (1983)

8 A.J.T. Holmes, T.S. Green, A.R. Walker and N. Hampton, Proc. 3rd Joint Varenna-Grenoble Int. Symp. on Heating in Toroidal Plasmas, Grenoble, France, p. 95 (1982)

9 K.N. Leung and K.W. Ehlers, J. Appl. Phys. 52, 3905 (1981)

10 M. Delaunay, R. Geller, C. Jacquot, P. Ludwig, J.C. Rocco P. Sermet, F. Zadworny, J. Bergstrom, G. Hellblom, R. Pauli, and H. Wilhelmsson, Proc. 3rd Joint Grenoble - Varenna Int. Symp., Grenoble, France, p. 143 (1982)

11 E.B. Hooper Jr., O.A. Anderson, T.J. Orzechowski and P. Poulsen, Proc. Int. Symp. on the Production and Neutralization of Negative Hydrogen Ions and Beams, Brookhaven, USA, p. 163 (1977)

12 H.J. Hopman, P.J.M. van Bommel, P. Massmann and E.H.A. Granneman, Proc. 2nd Int. Symp. on the Production and Neutralization of Negative Hydrogen Ions and Beams, Brookhaven, USA, p. 233 (1980)

13 J.N.M. van Wunnik, J.J.C. Geerlings, E.H.A. Granneman and J. Los, Surf. Sci. 131, 17 (1983)

14 P.J. Schneider, W. Eckstein and H. Verbeek, Proc.5th Int. Conf. on Plasma Surface Interactions in Controlled Fusion Devices, Gatlinburg, USA (1982); J. Nucl. Mat. 111 & 112, 795 (1982)

15 K. Wieseman, K. Prelec and Th. Sluyters, J. Appl. Phys. 48, 2668 (1977)

16 J. Alessi and Th. Sluyters, Proc. 2nd Int. Symp. on the Production and Neutralization of Negative Hydrogen Ions and Beams, Brookhaven, USA, p. 153 (1980)

17 Yu.I. Bel'chenko, G.I. Dimov and V.G. Dudnikov, Proc. Symp. on the Production and Neutralization of Negative Hydrogen Ions and Beams, Brookhaven, USA, p. 79 (1977)

18 K.N. Leung and K.W. Ehlers, Rev. Sci. Instrum. 53, 803 (1982)

19 K.N. Leung and K.W. Ehlers, Rev. Sci. Instrum. 51, 721 (1980)

20 P.J.M. van Bommel, J.J.C. Geerlings, J.N.M. van Wunnik, P. Massmann, E.H.A. Granneman and J. Los, J. Appl. Phys. 54, 5676 (1983)

21 M. Kaminsky, Atomic and Ionic Impact Phenomena on Metal Surfaces, Springer-Verlag, Berlin, FRG (1965)

22 K.N. Leung, R.D. Collier, L.B. Marshall, T.N. Gallaher, W.H. Ingham, R.E. Kribel and G.R. Taylor, Rev. Sci. Instrum. 49, 321 (1978)

23 S.J. Hellier, Proc. 4th Int. Symp. on Residual Gases in Electron Tubes, Florence, Italy, p. 2PP (1971)

24 H.P. Popp, Phys. Rep. 16 C, 169 (1975)

25 P. Massmann, H.J. Hopman and J. Los, Nucl. Instr. & Meth. 165, 531 (1979)

26 J.R. Hiskes and P.J. Schneider, Proc. 2nd Int. Conf. on Low-energy Ion Beams, Bath, UK, p. 182 (1980)

27 E. Taglauer and U. Beitat, Proc. 5th Int. Conf. on Plasma Surface Interactions in Controlled Fusion Devices, Gatlinburg, USA, (1982); J. Nucl. Mat. 111 & 112, 800, (1982)

28 F. Waelbroeck, P. Wienhold and J. Winter, Proc. 5th Int. Conf. on Plasma Surface Interactions in Controlled Fusion Devices, Gatlinburg, USA (1982); J. Nucl. Mat. 111 & 112, 185 (1982)

29 J.L. Desplat and C.A. Papageorgopoulos, Surf. Science 92, 97 (1980)

30 J.R. Hiskes, A. Karo and M. Gardner, J. Appl. Phys. 47, 3888 (1976)

31 M.L. Yu, Proc. Int. Symp. on the Production and Neutralization of Negative Hydrogen Ions and Beams, Brookhaven, USA, p. 48 (1977)

FIGURE CAPTIONS

Figure 1

Schematic diagram of the multicusp negative-ion source. The source is not drawn to scale. The diameter of the source is 20 cm, its length is 18 cm.

