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Optical Absorption Measurements of Tantalum, Tungsten, Rhenium and Platinum in the Extreme Ultraviolet

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The absolute absorption coefficient of Ta, W, Re and Pt has been determined in the photon energy range 30 to 600 eV by use of synchrotron radiation at the 7.5-GeV electron synchrotron DESY. The most prominent structure is a broad double peak, which is caused by transitions from the 5p shell into the empty d states of these transition metals.

Measurements of the absorption coefficient of Ta, W, Re, and Pt in the photon energy region 30 to 600 eV have been performed in the course of a systematic investigation of optical properties of metals in the extreme vacuum ultraviolet.[1,2,3] The present results are a continuation of our measurements of the 3p electron transitions in the transition metals Ti to Ni.[2] The heavy metals Ta, W, Re, and Pt are investigated in the region of 5p electron transitions. Another reason for these measurements were discrepancies between experimental results by Jaeglé et al.[4] in the region 60 to 450 eV for Ta, 70 to 420 eV for Pt and atomic calculations.[4,5,6] The results of such calculations were in excellent agreement with measurements on Au.[1,7]

The experimental layout was the same as described in Ref. 1. In order to reduce background (straylight and higher orders) in the energy region 30 to 100 eV we used Si-, Al- and Mg-foils as prefilters. The 1m Rowland monochromator was operated in the energy region 30 to 100 eV with a 2400 lines/mm grating. The blaze angle was $4^{\circ}16'$, the entrance angle was $12^{\circ}36'$. In the energy region 100 to 600 eV we used a grating with 3600 lines/mm and a blaze angle of $3^{\circ}8'$. In this case the entrance angle was $3^{\circ}50'$. The resolution in both adjustment was better than 0.5 Å.

The samples were prepared as thin films (thicknesses 100 to 500 Å) by evaporation from an electron gun onto glass slides covered with NaCl. After evaporation the metal was covered with bakelite. Then the metal-bakelite film was floated off in water and mounted on a copper mesh.

The film thicknesses were determined by measuring the frequency shift of an oscillating quartz onto which the metal was evaporated simultaneously. The quartz was calibrated by weighing some of the foils. Control measurements of the thicknesses by a Tolansky interferometer gave agreement for Pt. For Ta, W and Re the Tolansky measurements gave larger values than calculated when using the mass deposition values and assuming bulk density. These discrepancies have also been observed by other authors.[8]

The results of our measurements are given in Fig. 1. Representative errors for the different energy regions are shown as error bars in the curve for Ta; for adjacent regions the relative error is much better. The binding energies for the different subshell electrons as given by Siegbahn et al.[9] are included in Fig. 1 as vertical bars. The absorption spectrum of Au has been included for comparison. The data up to 150 eV are taken from older measurements.[1] These measurements on Au have been repeated and extended between 150 and 500 eV. The results are in excellent agreement with Refs. 1 and 7. In the region where our data for Ta and Pt overlap with the results of Jaeglé et al.[4]

the agreement is also very good.

In all metals we find a strong absorption at low energies due to transitions from the valence band into high lying continuum states. The $O_{II,III}$ transitions in Ta, W, Re, and Pt show up as broad absorption maxima. The small shoulder at the rise to the first maximum was clearly reproducible for Ta, W and Re. We must also take into account that in these metals part of the absorption in the region of the $O_{II,III}$ peaks may be due to transitions from the $N_{VI,VII}$ shell. Except for Re we find reasonable agreement between the energy values for the $O_{II,III}$ levels given by Siegbahn et al.[9] and the onset of these absorption peaks.

When going from Ta to Au the 5d shell becomes occupied. Therefore at the onset the absorption due to transitions from $O_{II,III}$ to unoccupied d-symmetric final states gets weaker with increasing atomic number, in agreement with the experimental results. The shape of the $O_{II,III}$ absorption maxima is very similar to that found at the onset of the $M_{II,III}$ absorption in the transition metals Ti to Cu[2] and might also be explainable by interchannel interaction according to Fano and Cooper.[10]

Transitions from $N_{VI,VII}$ shell are depressed at the onset by a centrifugal barrier. Only in Pt could we find two sharp absorption edges which we ascribe to the onset of these transitions. Most of these transitions contribute to the absorption at higher energies and give rise to an increase in the absorp-

tion coefficient beginning at 108 eV in Re, at 145 eV in Pt and at 150 eV in Au. For Ta and W this rise may be hidden by the $O_{II,III}$ absorption. A similar explanation should be true for the absence of $N_{IV,V}$ edges.

We have calculated the number of effective electrons contributing to the absorption in the measured energy region assuming that the real part of the dielectric constant is equal to one. For Ta we obtained 38.2, for W 32.1, for Re 30.1, for Pt 32.5, and for Au 26 effective electrons. These numbers are in reasonable agreement with the expected values.

