TEM holder for observing radioactive or magnetic specimens

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1. Introduction

When the microstructure of radioactive or magnetic specimens are observed by conventional transmission electron microscopes, they would produce many problems such as radioactivity of the specimens or escape of images resulting from a shift in the optical axis after moving and tilting the specimen. The problems of radioactivity are based on irradiated materials and those of beam shift are caused by the deflection of the electron beam by Lorentz force due to the magnetic induction of magnetized specimens.

Usually TEM specimen is inserted near the maximum of the field distribution of the objective lens so as to obtain the minimum spherical and chromatic aberrations. In case of observing the magnetic specimens, the image resolution is highly reduced because of the large lens aberrations. These problems could be overcome by using a special objective lens called by a magnetic-field-free objective lens.

If the diameter of specimen is reduced to one third, the radioactivity and the magnetic induction of one will be decreased by one ninth. By reducing the diameter of one can be solved the abovementioned problems.

In this presentation, we will propose to use a special holder for overcoming the problems described above.

2. Methods and Results

Figure 1 shows cross-sections of the spherical objective lens (on the right) and that of a conventional one (on the left). In the conventional lens, the specimen is set near the center of the gap between the pole-pieces. However, in the special objective lens called a magnetic-field-free objective lens, the specimen is inserted in the hole of the upper pole-piece. Thus the magnetic field around the specimen is shielded by the upper pole-piece itself.

The magnetic flux density in the magnetic-field-free objective lens is reduced to one thousandth of that of a conventional lens and the flux density reduces to a few mT. Thus deflection of the incident electrons becomes negligible small.

Figure 2 shows C_s as a function of the specimen position Z together with the chromatic aberration C_c and the focal length f_0. If the specimen position approaches the maximum of the field (about Z=10 mm), Cs decreases continuously. The distance between the specimen position and the maximum position of the field can be reduced by reducing the diameter of the hole made in the upper pole-piece for inserting the specimen. However, the specimen tilt angle is limited to the lower one by reducing the diameter of the hole.

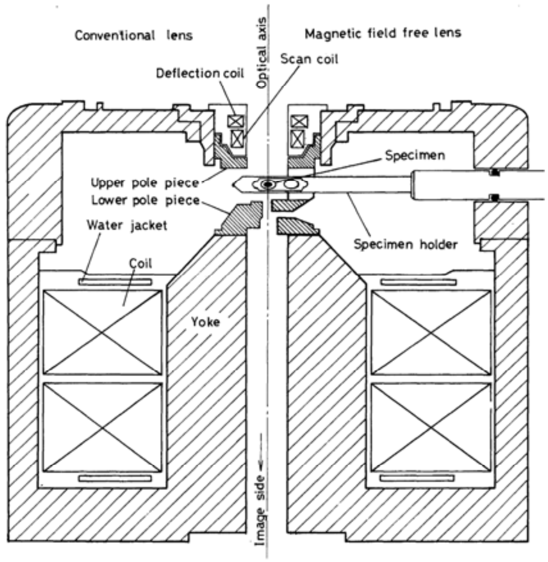


Fig. 1. Comparison of cross-sections of magnetic-field-free lens (right hand half) and conventional objective lens (left-hand half) together with arrangement of specimen holder [1].

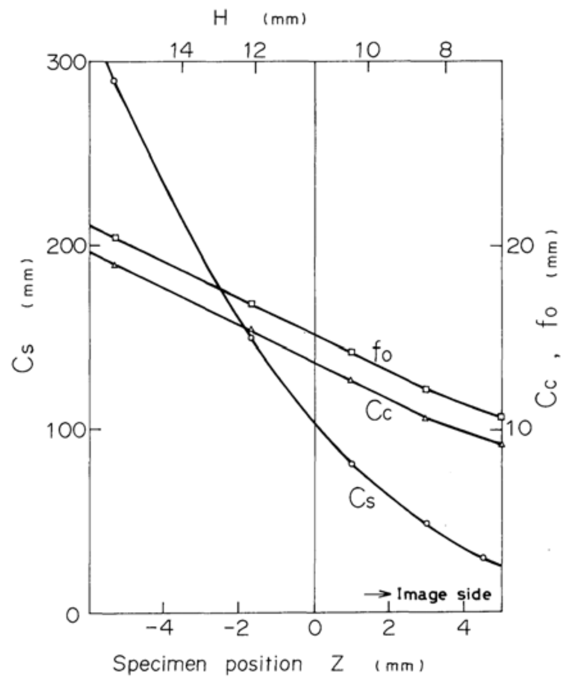


Fig. 2. Optical properties of the magnetic-field-free objective lens calculated numerically from measured axial field distributions [1].