Figure 2

Topview of the converter. By rotating the converter the H^- yield of four different materials can be measured independently. The crystals and the molybdenum foil are brazed upon an oxygen free copper (OHFC) disk. The diameter of the disk is 5.72 cm, its thickness is 1 cm.

Figure 3

The mass spectra of the negative ions leaving the four converter surfaces. The surfaces are contaminated with oxygen. The arc current is 4 A, the arc voltage 70 V. The estimated pressure in the discharge chamber is $\approx 1.5 \times 10^{-3}$ torr. The converter voltage is -200 V with respect to the source wall. The converter current is approximately 80 mA.

Figure 4

The energy spectra of the H^- ions leaving the four converter surfaces, for both contaminated and clean surface conditions. The spectra for the contaminated surfaces correspond with the H^- peaks in figure 3. With

respect to the measurement resulting in figure 3 the sensitivity along the energy scale is increased with a factor of 5 and along the current scale a factor of 10. The discharge conditions for the energy spectra taken on contaminated surfaces, are the same as in figure 3. For the case of clean surfaces, the arc current was reduced to 3 A. The surfaces are cleaned by sputtering with Ar.

Figure 5

The energy spectrum of the H^- ions leaving the polycrystalline molybdenum converter surface. Various amounts of oxygen are introduced into the plasma. The discharge current is 4 A, the discharge voltage 70 V. The converter voltage is -200 V. The partial hydrogen pressure measured by the gauge downstream of the mass spectrometer is 8×10^{-5} torr. The partial oxygen pressure measured by the same gauge is 2×10^{-5} torr (Curve 1), 3×10^{-5} torr (Curve 2) and 4×10^{-5} torr (Curve 3). At higher partial oxygen pressures the high energy back-scattering peak disappears.

Figure 6

The energy spectra of the H^- ions leaving the four converter surfaces. The discharge current is 4 A, the discharge voltage 70 V. The converter voltage is -200 V. The converter current is approximately 100 mA. The estimated pressure in the discharge chamber is $\approx 1.5\times10^{-3}$ torr. Cesium is added to the discharge by means of a cesium dispenser. The detection sensitivity is decreased a factor 500 with respect to the measurements

without cesium, e.g. figure 4.

Figure 7

The peak heights of the energy spectra of the H^- ions as a function of the converter voltage, for an approximately constant cesium pressure. The discharge parameters are the same as in figure 6. One curve is shown with an arc current of 10 A.