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1. R. Haensel, C. Kunz, T. Sasaki, and B. Sonntag Appl. Opt. 7, 301 (1968)
2. B. Sonntag, R. Haensel, and C. Kunz, Sol.State Comm. 7, 597 (1969)
3. R. Haensel, G. Keitel, P. Schreiber, B. Sonntag, and C. Kunz (to be published)
4. P. Jaeglé, F. Combet Farnoux, P. Dhez, M. Cremonese and G. Onori, Physics Letters 26A, 364 (1968)
5. J.W. Cooper, Phys.Rev. 128, 681 (1962)
6. J.W. Cooper, Phys.Rev. 13, 762 (1964)
7. P. Jaeglé and G. Missoni, Compt.Rend. 262, 71 (1966)
8. K.L. Chopra, M.R. Randlett, and R.H. Duff Phil.Mag. 16, 261 (1968)
9. K. Siegbahn et.al. ESCA Atomic, Molecular and Solid State Structure Studied by Means of Electron Spectroscopy (Almqvist & Wiksells Boktryckeri AB, Uppsala, 1967)
10. U. Fano and J.W. Cooper (to be published)

Figure captions

Fig. 1 Photoabsorption coefficient μ of Ta, W, Re, Pt, and Au in the energy range 30 to 600 eV. The error bars in the curve for Ta give representative errors of the absolute μ values for all measurements.

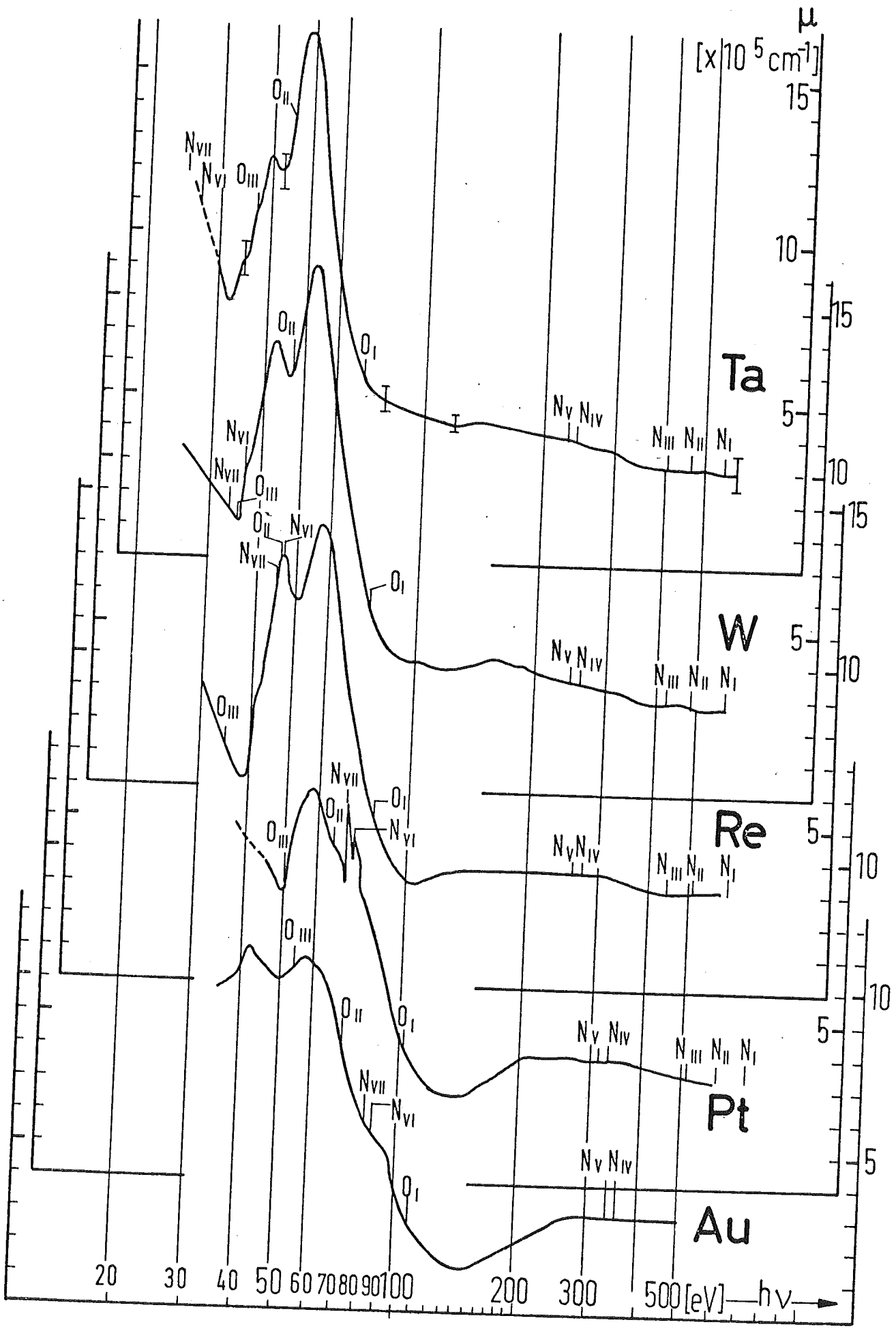
μ
[x 10 5 cm-1]
15
10
5
Ta
W
Re
Pt
Au
OII
NVII
NVI
OIII
OI
NV NIV
NIII NII NI
20 30 40 50 60 70 80 90 100 200 300 500 [eV] — hν

Fig. 1