Feb. 19, 1957 S. G. ELLIS 2,782,335

ELECTRON-OPTICAL APPARATUS

Filed Feb. 29, 1952

Fig. 1.

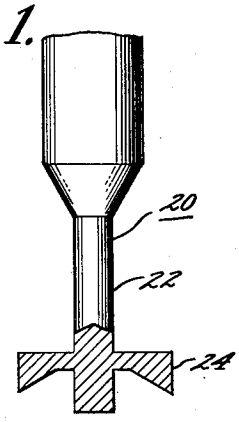


Fig. 2.

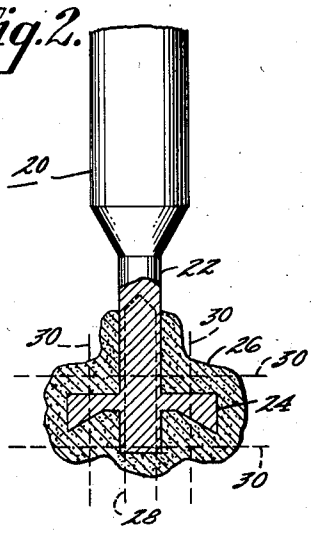


Fig. 3.

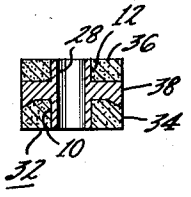
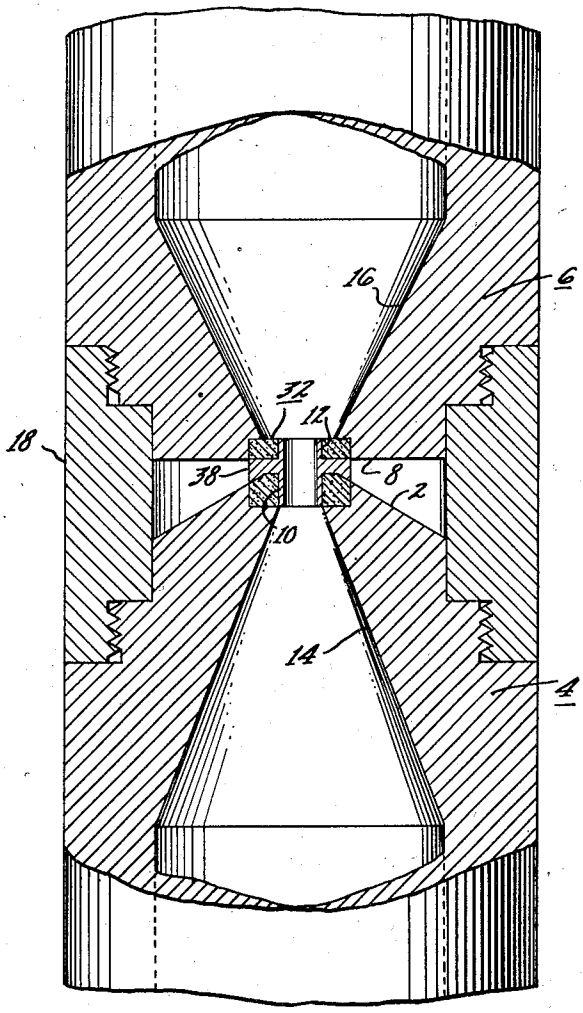


Fig. 4.



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United States Patent Office 2,782,335 Patented Feb. 19, 1957

2,782,335

ELECTRON-OPTICAL APPARATUS

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Application February 29, 1952, Serial No. 274,217

5 Claims. (Cl. 313—84)

This invention relates to electron optical apparatus, and more particularly to magnetic pole pieces which constitute lenses in such apparatus.