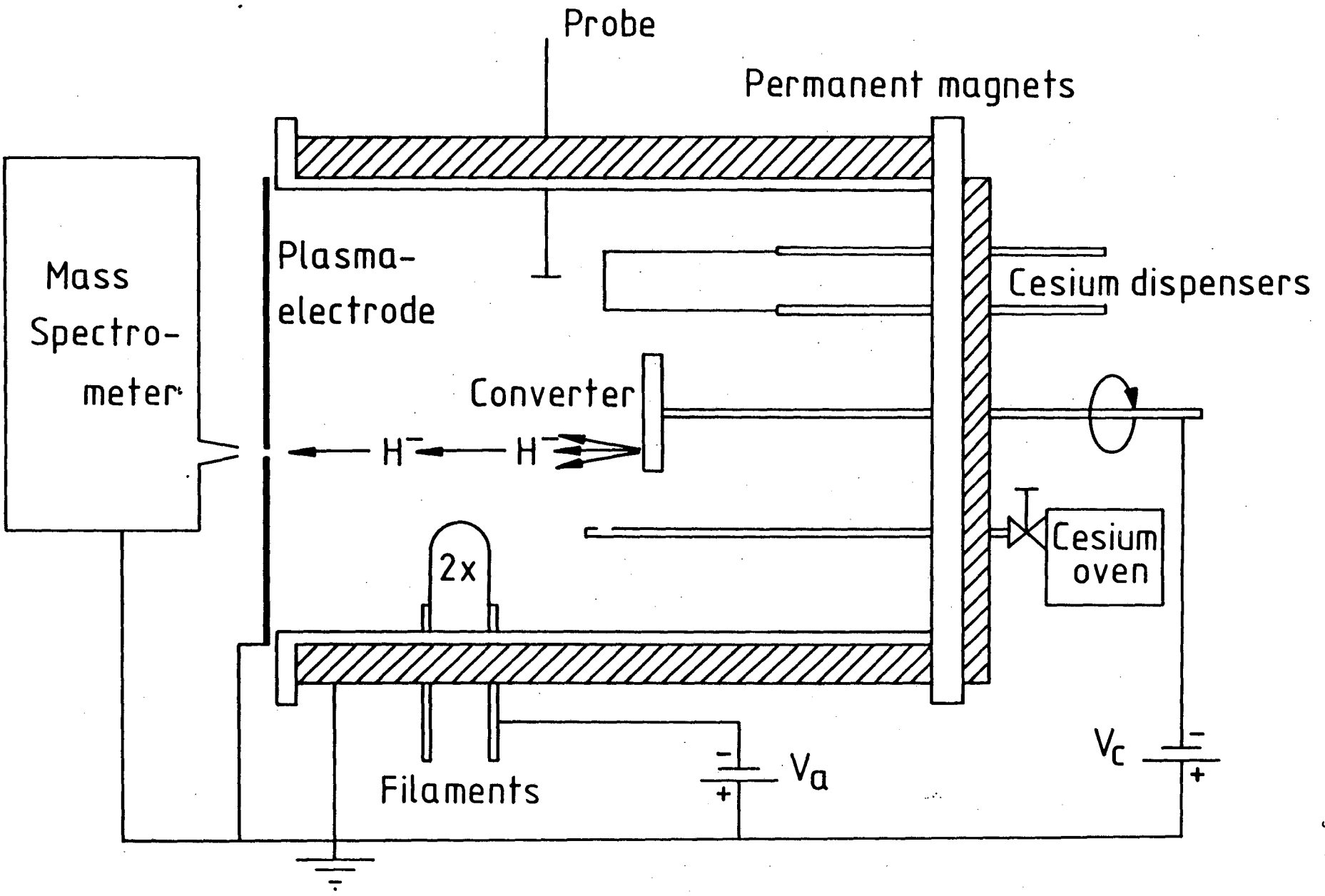
