Practical Methods in ELECTRON MICROSCOPY

Volume 4

AUDREY M. GLAUERT

DESIGN OF THE ELECTRON MICROSCOPE LABORATORY

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Editor's preface

Electron microscopy is now a standard technique with wide applications in all branches of Science and Technology, and every year a large number of students and research workers start to use the electron microscope and require to be introduced to the instrument and to the techniques for the preparation of specimens. Many books are available describing the techniques of electron microscopy in general terms, but the authors of Practical Methods in Electron Microscopy consider that there is an urgent need for a comprehensive series of laboratory handbooks in which all the techniques of electron microscopy are described in sufficient detail to enable the isolated worker to carry them out successfully. The series of books will eventually cover the whole range of techniques for electron microscopy, including the instrument itself, methods of specimen preparation in biology and the materials sciences, and the analysis of electron micrographs. Only well-established techniques which have been used successfully outside their laboratory of origin will be included.

Great care has been taken in the selection of the authors since it is well known that it is not possible to describe a technique with sufficient practical detail for it to be followed accurately unless one is familiar with the technique oneself. This fact is only too obvious in certain 'one author' texts in which the information provided quickly ceases to be of any practical value once the author moves outside the field of his own experience.

Each book of the series will start from first principles, assuming no specialist knowledge, and will be complete in itself. Following the successful innovation, made by the same publishers in the parallel series Laboratory

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Author's preface

In the early formative years of electron microscopy, laboratories were seldom designed; they evolved, as the need arose for more space for the instruments and the specimen preparation apparatus, and more comfort and status for the microscopist. An early EM laboratory design specification – if one was ever called for – would have asked simply for a roof and four walls, with electricity and water supplies, and a number of flat surfaces. The pioneers of electron microscopy – engineers, physicists, biologists and metallurgists – probably gave little thought to the laboratories in which they worked; they were too involved in designing the instruments, developing the preparation techniques, discussing the theory and interpretation, and extending the fields of application.

Today, the situation is different. Electron microscopy is a mature and established technique. An extensive range of commercial instruments is available, in an advanced state of development. The microscopist has to contend with building regulations, and with the intricacies of funding. The use of research funds and public money involves extensive justification of the EM project, and in turn this requires a great deal of careful thought in the planning and designing of the laboratories and their contents, in addition to the planning of the scientific programme.

Many of the design aspects emerge naturally from the application of good general laboratory practice and the exercising of common sense. Other aspects, however, are less obvious and may need some specialist knowledge. In particular, electron-optical instruments are susceptible to electrical and mechanical disturbances, and for optimum performance the environment

of all electron microscopes – scanning (SEM), transmission (TEM), scanning transmission (STEM), and related instruments such as the electron-probe microanalyser (EPMA) – must be very carefully controlled.

Economic and ergonomic considerations are of increasing importance; the incorporation of design features which save time, effort, space and money, is essential in a situation where funds for scientific purposes are becoming less readily available.

The purpose of this book is not to provide typical layouts and detailed plans which may or may not be suitable for adoption by the reader, but rather, to indicate the purpose of each room and the detailed design requirements of each room, so that the *microscopist* can assemble a laboratory or department which will satisfy the scientific needs and also the various boundary conditions of space, money, and time, which are inevitably imposed in a practical situation.

The information in this book is provided essentially for the microscopist, and especially for the beginner who has little or no previous experience, but it is hoped that the appropriate information will be communicated to, and understood by, the architects, the consultants, the site engineers, and all those concerned with converting the microscopist's design dreams into the reality of an attractive, efficient, and scientifically effective electron microscope laboratory.

Acknowledgements

I have been privileged to visit many hundreds of electron microscope laboratories in many countries; I wish to thank the electron microscopists who have allowed me to inspect their laboratories and who have given so generously of their time and advice.

My former colleagues in AEI Scientific Apparatus Limited and in the earlier Metropolitan-Vickers Research Laboratory have helped in many ways, over many years of electron microscopy, and I particularly wish to thank Mr. A.W. Agar, Dr. M.E. Haine, Professor T. Mulvey and Mr. R.S. Page for stimulating discussions on many facets of electron microscopy, including matters of design.

It is a pleasure to thank Dr. Audrey M. Glauert for her editorial help and encouragement during the preparation of the manuscript.