In electron optical apparatus such as electron microscopes and electron diffraction cameras, a beam of electrons is controlled by one or more magnetic lenses. These lenses comprise a magnetic field developed between a pair of magnetic pole pieces. It has been found that distortion may be introduced into the operation of the lenses in much the same manner as in light optical lenses. If the magnetic field constituting a lens is asymmetrical, the control it exerts over the electron beam passing therethrough will be distorted. Asymmetry in the magnetic field may be due to the occurrence of either or both of two situations. The first of these involves the composition of the iron from which the pole pieces are made. The surface condition of the pole piece in the immediate vinicity of the lens is quite important to the development of a satisfactory lens. If a particle of impurity occurs at the surface of the iron, the magnetic field may be thereby distorted. Further, the crystalline structure of the iron, itself, is found to influence the symmetry of the magnetic field. If the crystals of the iron forming the pole pieces are not uniformly oriented with respect to the surface of the pole piece in the vicinity of the lens, magnetic field developed by such pole pieces may be adversely affected to the extent of producing a distorted or asymmetrical lens.

A second cause of asymmetrical lenses involves the alignment of the pole pieces with respect to each other. In conventional pole pieces, there is a hole formed in the ends of the pieces through which the electron beam passes. Since the pole pieces used for forming the lens occur in pairs, the hole in one pole piece of the pair must be very accurately aligned with the hole in the other of the pair. If the holes are not thus aligned, the resultant magnetic field, or lens, is asymmetrical and introduces distortion.

Prior efforts to overcome the asymmetry of electron lenses have involved the use of auxiliary magnetic field producing means which are used in an effort to neutralize the effect of the asymmetry. These prior art methods, however, add considerably to the mechanical complexity of the apparatus, since the auxiliary means must be adjustable, and hence to the cost of the apparatus.

It is, accordingly, an object of the present invention to provide improved lens pole pieces for electron optical apparatus.

It is another object of this invention to provide improved lens pole pieces for electron optical apparatus wherein certain causes of lens asymmetry are eliminated.

A further object of this invention is to provide pole pieces as set forth wherein the asymmetry is eliminated without the use of auxiliary magnetic field producing means.

In accomplishing these and other objects, there has been provided, in accordance with the present invention,

a novel pole piece arrangement wherein the pole pieces are provided, in the vicinity of the lens, with separately formed pole tips. The pole tips are formed of iron deposited on a former in such a way that the crystals of the iron are uniformly oriented with respect to the surface of the pole tip. In one form of the invention, the former is made of a non-magnetic material, such as brass, and shaped to conform to a part of the space between the pole pieces in the vicinity of the lens. Iron is deposited on the former as above. When finished, the unit constitutes a unitary member which includes pole tips for both pole pieces of a lens pair.

A better understanding of the present invention may be had from the following detailed description, when read in connection with the accompanying drawing, in which,

Fig. 1 is a view, partly in section, of a non-magnetic former,

Fig. 2 is a view similar to Fig. 1 but showing iron deposited on the former,

Fig. 3 is a cross sectional view of a unitary pole tip member made in accordance with the present invention, and

Fig. 4 is a fragmentary view, partly in section, showing the pole tip unit of Fig. 3 mounted on a pair of electron lens pole pieces.

When iron is plated or electro-deposited onto a smooth surface, it will be found that the iron forms needle-like crystals with their long axes oriented normal to the surface of the material upon which it is deposited. This phenomenon is utilized in one form of the instant invention.

In such electron-optical apparatus as electron microscopes and electron diffraction cameras, means are provided for the generation of an electron beam. This beam is caused to pass through one or more magnetic lenses. The lenses are usually carefully defined magnetic fields developed in the space between pairs of spaced magnetic pole pieces. In one common form of apparatus, such as the one illustrated in Fig. 4, one of the faces **2** of one of the pole pieces **4** is in the shape of a truncated cone. The other pole piece **6** has a face **8** which is flat. The two pole pieces respectively have a hole **10**, **12** through which the electron beam passes. The pole pieces also have, respectively, inner faces **14**, **16** which are substantially in the shape of a truncated cone. The two pole pieces are held in their relatively separated positions by a threaded, non-magnetic spacer **18** which may be made of brass. Since the pole pieces must be very accurately formed, they must be machined, as on a lathe. Because of the configuration of the separate pole pieces, it is difficult, if not impossible, to machine these units with a single setup of the machine. With several machine setups, there is introduced the likelihood of slight discrepancies which would result in asymmetrical lenses. In Fig. 1, there is shown a non-magnetic former **20** which may be made of brass or other suitable non-magnetic material. The former **20** includes a stem **22** which may be machined to the exact diameter of the apertures through the pole pieces, and a flange member **24**. The flange member is machined to conform to the configuration of that portion of the space defined between the two pole piece faces **2** and **8** in the vicinity of the lens.