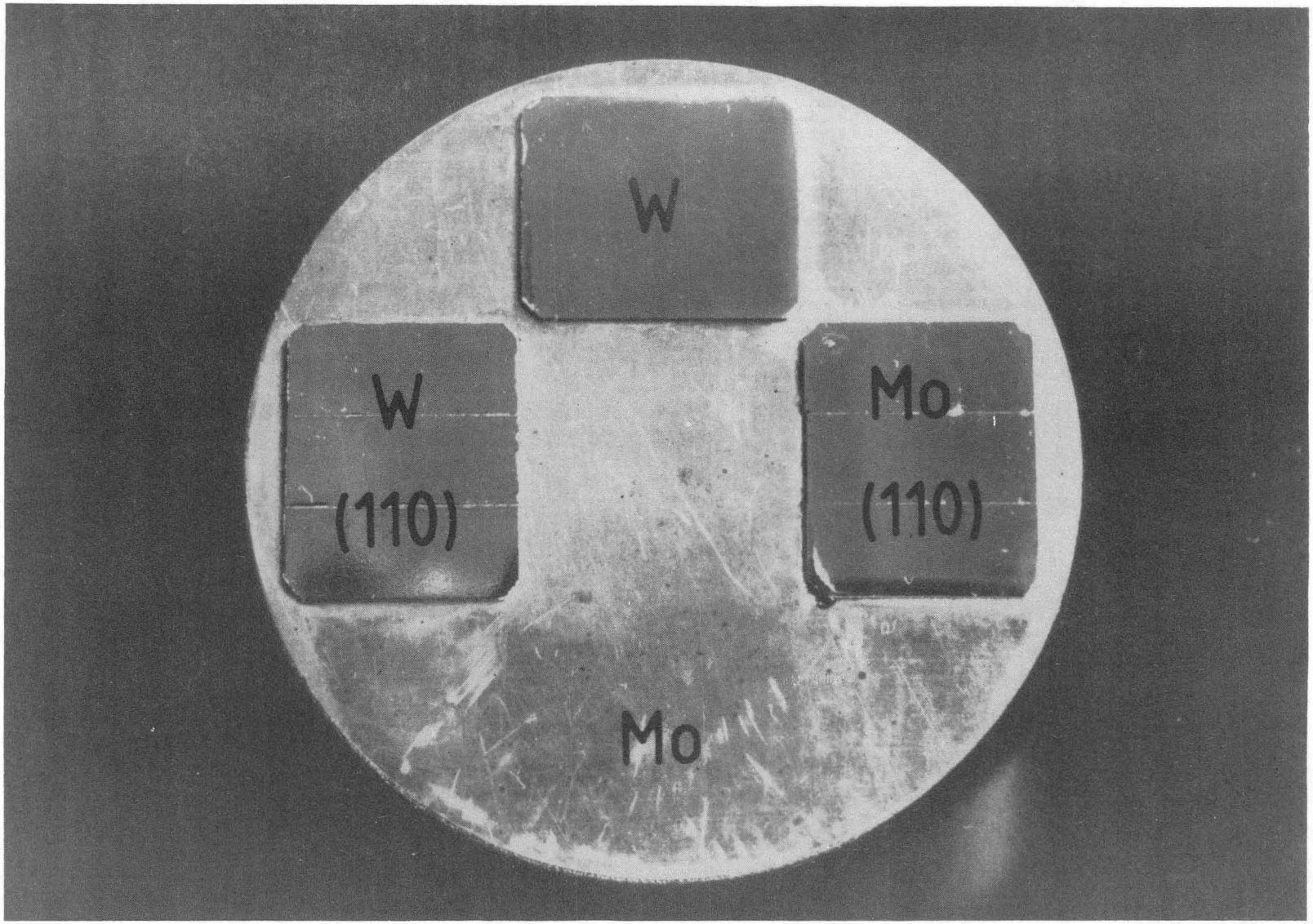

