Pioneers of Electron Microscopy at Washington State University and Their Work

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(Received November 2, 1970)

SUMMARY

The first appearance of a transmission-type electron microscope in North America was reported to have occured in Toronto, Canada in 1939. However, two physicists, Paul A. Anderson and Kenneth E. Fitzsimmons, had worked toward the development of electron microscopy at Washington State University in Pullman from 1931–38. Moreover, they built a prototype electron microscope before 1935 and performed many kinds of electron optical experiments. Unfortunately, their pioneering efforts had to be halted for various reasons and their results were not published except for the structure of the camera chamber. Their prototype electron microscope has since been rebuilt and is currently on display in the Museum of Washington State University. The author introduced this fact and evaluated their efforts from a historical viewpoint.

INTRODUCTION

In the history of science it is very clear that the invention of an instrument does not appear accidentally without preceding studies. For example, the invention and development of the electron microscope, a common instrument in scientific research at the present time, was based on earlier studies of electron optics and the experimental works which followed the establishment of optics and the light microscope.

Nowadays, the efforts of European pioneers, Knoll, Ruska and von Borries in Germany and Marton in Belgium, are valued highly in the history of development of electron microscopy[1)2)3)]; Martin and his coworkers[4)] in England, and Mahl[5)] in France are also well-known people with distinguished service in the advancement of electron microscopy.

On the other hand, some people[6)7)] on the American Continent, who were stimulated by the proceedings in Europe, started studies of electron microscopy. However, their works were limited to the studies of oscillograph or emission-type electron microscope. According to Hall[8)] the first appearance of a transmission-

type electron microscope on the American Continent was by Prebus and Hillier[9] of Toronto, Canada in 1939.

Once in 1969, while the author was working as a visiting investigator at Washington State University (WSU) in Pullman, Washington, he found that a very old, primitive prototype of an electron microscope was on exhibit in the museum of Science Hall on the WSU campus. The author was surprised to read in the explanation that the electron microscope had been built and used in 1935–37 by two people at this University. He remembered that the reported history of the transmission-type electron microscope in North America did not begin until 1939, and thought that the historical value of the construction of this instrument was worthy of investigation.

PIONEERS OF ELECTRON MICROSCOPY IN PULLMAN

Two physicists worked on electron microscopy at WSU (at that time The State College of Washington) in the 1930's. They were Paul A. Anderson and Kenneth E. Fitzsimmons. Anderson was a professor of physics from 1931 to 1963, the chairman of the department and the director of the project at that time; Fitzsimmons was an instructor of fundamental physics. They worked together on design while Fitzsimmons took charge of the construction.

Anderson retired from WSU in 1963 and he is a professor-emeritus of WSU now. (Fig. 1) Fitzsimmons received his Bachelor's degree in physics at the State College of Washington in 1929 and obtained his Master's degree there in 1931. After that, he became a staff member of the Department of Physics at the College and studied electron microscopy with Anderson about 8 years. (Fig. 2)

During this period their main occupations were teaching and only part-time hours could be devoted to electron microscopy. Fitzsimmons changed his project to Mass-spectrometry in 1938, while Anderson continued the program of electric work function measurements and high vacuum on which he had been working since 1932.

At the end of 1938 Fitzsimmons took an one-year leave of absence to work at the University of California at Berkeley for his Ph.D. degree. He returned to WSU before the beginning of World War II and during that war was a member of a radar research team at WSU. He became an assistant professor at that time, but he did not again work on the electron microscope project. He died of **Multiple Osteomyeloma** in 1955 at the age of 49.