August 1974 R.H. ALDERSON

Contents

Chapter 1

Introduction

Electron microscopy is largely experimental or practical in nature. In many of the more quantitative applications there is often much calculation and theoretical study to be undertaken, but even in these types of application the microscopist will be occupied for lengthy periods in specimen preparation and operation of the instrument.

The work pattern of the electron microscopist generally falls into the repetitive sequence:

consideration of the scientific problem,
general preliminary technical work,
specimen preparation,
operation of the electron microscope,
image recording,
evaluation of the results, and
re-consideration of the scientific problem.

On occasions, if difficulty is experienced with the practical work, the pattern may alternate simply between specimen preparation and operation of the electron microscope, until such time as the difficulties have been overcome and satisfactory results obtained.

From this work pattern the main requirements for an electron microscope department are immediately apparent – desk-space or office accommodation for reading, writing, calculation and other mental activities, laboratory facilities for specimen preparation and for the development of associated techniques, an electron microscope and ancillary apparatus, suitably housed, and photographic processing facilities for converting the output of the electron microscope into usable permanent images.

Most electron microscope departments, whatever their purpose, start in

a modest fashion with one electron microscope and with one or perhaps, two scientific workers. Except for certain differences in specimen preparation apparatus, the majority of these laboratories are very similar in terms of size and the relative allocation of space. Thus, the basic requirements for a small electron microscope (EM) department can be readily defined; the general features, size, space and relative disposition of rooms for a basic EM department are discussed in Chapter 3.

It is inevitable that most EM departments will tend to specialise, both in the field of application and the type of activity; many laboratories will grow in size and stature as the work of the department progresses. At this growth stage, divergencies in the design and layout begin to appear, according to the purpose of the department. In deciding how much space to allocate and how extensive the facilities should be, it is necessary that a very clear idea of the main purpose of the EM department is in mind. There are many factors to consider and the influence of each type of activity on the design and layout of the various rooms is discussed in Chapter 4; it is well to consider the likely future trends at the start of the planning.

As for all scientific laboratories, there are a number of general requirements such as lighting, heating, ventilation, privacy and safety, the provision of which is a matter of common sense and good general laboratory practice. Certain aspeets of these general requirements need special attention for electron microscopy, however, and these aspects are emphasised in Chapters 5 to 8 which describe in detail the requirements of the individual rooms comprising the electron microscope department. Electron microscopy is a technique requiring relatively high capital expenditure and a full utilisation of the apparatus and other facilities is necessary if the investment is to yield an adequate return in scientific terms. The utilisation aspects influence the amount of apparatus and space required and are of direct concern in designing the department. It is not easy to quantify the utilisation aspects of electron microscopy; so much depends on the ability, skill and experience of the scientists concerned. However, wherever possible, an attempt is made in this book to give meaningful figures which will be of help in planning the department.

In addition to the more obvious general requirements, there are a number of rather special requirements associated with the housing and environment of the electron microscope itself. Most of these special requirements arise from the fact that electron-optical instruments such as the scanning electron microscope (SEM), the transmission electron microscope (TEM), and the recently developed scanning transmission electron microscope (STEM),

together with closely allied instruments such as the electron-probe X-ray microanalyser, are sensitive detectors of mechanical vibration, magnetic fields, and electrical and thermal disturbances. The optical performance of an electron microscope is seriously degraded if the various ambient disturbances are not reduced to an adequately low level, and much of the initial design work in setting up a new building, or in accommodating an EM department within an existing building, is concerned with the provision of an adequate environment for the electron microscope.

These special requirements are *very important*, and are discussed in detail in Chapter 5. The vast majority of difficulties associated with the installation and satisfactory operation of electron-optical instruments on a new site, arise from a neglect of the necessary environmental precautions *at the start of the project*. Unfortunately, many of the potential disturbances to the electron microscope are located outside the confines of the EM department itself, and it cannot be too strongly emphasised that when a new department is being planned, consultation between representatives of the EM department, the architect, site engineer, and the overall authority for planning and administration should take place at the earliest possible opportunity. The ideal time for consultation is before a building has been designed, but this is not always possible. It is equally important to ensure that when the new EM department has been completed, the continuing cooperation of the site engineer and of other departments in a building, is sought in an effort to ensure that the initial satisfactory environment for the electron microscope is not disturbed at some later date, especially in present-day conditions where space is at a premium and buildings are becoming more densely populated.