Probe
Permanent magnets
Mass Spectro-meter
Plasma-electrode
Cesium dispensers
Converter
H⁻
H⁻
Cesium oven
2x
Filaments
Va
Vc

Figure 1



XBB 830-10981

Figure 2

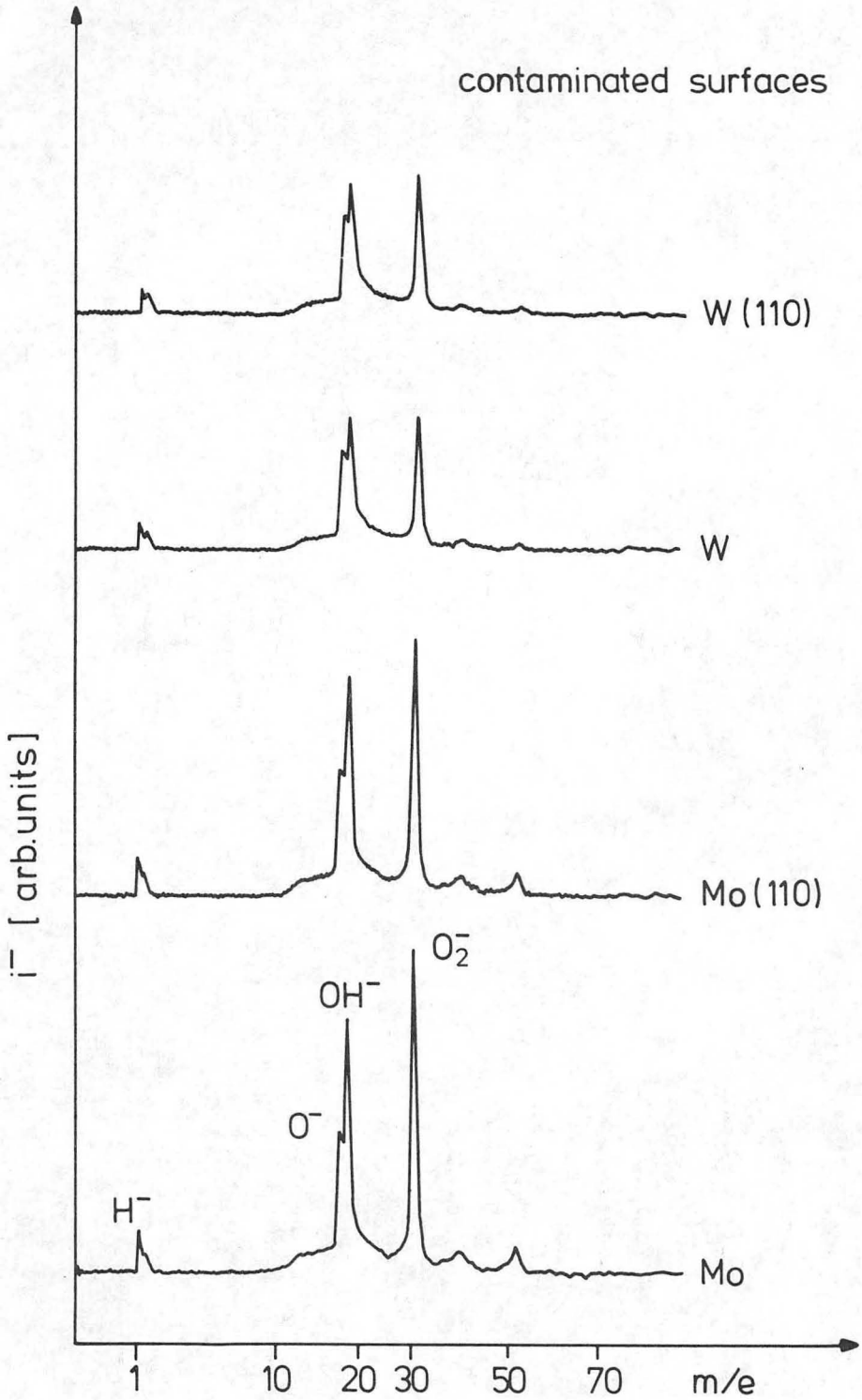

contaminated surfaces
W (110)
W
Mo (110)
Mo
i^- [arb.units]
O_2^-
OH^-
O^-
H^-
1
10
20
30
50
70
m/e

