Study of TEM fluorescent screens

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In a transmission electron microscope (TEM), the electron image must be visualised by the observation system of the instrument. For this purpose, an imaging fluorescent screen has to be used which is capable of converting the energy of signal electrons into photons and offers the resulting image to the human eye or to a recording device. The screen provides the possibility for the location of the desired field of view, for the focussing of the lenses, and particularly for the study of the specimen. If necessary, the image from the screen is observed through a light optical magnifier.

1. Screen performance

An imaging screen should provide high cathodoluminescent (CL) and photon collection efficiencies (i.e. high light output L) and good spatial resolution δ. High light output determines good signal-to-noise ratio, but more often the ratio L/δ^2 is considered as a measure of screen quality [1]. With the TEM screen the highest demands are put on the spatial resolution. The reason is that the image on TEM screen can be very small with pixel size 1-2 orders smaller than that with TV screens. In miniature TEM the image must be considerably magnified by light optics, and sometimes even a submicron pixel size of the screen image is required. Such a small pixel size is unattainable when classical powder screens are used, because the resolution obtainable depends primarily on the grain size (3-10 µm) of the powder material, and only secondly on the spreading of the penetrating electron beam. Single crystal imaging screens have no limitation in the grain size. They are optically transparent and possess perfectly defined optical properties. Moreover, crystals can be modified with a high accuracy, even into very thin and small screens. Besides, they show an extremely high electron beam resistance.

2. Spectral characteristics

No high demands are put on the true colour reproduction of the screen, but the spectrum of the emitted light should be suitable both for the direct observation with the human eye and for a photograph or CCD camera recording. As is shown in Fig. 1, at daylight vision, spectral sensitivity of the human eye has its maximum in the yellowgreen spectral region (approximately 550 nm). At dark, the characteristic shifts to the green region. Monochrome CCD image sensors have also very high sensitivity in this spectral region. Therefore, with TEMs, a yellow emitting silver and chlorine activated mixture of zinc and cadmium sulfides was found the most suitable powder screen tens years ago [1], and it is still used even with digital observation systems. At our laboratory, the cerium activated Yttrium Aluminium Garnet – YAG:Ce was developed as the most advantageous single crystal for the use as a TEM screen. Its emission spectrum matches nearly ideally to the human eye sensitivity (see Fig. 1).

3. Spatial resolution

The most simple and often used method for the study of the screen spatial resolution is the mask method, when a line figure or grid mask is placed on the surface of the screen studied, and the limit of the resolution is determined by direct observation. To get correct results by these methods, one must have a mask with a sufficient absorption capability. But especially for high

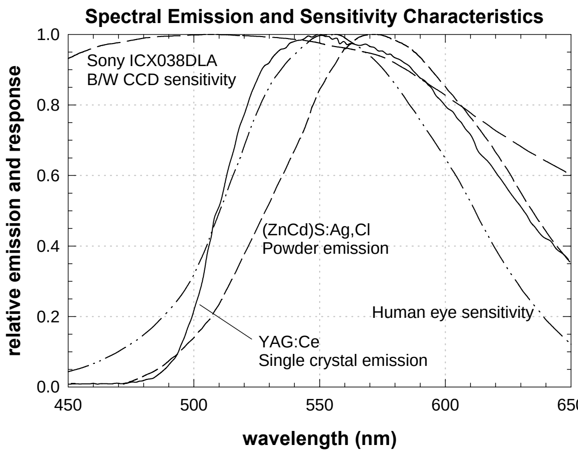

Figure 1. Spectral characteristics of TEM observation elements. Emission (CL) spectra: – – – – (ZnCd)S:Ag,Al powder screen; ——— YAG:Ce single crystal screen. Spectral sensitivities: — · · — human eye at daylight vision; — — — Sony CCD ICX038DLA B/W image sensor (lens characteristic of the 1/2" optical system included).

