Single crystal scintillation detectors for LVSEM

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The scintillator-photomultiplier system to detect signal electrons has, from the viewpoint of detection efficiency, not been surpassed as yet. In combination with single crystal scintillators based on yttrium aluminium garnet (YAG) or yttrium aluminium perovskite (YAP) [1], it allows achieving of a highest signal-to-noise ratio that ensures attainment of a high image resolution.

Problem

The quantum efficiency of any scintillator depends on the energy and intensity of electrons that are incident on it. There is a certain scintillator threshold electron beam energy at which the incident electrons are capable of generating such an amount of photons that can produce a signal usable from the point of view of the noise level. For these reasons, the scintillator of secondary electrons (SE) is equipped with an electrode supplied with a voltage of +10 kV by means of which the SEs are accelerated toward the scintillator. A problem arises when backscattered electrons (BSE) are to be detected at a low or very low accelerating voltage of the electron beam. If one electron with the energy E_0 = 10 keV is incident on the YAG, eight photoelectrons are incident on the first dynode of PMT. But if E_0 = 1.0 keV, only one photoelectron is incident on the first dynode. As a result, a lower signal-to-noise ratio causes problems in high resolution imaging. Fig. 1 illustrates the dependence of the measured detection quantum efficiency (DQE) of the BSE detector (scintillator and light guide position is evident from Fig. 2) on the energy of the incident electrons of the electron beam (PE). The DQE dependence drastically decreases with decreasing PE energy, and at E_0 = 1 keV the value of the DQE coefficient amounts to 0.1 (curve A). These values are threshold ones, i.e. at these values the image quality is at the boundary of a sufficient resolution [2] (shown in Fig. 3A).

Solution to the problem

A low value of DQE at low energies of PE can be increased so that low energy BSEs are accelerated in the electrostatic field toward the scintillator. The electrostatic field is produced by applying a positive high voltage (+3 kV to 10 kV) to the electrode deposited on the YAG surface. In such an electrostatic field, however, not only BSEs but also SEs are accelerated to the scintillator and the result is not the true detection of BSEs [3]. The introduction of a grid with a negative bias whose value must be in optimum proportion to the value of high voltage applied to the scintillator suppresses the detection of SEs.

Results

The detector configuration is shown in Fig. 2. A change in the dependence of DQE on the PE energy when a voltage of 3 kV is applied to the scintillator and when only BSEs are detected is illustrated in Fig.1(B). Fig. 3 is the practical result of magnetic tape imaging under different described conditions of BSE detection. Best resolution is achieved if BSEs are accelerated for 3 kV and higher.

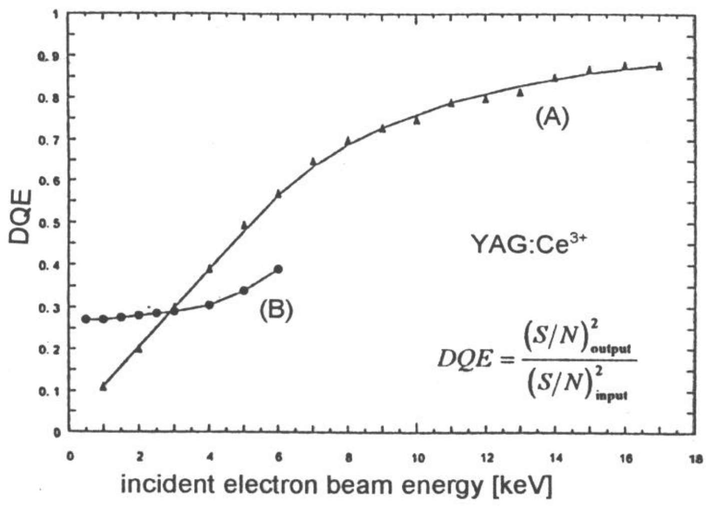

FIG. 1 - DQE of BSE detector of optimal configuration used a) without HV on scintillator, b) with HV on scintillator