MOTIVES AND PROGRESS OF THEIR STUDIES

Anderson was quite interested in the description of electron microscopy published by Knoll and Ruska in 1929–31. He believed that electron microscope would be

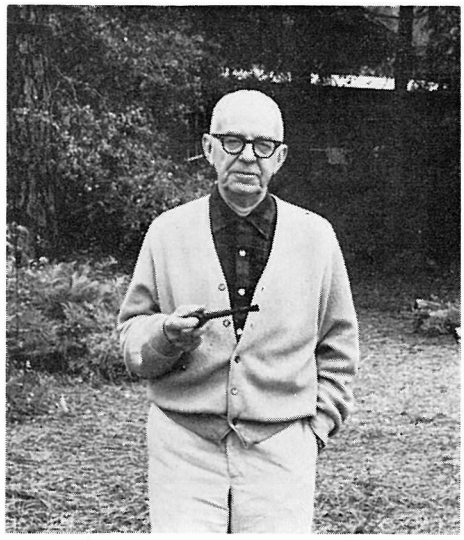


Fig. 1. Portrait of Dr. Paul A. Anderson, at his summer house in Idaho (1969).

Fig. 2. Portrait of Late Mr. Kenneth E. Fitzsimmons (1935).

useful in many fields of scientific research and particularly in medical and biological studies. Although he wanted to start a formal experimental study of the electron microscope, financial support was not forthcoming.

At that time, Fitzsimmons was at the laboratory of Anderson and was also interested in working on electron microscopy. The two physicists worked very hard in their spare time collecting parts and fabricating the more important items. They obtained a discarded medical X-ray outfit from a hospital as the power supply. They designed and made many other parts by themselves ; especially, lenses, camera chamber, specimen chamber, and oil diffusion pump. Due to their scanty budget, only a few items such as meters and the motor pump were purchased.

Fitzsimmons was an excellent machinist with endless patience. He worked very much enthusiastically in the odd hours left him by a heavy teaching schedule. Construction of their prototype electron microscope proceeded and gradually took shape. Then the electron optical experiments and function test using their microscope were executed. (Fig. 3)

Many experimental headings, data and electron micrographs can be seen in the record book covering the period between that date of January 16, 1936 and June 4, 1938. Therefore, it may be assumed that the construction of their electron microscope was accomplished before December of 1935. Regrettably, no earlier

description could be found ; so the exact date of accomplishment is not clear. According to Edward R. G. Steever, Jr. who is on the staff of the Electron Microscope Laboratory at WSU and to the record book, the accelerating voltage was 30 KV and the highest resolving power obtained seemed to be close to that of the light microscope. Thin tungsten wire (0.4 ml≒12.16 u) was used as a specimen. The maximum magnification of electron microphotographs taken was 1,250 times. (Fig. 4)

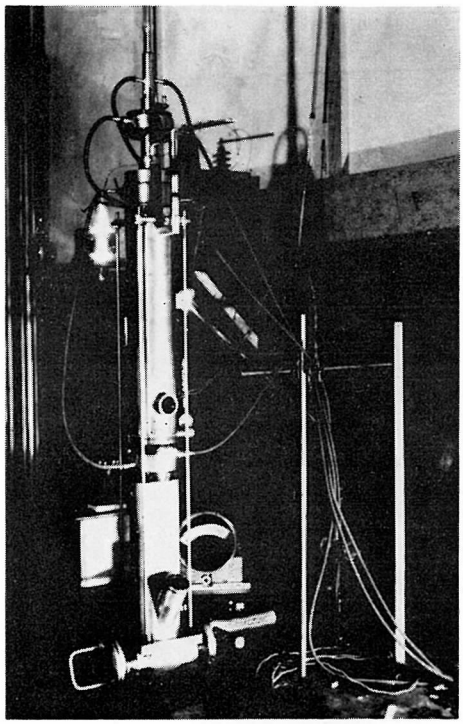


Fig. 3. The electron microscope of Pullman group in their laboratory (1937). (Left)

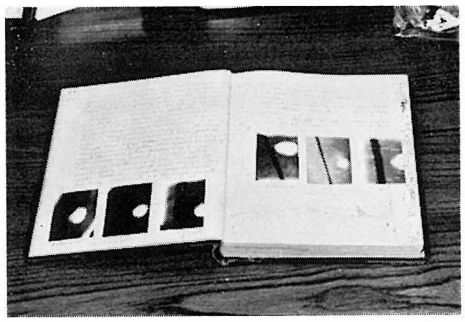


Fig. 4. Record book of Late Mr. Fitzsimmons. Some electron micrographs taken by him can be seen.