Magnetic iron **26** is then deposited on the former **20** surrounding the stem **22** and the flange member **24**, as shown in Fig. 2. As has been indicated, electro-deposition of the iron **26** onto the former **20** provides uniformly oriented iron crystals. However, if the crystal size is very small with respect to the size of the holes in the pole pieces, the adverse effect of the random orientation of the crystals may be negligible. In such case, other means of depositing the iron on the former may be used.

For example, powered iron may be pressed onto the former.

After the iron **26** has been deposited on the former, a hole **28** is drilled into the stem **22** longitudinally thereof. The diameter of the hole **28** may be slightly less than the diameter of the stem, thus leaving a thin layer of the material of the former to protect the surface of the deposited iron. Since the former is made of non-magnetic material, the presence of the thin layer of the material will not adversely affect the magnetic field which will be developed by the pole pieces.

Next, the former, with the deposited iron thereon, is trimmed as indicated by the dotted line **30** in Fig. 2. After the trimming operation, there is produced a pole tip unit **32** shown in Fig. 3. This unit includes a pole tip **34** for one of the pole pieces, for example, the pole piece **4** and a pole tip **36** for the other pole piece **6**, with a permanent, non-magnetic pole tip spacer **38** in between them. Since the element **32** is unitary, there can be no misalignment of the pole tips which would produce an asymmetrical lens field. Distortion of the field due to the crystalline structure of the iron of the pole tips is precluded because of the pole tip construction which is in accordance with the invention.

In Fig. 4, the pole tip unit **32** is shown in place in association with the corresponding pole pieces **4** and **6**. The conventional pole pieces, which normally terminate in integral pole tips, have been modified to receive the pole tip unit **32**. The modification of the pole pieces amounts to removing that part of the respective pole pieces which comprise the pole tips, and leaving recesses for the reception of the pole tip unit **32**.

Thus, it may be seen that there has been provided an improved pole piece arrangement for the magnetic lenses of electron optical apparatus. The pole pieces are characterized in that the lens field developed thereby will be free from asymmetric distortion due to the crystalline structure of the iron of the pole tips in the vicinity of the lens, or due to misalignment of the holes through the pole pieces.

What is claimed is:

1. In electron optical apparatus of the type having a magnetic field electron lens, pole piece means between which said magnetic field is formed, said pole piece means having pole tips, said pole tips having magnetic field defining surfaces and being constituted of iron the crystals of which are uniformly oriented with respect to the surfaces of said pole tips.

2. In electron optical apparatus of the type having a magnetic field electron lens, pole piece means between which said magnetic field is formed, pole tips for said pole piece means, said pole tips having magnetic field defining surfaces and being constituted of electrolytic iron the crystals of which are uniformly oriented with respect to the surfaces of said pole tips.

3. In electron optical apparatus of the type having a magnetic field electron lens and a pair of spaced pole pieces between which said field is formed, a unitary member comprising magnetic pole tips of each of the pole pieces of said pair, said pole tips having surfaces defining said magnetic field, and a non-magnetic former integral with said pole tips, said pole tips being constituted of iron the crystals of which are uniformly oriented with respect to said field defining surfaces of said pole tips.

4. In electron optical apparatus of the type having a magnetic field electron lens and a pair of spaced pole pieces between which said field is formed, a unitary member comprising magnetic pole tips for each of the pole pieces of said pair, said pole tips having surface defining said magnetic field, and a non-magnetic former, said pole tips being constituted of electrolytic iron integrally united with said former and having a crystalline structure wherein the crystals of said iron are uniformly oriented with respect to said pole tip field defining surfaces.

5. The invention set forth in claim 3 wherein said former is shaped to conform to the space defined by said pole pieces.

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