A CLOUD CHAMBER STUDY OF ELECTRON TRACK ENDS

R. B. INGALLS*

الخلاصة

جمعت غرفة غيميه ومصدر للأشعة السينية امادية الطاقة ، وقد تولدت الكترونات ضوئية ، ذات طاقة منخفضة ومتساوية الطاقة تقريباً وتتراوح طاقتها بين ١ – ٥ كيلو الكترون فولط ، داخل الغرف الضوئية ذات الضغط المنخفض كنتيجة لإمتصاص الأشعة السينية امادية الطاقة . وقد صور مسار الالكترونات بواسطة آلتي تصوير وبذلك تمكن من النظر الى المسارات بالابعاد الثلاثة وتقدير أطوالها وأقطار شبه كريات نهائية هذه المسارات .

تظهر القياسات العملية ان طاقة تزيد على ١ كيلو الكترون فولط قد ترسبت في حجم صغير قرب نهاية مسار الالكترون . وبالامكان تمييز هذا الترسب للطاقة بوضوح عن ترسب الطاقة في أجزاء المسار ذات الطاقة الأعلى .

ABSTRACT

A cloud chamber and a source of monoenergetic x-rays were assembled, and low energy, nearly monoenergetic photoelectrons in the 1-5 keV energy range were generated inside the low-pressure cloud chamber by the absorption of the monoenergetic x-ray beam. The electron tracks were photographed by two cameras and viewed in three dimensions, and the track lengths and end-of-track spheroid diameters were estimated.

Data indicate that more than 1 keV of energy is deposited in a small volume at the end of the electron track. This energy desposit is clearly distinguishable from that of energy deposited in the higher energy portions of the track.

INTRODUCTION

Experimental investigation of energy loss from electrons in the 1-5 keV energy range has not been satisfactory for several reasons: (1) the low energy range is unimportant to the high energy physicist and too high to concern the chemist, (2) the experimental techniques of Simpson, *et al.* [1], [2], used to investigate energy loss from energetic electrons do not apply to the 1-5 keV energy regions, and (3) theory is lacking because the Bethe equation for electron stopping power is based on the assumption that the ionizing electron has a velocity which greatly exceeds that of all electrons of the medium, an unjustifiable assumption for electrons in the 1keV energy range. Although the theory relative to ionizing electrons has been modified [3], [4], no satisfactory theory is available for electrons in the 1keV energy range.

Low-energy electrons can be of practical importance. It has been proposed that about 8% of the energy deposited in organic liquids from Co^{60} gramma radiation is in the form of low-energy, end-of-track or delta ray electrons and that these low-energy electrons produce thermal spikes which reach 500-700°C above the bulk temperature [5], [6]. An understanding of energy loss processes of these electrons is important in (1) relating cloud chamber track lengths to incident x-ray energy, (2) simulating x-ray energy deposition by electrons, (3) determining the dependence of passive dosimeter response on x-ray photon energy, and (4) EMP. Although the importance of these phenomena to cancer therapy or other radiation biological problems is not yet clear, it may be significant.

TECHNICAL DISCUSSION

Experimental Setup

The experimental setup consisted of an x-ray source, a set of appropriate filters, and an expansion cloud chamber filled with low pressure helium. The x-rays were produced external to the cloud chamber, filtered, and passed into the cloud chamber through a thin beryllium window.

Production of Monoenergetic X-rays

Accurately timed, high-intensity monoenergetic beams of x-rays were required. Acceptable beams

* *Department of Chemistry University of Petroleum and Minerals, Dhahran, Saudi Arabia.*

were obtained by switching the high voltage to a Dunlee Corporation S-24 x-ray tube and by filtering the beams. A 4−µF capcitor was connected in parallel with the high voltage supply so that the voltage drop during the high current pulse would not be a serious problem. The voltage was turned on and off at the tube by a d-c relay timed from the cloud chamber expansion. The filters used were a titranium foil (0.002 inch thickness), five inches of argon gas (ambient), a pressed sulphur disk (0.004 inch thickness), and an aluminum disk (0.0015 inch thickness). the K-edges of these filters were at 4.5, 3.1, 2.5, and 1.5 keV, respectively.