CESSATION OF STUDY

The final date of Fitzsimmons' work in electron microscopy is June 4, 1938, recorded on page 33 of his record book. Records of later days are all the data on mass-spectrometry to which Fitzsimmons turned his attention after electron microscopy.

The Pullman group stopped their project on electron microscopy after a long term assiduous effort with some good results. Such pioneer experimental work usually requires ample financial support, good instrumental conditions and some organization. It is true that they were not fortunate in financial conditions. At that time, the influence of the depression was still being felt in every university

finances as well as those of Pullman.

According to Anderson[10], two other reasons were more important factors for the cessation of their study on electron microscopy of Pullman group. Their rate of progress, so limited by their facilities and manpower, was nesessarily far below that of large laboratories and of more importance perhaps, each of them had research in progress, problems which did not require extensive instrumentation and on which they could compete successfully with other laboratories.

The first of these two reasons might have indicated that the German group[11] with a larger laboratory was successful in surpassing the resolving power of the light microscope by using their commercial electron microscope in 1938. The latter of the two reasons mentioned above might have been an adminstrative judgement that he had to make as the department chairman at that time.

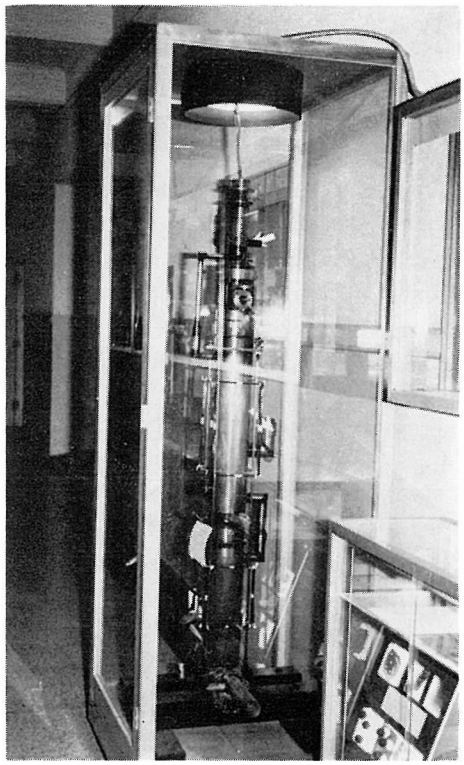
The situations presented are understandable. The Pullman group resigned the study of electron microscopy completely in the middle of 1938 ; and they did not later reopen the study of the same project.

REMAINING ITEMS

1. **Main body of the electron microscope :** This consists of the electric gun, condensor lens, specimen chamber, objective lens, projective lens and camera chamber. All the lenses have a cooling system using tap water. Both objective and projective lenses have deflection coils. Neither oil diffusion nor motor pumps can be found. They might have been used for other purposes later. The regulators of the lens-system and the accelerating high voltage system, and the electric transformers are all missing. (Figs. 5, 6, 7)
2. **Record book :** The date of the first page is January 16, 1936 and the descriptions of electron microscopy continues to page 33 with the date of June 4, 1938. Later pages are filled with data of another project. (Figs. 4, 8)
3. **Photoslide-glasses :** Five plates photographed with the electron microscope, images of specimens (tungsten wire of 0.4 ml) and some photographic data remain. These slide-glasses supposedly were prepared for publication.
4. **Diagrams of the camera chamber :** Four diagrams of the camera chamber remain. These may have been prepared for construction and publication.

The main body of the electron microscope is set in the museum, the record book and the photoslide-glasses are preserved in the Electron Microscope Laboratory of WSU ; the diagrams of the camera chamber are kept by Mrs. Nelson, in Pullman.