Figure 3

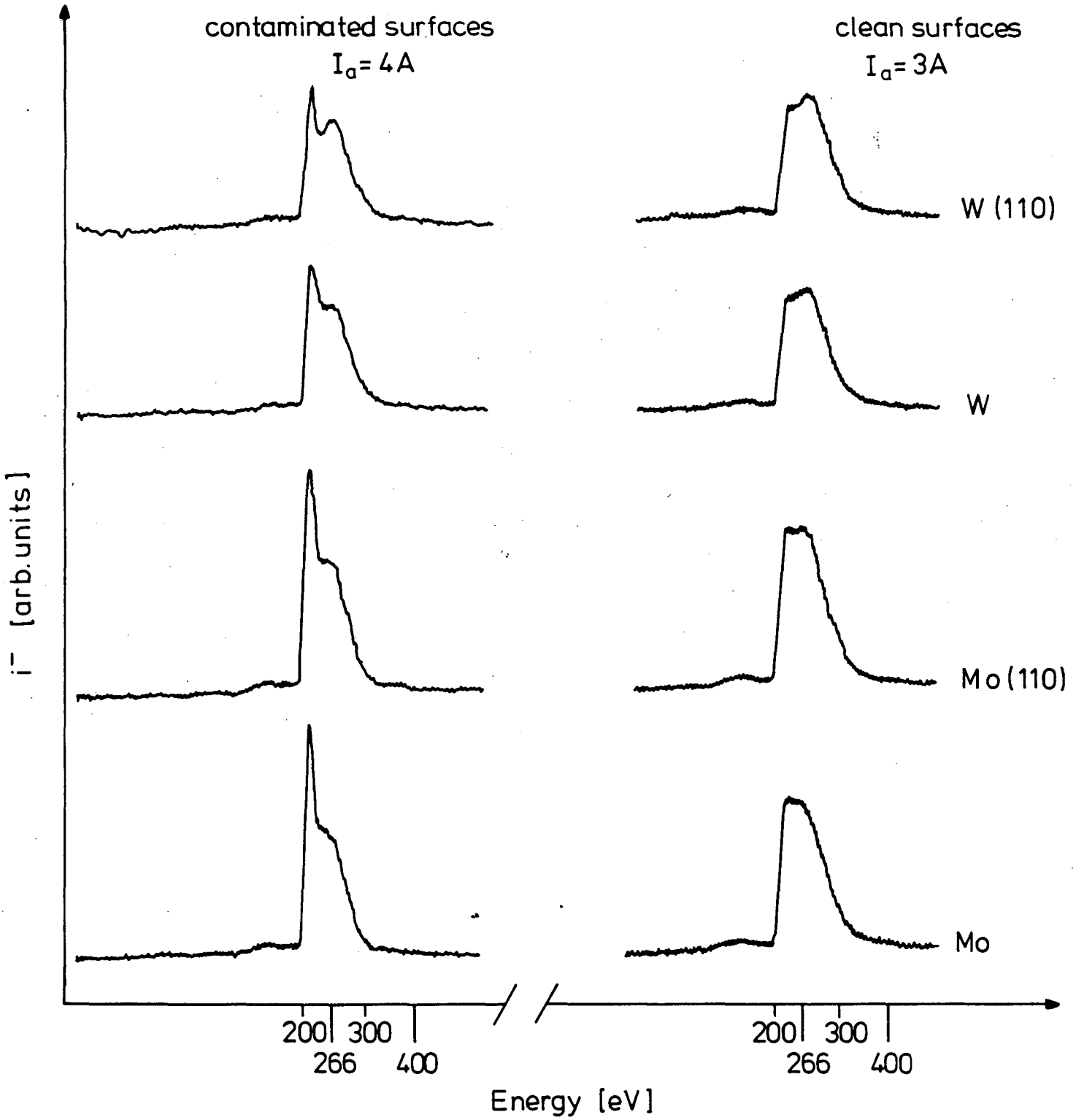

contaminated surfaces
I_a= 4A
clean surfaces
I_a= 3A
W (110)
W
Mo (110)
Mo
i^- [arb.units]
200
300
266
400
200
300
266
400
Energy [eV]