The spectrum obtained by filtration of the beam was monoenergetic within the resolution of the proportional counter, which is about 20% of the photon energy when the high voltage applied to the x-ray tube was adjusted to about 120% of the filter K-edge energy. The output from the proportional counter

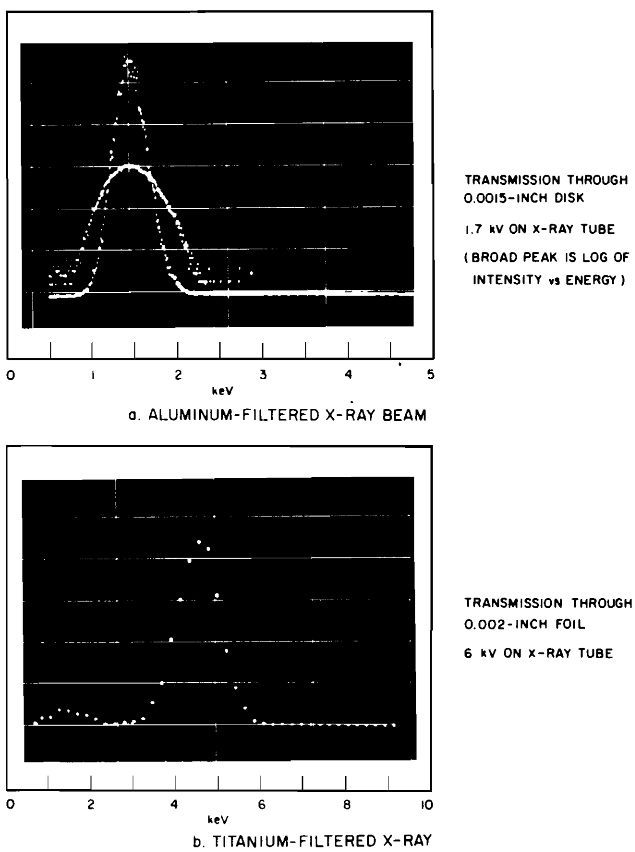

Figure 1. *Intensity of filtered X-ray beams versus X-ray photon energy.*

for beams filtered by aluminum and titanium is shown in Figure 1. The peak at about 1.4 keV. in the titanium-filtered beam is an artifact of the measurement technique, namely, fluorescence escape from the argon gas used in the counter.

Cloud Chamber

The cloud chamber is a volume-defined expansion chamber which is 18 inches in diameter and eight inches high. Typical operating parameters are given in Figure 2. The expansion requires about 50 msec at the 15 torr initial pressure of helium and condensable gases used in these experiments. The x-rays were injected after the expansion was complete, and the lights followed 70 msec later.

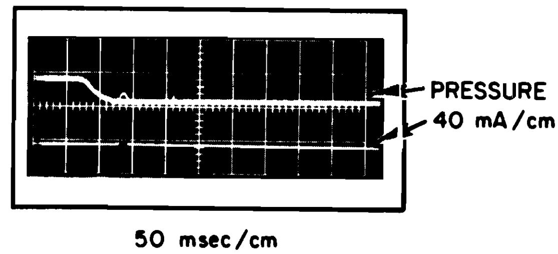

Figure 2. *Cloud chamber operating parameters.*

RESULTS

The photoelectrons produced in the cloud chamber formed many short tracks, each of which was initiated by a small spheroid and terminated by a large spheroid. While the length of the track between the spheroids is dependent on x-ray photon energy, the sizes of the spheroids are not. Stereo photographs were taken of these tracks and the length of the tracks and size of the spheroid ends were estimated by viewing the tracks in three dimensions using two photographs and a stereoscope. Dividers were adjusted to match the apparent dimensions of the individual tracks. The divider separations were measured and these values were corrected for enlargement to obtain the dimensions of the electrons tracks, By selecting tracks nearly parallel to the plane perpendicular to the line-of-sight, track dimensions could be determined within an estimated uncertainty of 20%.