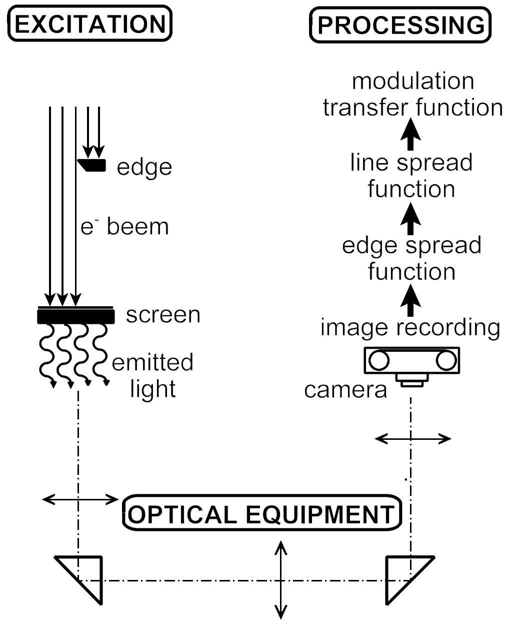

Figure 2. Spatial resolution measurement setup using sharp edge projection method.

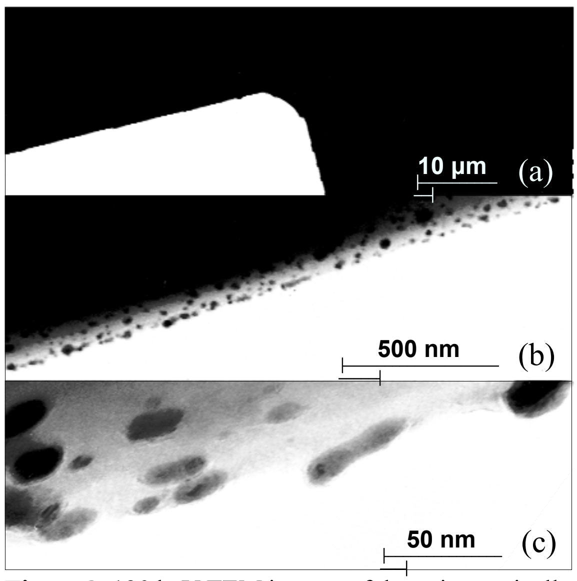

Figure 3. 120 keV TEM images of the anisotropically etched hole in single crystal silicon. (a) The corner at the magnification 450x. (b) The edge at the magnification 13000x. (c) Detailed structure of the edge at the magnification 125000x.

energy electron beams, the spread of electrons in the mask is very large, and it is quite impossible to stop all electrons within the mask.

At our laboratory, measurement of the resolution was realized using the projection of a sharp edge on to the examined YAG:Ce screen. The experimental setup of this method is in Fig. 2. As a projection object (placed in the specimen chamber of the TEM Philips CM 12), the silicon single crystal plate with the hole made by the anisotropic etching was used. The prepared silicon plate with the pyramidal hole marked out by a large area of crystallographically flat and accurately defined geometry. The edge geometry was examined by TEM Philips CM 12 and results are demonstrated in Fig. 3.

The edge image from the screen was magnified 40x using light optics. By the differentiation of edge spread functions (obtained using photographs of the edge images) line spread functions were received, and using the modulus of the Fourier transform, the MTFs of the measured edge responses in the YAG:Ce screen were obtained for different energies of the primary electron beam [2]. From MTFs the values of spatial resolution of 150, 18 and 8 lp/mm for 20, 60 and 100 keV electrons, respectively, have been taken for YAG:Ce single crystal screens.

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References

1. Reimer L., Transmission electron microscopy, Springer-Verlag, Berlin 1984, p. 125-126.
2. Schauer P., Autrata R., Performance of YAG:Ce single crystal screens for TEM, Proc. ICEM14, Cancún 1998, Vol. 1, p. 633.