The reconstruction of the electron microscope was accomplished by Steever and Dan Marlow who are on the staff of Electron Microscope Laboratory of WSU in



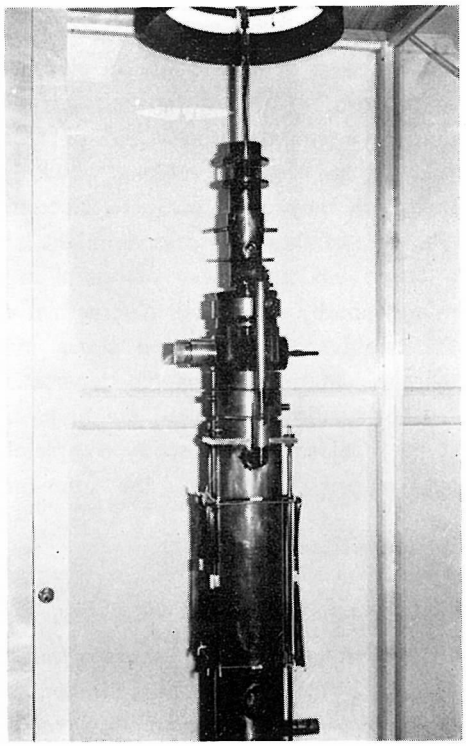


Fig. 5. Reconstructed electron microscope of Pullman group, displaying in the museum of Science Hall on the campus of Washington State University in 1969. (From the left side) (Left)

Fig. 6. Upper part of the electron microscope. Gun, condensor lens, specimen chamber and objective lens can be seen. (From the front) (Right)

1965. They found the discarded and decomposed parts of the instrument in storage at the Department of Physics on WSU campus, salvaged them and rebuilt the electron microscope. The reconstructed electron microscope was displayed in the museum of Science Hall at WSU under the direction of Arthur L. Cohen who was a professor and director of the Electron Microscope Laboratory at WSU. (Figs. 5–7)

PUBLICATION OF WORK OF THE PULLMAN GROUP

According to Anderson[10], they had publications of their work on electron microscopy and electron microscope in neither journals nor academic meetings. They judged that the publication of their work was pointless, because their microscope was almost the same as the instrument of the Toronto group. Their contributions

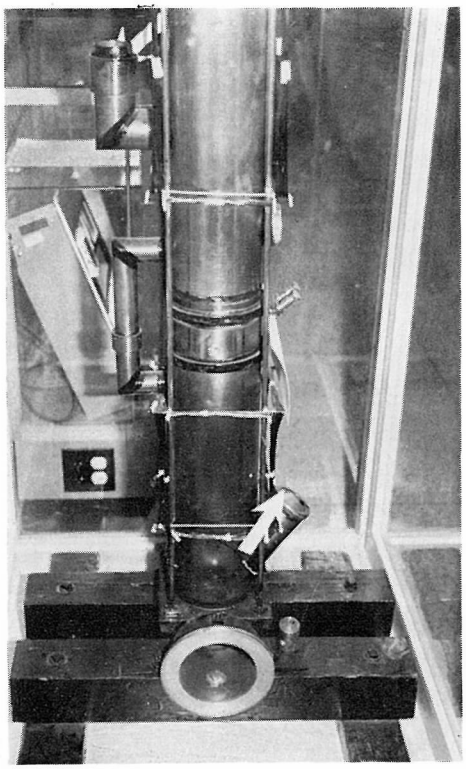


Fig. 7. Lower part of the electron microscope. Projective lens, deflection coil, view-window and camera chamber can be seen. (From the right side)

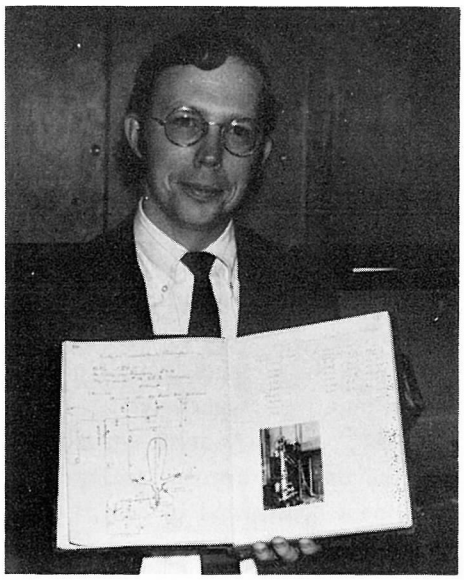


Fig. 8. Mr. Edward R.G. Steever who is one of the reconstructors of the electron microscope, holding the record book of Late Mr. Fitzsimmons. (1969)

were limited to some new mechanical design features in the specimen chamber and camera chamber.