Mathematically law of radioactive decay (RAD) is expressed as [2]:

$$\mathrm{RAD} = -\frac{d\mathrm{N}}{dt} = \lambda\,\mathrm{N} \qquad (1)$$

$$\mathrm{N} = \mathrm{N}_A \cdot \mathrm{W}(g) / \mathrm{Z} \qquad (2)$$

where N is the number of radioactive nuclei, λ is decay constant, i.e., the probability of decay per nucleus per unit of time, N_A is the Avogadro's number (N_A=6.02*10^{23}/mol), W(g) is mass of the radioactive materials and Z is atomic number. Reducing the diameter of specimen to one third, the specimen decreases the radioactivity of one into one ninth.

Magnetic field H (in Oersted: Oe) and magnetic induction field B (in teslar: T) are linked, in a given material, by the equation [3]:

$$\mathrm{B} = \mu\,\mathrm{H} \qquad (3)$$

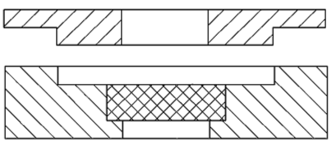
where μ is the magnetic permeability of the material (in Henry/meter). As an SI derived unit, the tesla can also be expressed as [4]:

$$1\mathrm{T} = 1\frac{\mathrm{V}\cdot\mathrm{s}}{\mathrm{m}^2} = 1\frac{\mathrm{N}}{\mathrm{A}\cdot\mathrm{m}} = 1\frac{\mathrm{Wb}}{\mathrm{m}^2} = 1\frac{\mathrm{kg}}{\mathrm{C}\cdot\mathrm{s}} = 1\frac{\mathrm{kg}}{\mathrm{A}\cdot\mathrm{s}^2} \qquad (4)$$

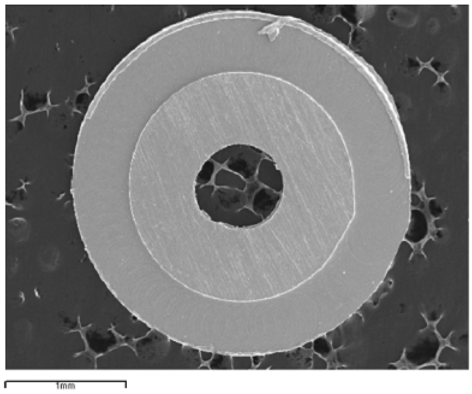
Also decreasing the diameter of specimen into one third, the specimen decreases the magnetic induction field into one ninth.

The special objective lens was developed to observe the magnetic materials but the radioactive materials, besides, it was necessary for another TEM to use the magnetic-field-free objective lens. Another solution of these problems is to reduce the specimen size. We propose to use a special holder for the small specimen of which the diameter is decreased in about 1mm. The special holder consists of cover part and supportive one. The small specimen set into the guide hole of supportive part. Total thickness (about 0.25 mm) of the holder after assembling the parts is thin enough to set into normal specimen holder.

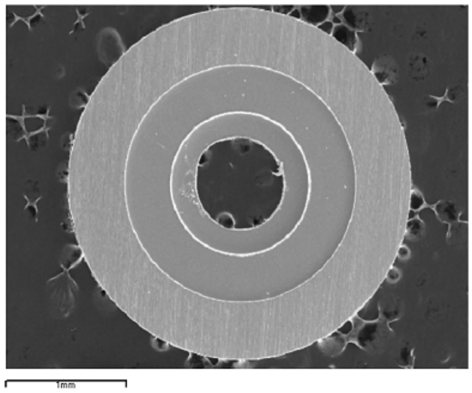
Figure 3 shows (a)the cross section of the special holder and SEM image of the special holder consisting of cover part (b) and supportive one (c). It is very hard to make the guide hole of supportive item due to the thickness of one.



(a)



(b)



(c)

Fig. 3. (a)The cross section of the special holder and SEM image of the special holder consisting of cover part (b) and supportive one (c)

3. Conclusions

Using the special holder has many advantages. One of them is that we can observe the magnetic materials very well without special objective lens. Another is that we can reduce radiation expose to the radioactive specimens by diminishing size of the specimen. Another is to cut down the time of making an experiment because beam shift becomes very small after moving and tilting the specimen.

REFERENCES

[1] K. Tsuno and T. Taoka, Magnetic-Field-Free Objective Lens around a Specimen for Observing Fine Strucutre of Ferromagnetic Materials in a Transmission Electron Microscope, Japanese Journal of Applied Physics, Vol.22, p. 1041, 1983.
[2] http://en.wikipedia.org/wiki/Radioactivity
[3] http://en.wikipedia.org/wiki/Magnetic_field
[4] http://en.wikipedia.org/wiki/Tesla_(unit)