When the various factors which influence the design of the department have been carefully considered the microscopist will be in a position to make some of the necessary basic decisions, and the ideas which are beginning to emerge can be formalised into the actual design. The design work itself will usually proceed in stages. The early thoughts of the microscopist will eventually appear in the form of detailed instructions and drawings on the architect's plans; the various stages of the design work, from the preliminary decisions to the final supervision of the construction and commissioning of the department, are discussed in the next chapter.

To a large extent, the success of a new EM department will be in proportion to the interest displayed by the microscopist in the planning and design work. At this stage in the life of an EM department there is no substitute for personal involvement on the part of the intending users of the department.

By the very nature of electron microscopy, it is almost impossible to design a 'standard' laboratory. 'Typical' layouts are of restricted value, although it is always worth looking over the designs of neighbouring laboratories in order to borrow bright ideas or to see how others have overcome particular difficulties. For these reasons, no copies of detailed layouts or architects drawings are presented in this book. In the following chapters the microscopist is encouraged to understand the purpose and requirements of each of the rooms comprising the department and then to design a department which will be unique and directly tailored to the personal and scientific requirements of the laboratory staff.

Chapter 2

Design procedure

2.1 *Preliminary decisions*

The provision, or otherwise, of office accommodation for the laboratory staff must be determined at an early stage in the planning. Some organisations prefer to provide their staff with office accommodation separated from the experimental laboratories; others prefer the majority of their staff to have desks alongside the scientific facilities. The author's preference, largely on the grounds of hygiene and safety, is for the former, but it must be conceded that there are strong arguments in favour of both arrangements, and the choice will ultimately depend on the policy of the director of the institute or department. This policy should be ascertained before the layout is considered, as in the larger laboratories the allocation of space varies markedly between the two arrangements. Whichever system is adopted, however, it is essential that staff with administrative or supervisory responsibilities should have separate accommodation.

In circumstances where the EM department occupies a part of a larger building, the provision of the more mundane facilities such as washrooms and restaurant, which are an established part of the normal commercial or scientific environment, may usually be taken for granted. If the EM department is to occupy the whole of a new building or is relatively isolated, these facilities may be properly regarded as being a necessary part of the EM department itself and the scope of the design work will be considerably widened. Larger EM departments, especially those concerned with teaching, may require the occasional use of a lecture theatre or meeting room. On a university site this will present no problem; on other sites this requirement may be difficult to meet, but it must not be overlooked in the planning.

The general field of application within the new department will have been known from the start of the project, and it is important that the main purpose of the department is equally clearly defined. In many respects, the purpose of an EM department has a greater influence on the design than the field of application. The work of an EM department may involve research and development, or teaching, trouble-shooting applications, routine and repetitive examinations, consultant work, demonstrations, or a combination of some of these activities. The influence of each activity on the design and layout of the EM department is discussed in detail in Chapter 4, and it is essential that a clear understanding of the main purpose of the department should emerge at an early state in the project.

When these basic decisions have been made, the microscopist will be ready to consider in more detail the individual rooms comprising the EM department.

2.2 *Individual rooms of the department*

The field of application and purpose of the department will have a strong influence on the number of major instruments, accessories, and specimen preparation apparatus required in the department. The utilisation aspects of EM equipment are discussed in Chapters 5 to 8, which also describe in detail the general and special requirements of the rooms necessary to house the different types of apparatus, and the associated staff. It will be clear that the likely extent of the funding, and other boundary conditions such as the overall amount of space allocated to the department, will have an influence on the number of rooms to be provided, but at this stage of the design procedure, it is well to consider the requirements solely from the scientific point of view. Any restrictions to be imposed by other factors can be considered at a later stage when the assembly of the whole department is being considered.

In view of the need for a controlled environment for an electron microscope, the detailed design of the EM room(s) must be considered very carefully indeed. The stringent design requirements for the EM room, imposed by the sensitivity of modern high-resolution instruments, are considered in detail in Chapter 5, and must be thoroughly understood and kept constantly in mind as the design work progresses.

When the factors affecting the design and layout of the individual rooms have been considered in relation to the proposed scientific work of the EM department, the microscopist will be in a position to plan the assembly of the various rooms and facilities into a coherent department.