Thus, only a short report on the design of the camera chamber was contributed to the **Journal of the Optical Society of America** by Fitzsimmons[12] in 1938. He did not describe the data of their electron microscope therein.

EVALUATIONS OF THEIR WORK FROM A HISTORICAL VIEWPOINT

After 1928 the transmission-type electron microscope with magnetic lenses gradually appeared in Germany. In 1928–31, Ruska and Knoll[13] studied the magnetic lens and verified Busch's theory. They accomplished the high voltage oscillographs (30–75 KV). They then published a paper on an electron microscope[14] developed from the oscillograph in 1932 and this instrument[15] predicated a future for the

electron microscope.

In 1934, Ruska[16] constructed a transmission-type electron microscope with a condensor lens and obtained a high resolution picture which surpassed the resolving power of the light microscope (resolving power was 500 Å). This is regarded as the first successful construction of the transmission-type electron microscope.

Marton[17], a Belgian electron microscopist, observed good results in using a biological specimen under electron microscopy (1934–35). In 1935, Driest and Müller[18] surpassed the resolving power of the microscope with a biological specimen by using Ruska's instrument, which was published in 1934 (resolving power was 400 Å).

In 1938 the German group (von Borries and Ruska)[11] constructed a new design for an improved magnetic electron microscope and obtained high resolution pictures (resolving power was approximately 100 Å). The next year, the Siemens Company sold the first commercial transmission-type electron microscope[19] based upon the instrument constructed by von Borries and Ruska[11].

The description above is a brief history of the development of the transmission-type electron microscope and microscopy in Europe. Publication of the transmission-type electron microscope with magnetic lenses appeared on the American Continent later. Prebus and Hillier[9] at Toronto in 1939, Marton[20] at RCA in 1940 and Hall and Schoen[21] at Eastman Kodak Company are the earliest workers on the American Continent.

From a historical viewpoint of electron microscopy, the construction of and experiments with a transmission-type electron microscope by the Pullman group during 1935–38 are to be regarded as pioneer work. At that time, the structure and design of their prototype electron microscope were excellent, even from the world-wide standard. Although they stopped the work before obtaining a higher resolving power than that of the light microscope, they could harvest a lot of good results in electron microscopy. Those can be seen in the record book and on the main body of their microscope. As Anderson reminiscences[22], the rate of progress of their work was very slow for many reasons.

It is to be regretted that the work of the Pullman group was not published, and that it was ended early in 1938. If their work had been published, even though they presented an unfinished situation, an impression and stimulation would have been provided to academic people not only in the United States but also throughout the world. If they could have obtained financial support to continue their work with the aid of researchers in other fields, they might have contributed greatly to electron microscopy. Because the Pullman group was so enthusiastic in their work, they obtained good results even under poor conditions and without coworkers.

It has been more than 35 years since the Pullman group worked on electron microscopy and they have sunk into the stream of history. Now the author wishes

to introduce them to pick up their work again and to note the fact that two pioneers were working together on electron microscopy in Pullman independently of European pioneers in such earlier days.

ACKNOWLEDGEMENT

The author wishes to thank Dr. Paul A. Anderson who is a Professor-Emeritus of Physics at Washington State University, for his kind information and proof-reading of the manuscript, Mrs. Earl Nelson who is widow of Mr. Fitzsimmons; Dr. Arthur L. Cohen and Mr. Edward R.G. Steever, Jr. of the Electron Microscope Laboratory, Dr. Haakon Bang who is a Professor of Pharmacy and was a good friend of Mr. Fitzsimmons, all at Washington State University in Pullman, Washington, for their kind information and help on this paper. This article was accomplished with the editing help of my good friends in Pullman, Mrs. Shirley D. Johnston and Dr. Toshio Akamine and the author would like to express his appreciation for their assistance.