Figure 4

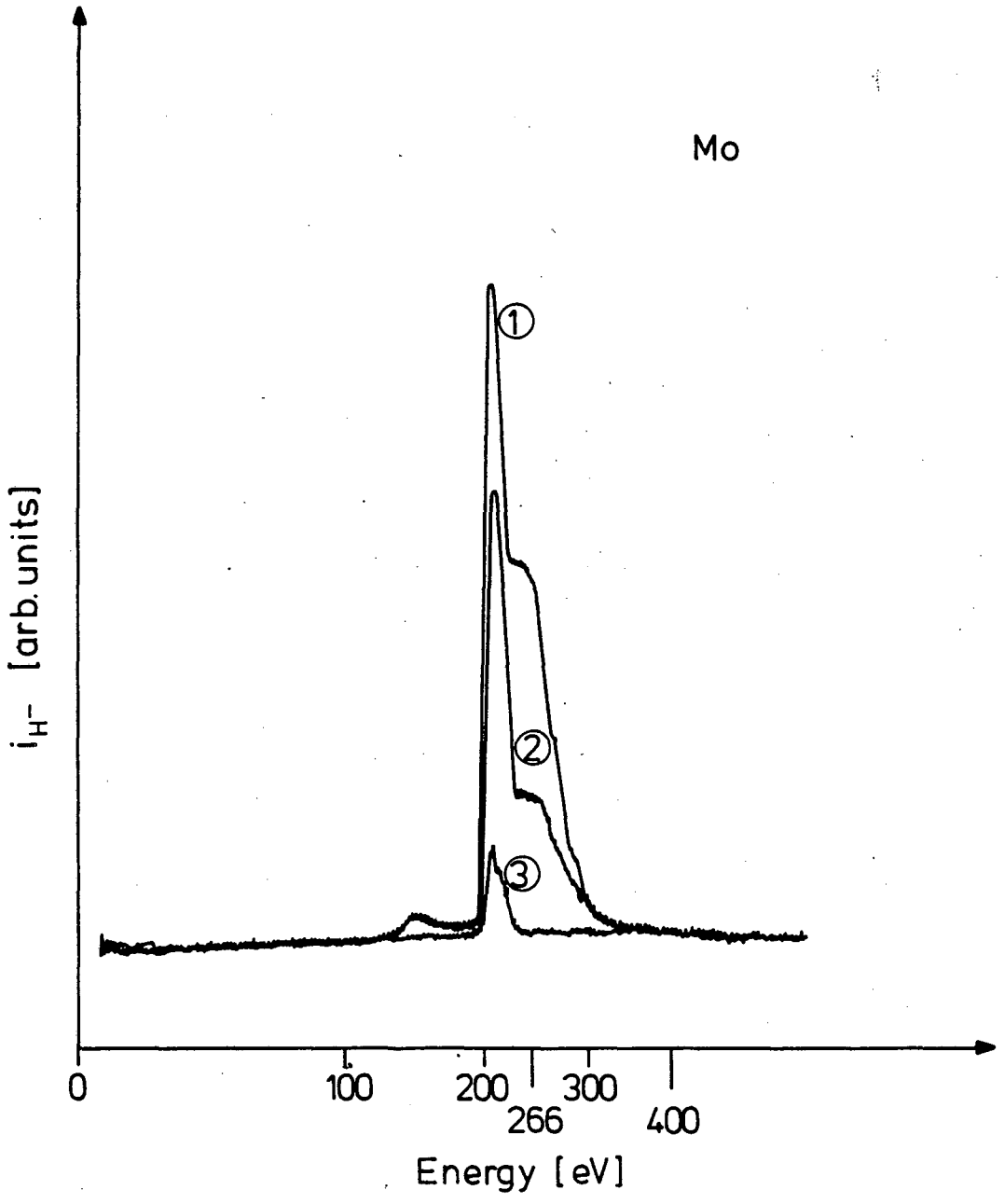


Figure 5

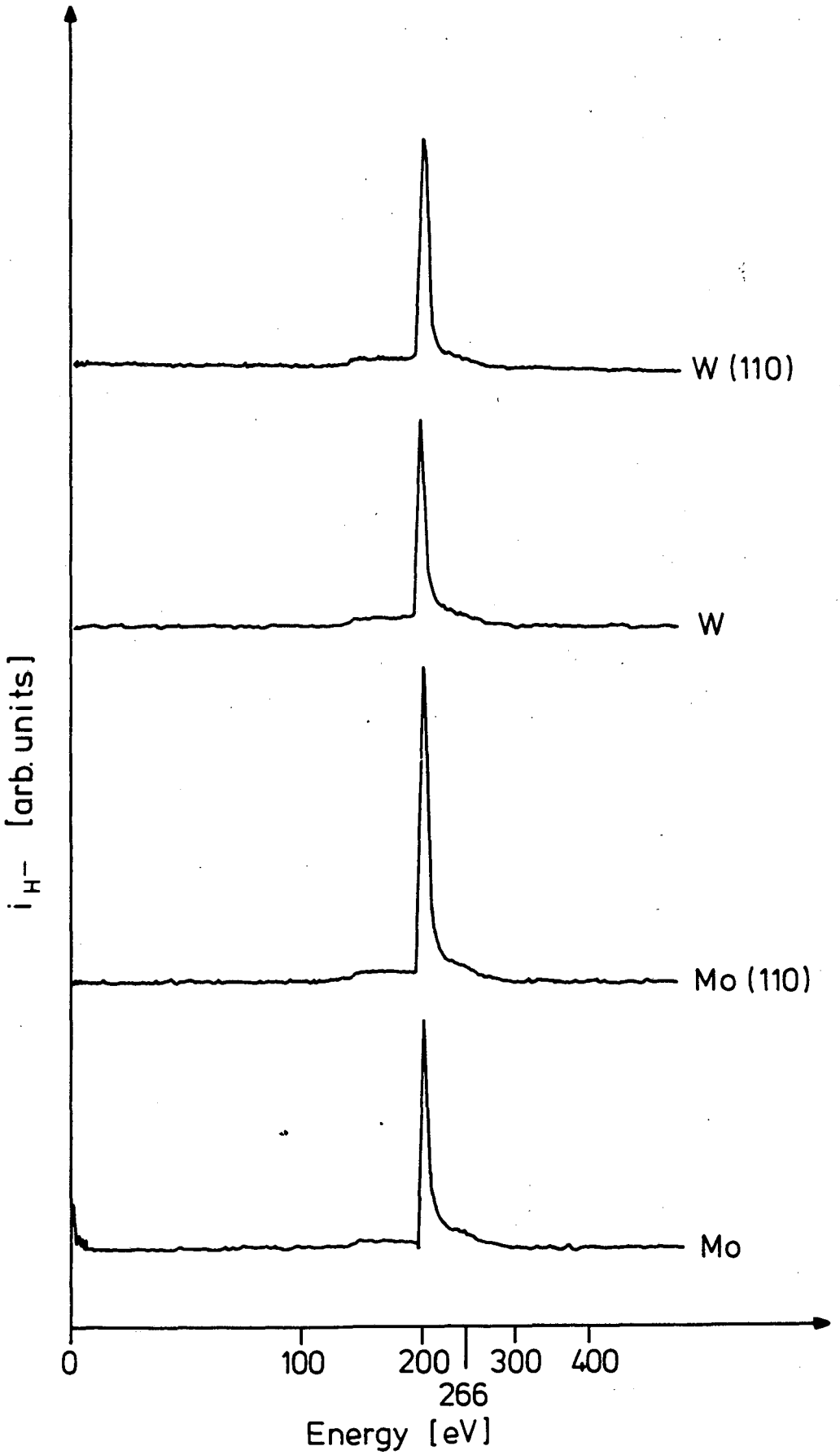


Figure 6

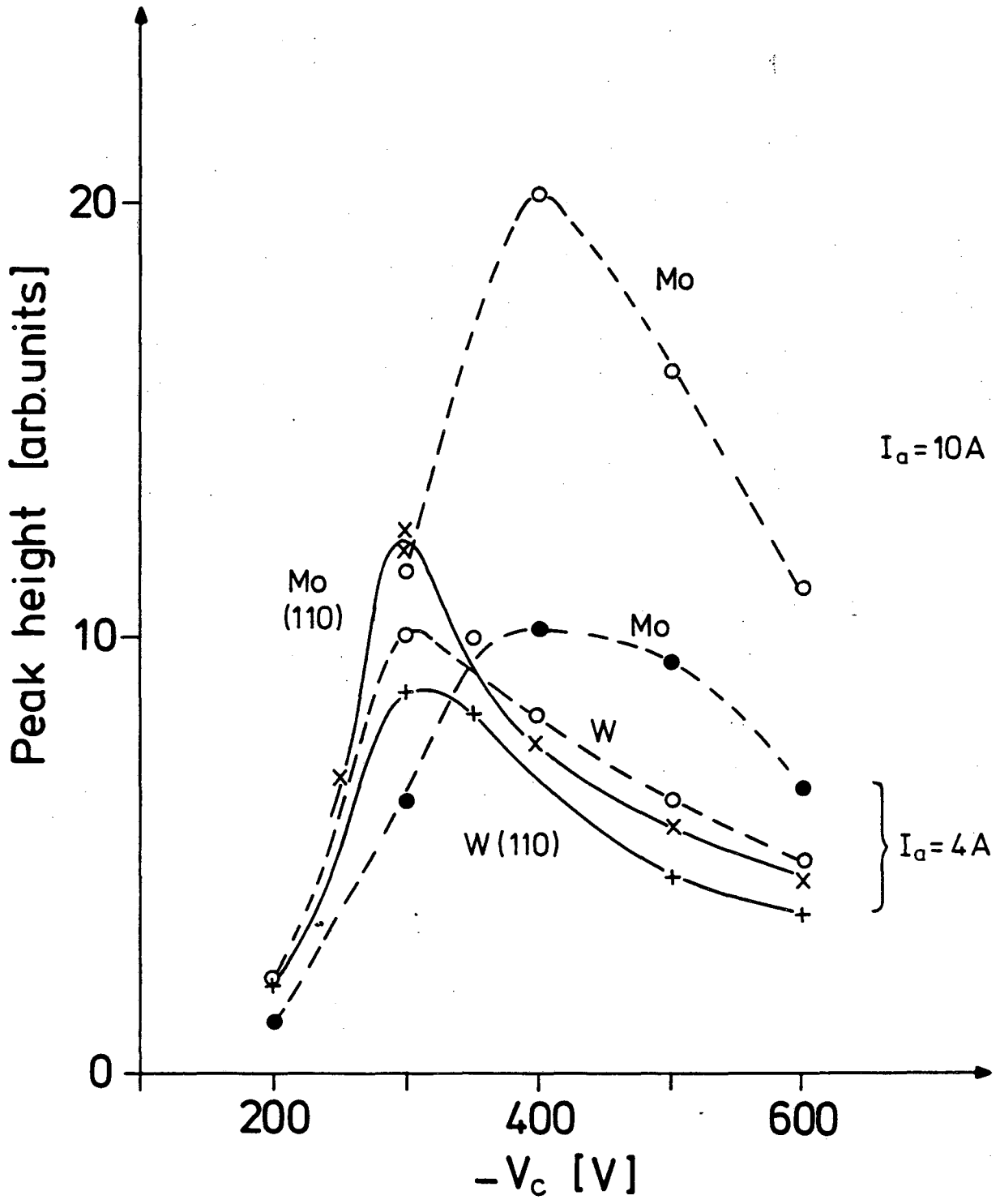

Peak height [arb.units]
20
10
0
200
400
600
$-V_c$ [V]
Mo
Mo
(110)
Mo
W
W (110)
$I_a = 10A$
$I_a = 4A$

Figure 7

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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