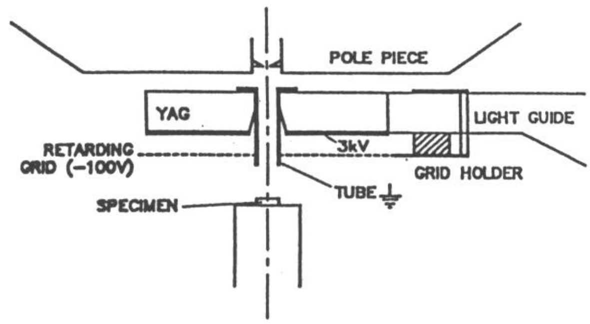

FIG. 2 - BSE single crystal scintillation detector for low voltage operation

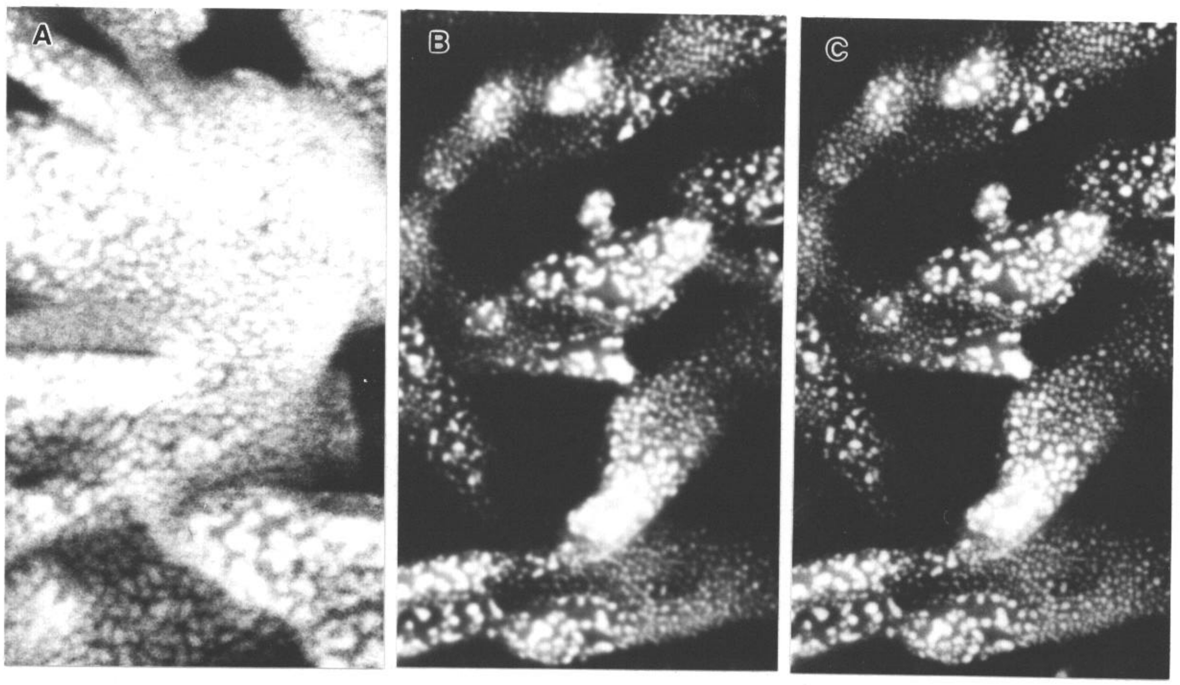

FIG. 3 - Backscattered electron image of magnetic tape at A) E_0 = 1 keV without high voltage on scintillator, B) E_0 = 2 keV without high voltage on scintillator, C) E_0 = 1 keV with 3 kV voltage on scintillator and -100 V on grid. View-field 300 nm.

References

1. Autrata R., *European Microscopy and Analysis*, 41 (1996) 9-11.
2. Joy, D.C., *Journal of Microscopy*, 140 (1985) 283-292.
3. Autrata, R., Hejna, J., *Scanning* 13 (1991) 275-287.