Supplement: Finer structures of the electron microscope and detailed data will be provided on request from the Electron Microscope Laboratory, Washington State University, Pullman, Washington 99163, U.S.A.

REFERENCES

1) von Gabor, D.: Die Entwicklungsgeschite des Elektronenmikroskops, *ETZ-A*, **78**: 522-530, 1957.
2) Mulvey, T.: Origin and historical devleopment of the electron microscope, *Brit. J. Appl. Phys.*, **13**: 197-207, 1962.
3) Freundlich, M.M.: Origin of the electron microscope, *Science*, **142**: 185-188, 1963.
4) Martin, L.C., Whelpton, R.V. and Parnum, D.H.: A new electron microscope, *J. Sci. Instruments*, **14**: 14-24, 1937.
5) Mahl, H.: Ueber das Elektrostatische Elektronenmikroskop höher Auf-lösung, *Z. Tech. Physik*, **20**: 316-317, 1939.
6) McMillen, J.H. and Scott, G.H.: A magnetic electron microscope of simple design, *Rev. Sci. Instruments*, **8**: 288-290, 1937.
7) Meschter, E.: An electron microscope for studying thermal and secondary emission, *Rev. Sci. Instruments*, **9**: 12-15, 1938.
8) Hall, C.E.: Historical Notes and Physical Concepts. *Introduction to Electron Microscopy* by Hall, C.E., 2nd Ed. 1-6, McGraw-Hill Book Co., 1967.
9) Prebus, A. and Hillier, J.: Construction of a magnetic electron microscope of high resolving power, *Can. J. Res.*, **17**: 49-63, 1939.
10) Anderson, P.A.: *Personal communication* (I), 1969.
11) von Borries, B. and Ruska, E.: Verlaufige Mitteilung ueber Fortschritte in Bau und in der Leistung des Uebermikroskops, *Wiss. Veröff. Siemens*, **17**: 99-106, 1938.
12) Fitzsimmons, K.E.: A magazine plate camera for photography in vacuum, *J. Opt. Soc. Am.*, **28**: 437-439, 1938.

13) Ruska, E. and Knoll, M.: Nachtrag zur Mitteilung: Die Magnetische Sample-spule für Schnelle Elektronenstrahlen, *A. Tech. Phys.*, **12**: 488, 1931.
14) Knoll, M. and Ruska, E.: Das Elektronen Mikroskop, *Z. Physik*, **78**: 318, 1932.
15) Knoll, M. and Ruska, E.: Beitrag zur geometrischen Elektronenoptik, *Ann. Physik Lpz.*, **12**: 607-640 and 641-661, 1932.
16) Ruska, E.: Ueber Fortschritte in Bau und in der Leistung des Magnetsichen Elektronen Mikroskops, *Z. Physik*, **87**: 580-602, 1934.
17) Marton, L.: Electron microscopy of biological objects, *Phys. Rev.*, **46**: 527-528, 1934; *Nature*, **133**: 911, 1934.
18) Driest, E. and Müller, H.O.: Elektronen Mikrograph des Chitin Substanz, *Z. Wiss. Mikrosk. u. Mikrosk. Techn.*, **52**: 53-57, 1935.
19) von Borries, B. and Ruska, E.: Ein Uebermikroskop für Forschungsinstitute, *Natwiss.*, **27**: 577-582, 1939.
20) Marton, L.: A new electron microscope, *Phys. Rev.*, **58**: 57-60, 1940.
21) Hall, C.E. and Schoen, A.L.: Application of the electron microscope to the study of photographic phenomena, *J. Opt. Soc. Am.*, **31**: 281-285, 1941.
22) Anderson, P.A.: *Personal communication* (II), 1969.