The averaged values of the overall length of the tracks are plotted versus x-ray photon energy in Figure 3. A line fit to these points extrapolates to zero length at 1 keV. This extrapolated value suggests that on the

* *Radii of other spheroids appearing in the track were arbitrarily subtracted from the track lengths between terminal spheroids.*

average a minimum of 1 keV is deposited in a very small volume at the end of the track.

Also plotted versus x-ray photon energy in Figure 3 is the length of track between terminal spheroid centers.* This line extrapolates to about 1.5 keV. Thus, it appears that on the average about 1.5 keV is deposited in an end-of-track spheroid and the smaller spheroid at the beginning of the track.

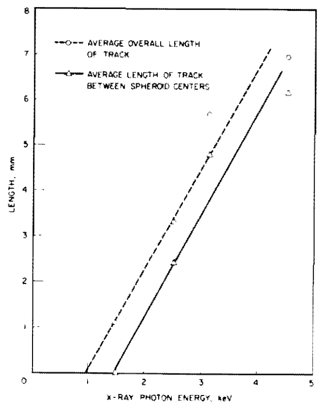

Figure 3. *Track dimension versus X-ray photon energy.*

The smaller spheroid at the beginning of the track is probably caused by Auger electrons produced by the initial x-ray photon interaction with oxygen atoms of the alcohol and water vapors in the cloud chamber. Since the K edge in oxygen is 0.532 keV and the size of the smaller spheroid is 0.5 mm in diameter, it appears that 0.5 keV of energy is deposited in a half-millimeter sphere. The larger spheroid at the end of a track appears to contain about 1.0 keV in a sphere about 1 millimeter in diameter, and its energy is roughly two times that of the smaller spheroid . The volume of the larger spheroid is approximately four times grater than that of the smaller spheroid, suggesting energy density differences of about a factor of 2.

Recent work[1] indicates that ionization is not necessary for the nucleation of supersaturated water vapor. This revolutionary discovery does not affect our conclusions here about the special distribution of energy deposition.

CONCLUSIONS

The data obtained in this study suggest that (1) the end-of-track phenomenon is distinct from the high energy portion of an electron track, and (2) on the average, about 1 keV energy is deposited in a small volume at the end of the track. This is in agreement with previous estimates. [6]

It is usually assumed that the energy associated with the electron end of track is between 100 and 500 eV. These result reported here, however, suggest that about 1000 eV is more likely to be involved in end-of-track phenomena in low atomic number materials such as water and hydrocarbons. Perhaps these track ends should be given a name such as "endotack" and should be listed along with "spur" (100 eV), "blod" (100 to 500 eV) and "short track" (500 to 5000 eV). In which case the short track might be modified to cover the range 1500 to 5000 eV, leaving the range between 500 and 1500 eV to be called endotack.

REFERENCES

[1] J. Arol Simpson, M.G. Menendez, and S.R. Mielczarek, "Angle and Channel Dependence of Resonance in e-He Scattering Near 60 eV," *The Physical Review*, **150,** 76-78 (1966).

[2] A.M. Rauth and J. Arol Simpson, "The Energy Loss of Electrons in Solids," *Radiation Research*, **22**, 643-661 (1964).

[3] M.C. Walske, "Stopping Power of L-Electrons," *The Physical Review*, **101**, 940-944 (1956).

[4] M.C. Walske, "Stopping Power of K-Electrons," *The Physical Revew*, **88**, 1283-1289 (1952).

[5] R.B. Ingalls, P. Speigler, and A. Norman, "Thermal Spike Model of Low L.E.T. Radiolysis: Temperature Dependence of Reactions Induced by Radiolysis in Liquid Toluene," *Journal of Chemical Physics*, **41**, 837-840 (1964).

[6] J.M. Scarborough and R.B. Ingalls, "Pyrolysis and High-Temperature Radiolysis of O-Terphenyl *Journal of Physical Chemistry*, **71**, 486-492 (1967).

[7] H. Reiss, R.H. Heist, and R.V. Casberg "Spectroscopy and Nucleation in Supersaturated Water Vapor," *The Physical Review*, in Press.

Referencc Code for AJSE Information Retrieval: QD 1276 IN 1, Paper Received April 15, 1975.