Single crystal scintillators for BSE detectors in SEM

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Single crystal scintillator-photomultiplier detectors of backscattered electrons (BSE) based on yttrium aluminium garnet (YAG) show a high detection quantum efficiency (DQE) (1). Even though semiconductor systems and multichannel plates have made considerable progress regarding the improvement of their dynamical properties, particularly for the BSE detection, the scintillator-photomultiplier system still retains, from the viewpoint of bandwidth and signal-to-noise ratio, the best detection capabilities.

There are two basic prerequisites for achieving a high DQE of the scintillation BSE detector: (i) a high quantum efficiency of the scintillator, and (ii) an efficient transfer of light generated in the scintillator toward the photocathode of the PMT. The fulfilment of the former prerequisite depends on the material of the scintillator, the latter prerequisite is influenced by the geometrical configuration of the scintillator light guide head of the detector and by its optical properties. The position of the scintillator with regard to the emitted BSEs plays also a very important role. The number of BSEs collected by the scintillator expressed by the collection efficiency is another criterion of the value of the light output signal of the BSE detector.

Besides the so far most frequently used scintillation single crystal, YAG, single crystals of yttrium aluminium perovskite (YAP) and yttrium silicate (YS) begin to be applied now. Their light output signals together with those of some other scintillators are shown in Figure 1. The presented characteristics have been obtained by measuring the output current of the PMT after the impact of electrons with different energies on a 0.5 mm thick scintillation disc whose bottom face was attached to a rod-shaped quartz light guide.

Thanks to an improved technology of growth of YAP crystals, the relative efficiency of YAP is higher than that of YAG. Nevertheless, YAP emits a maximum of light with a wavelength of 370 nm which is 100% transmitted only by the quartz glass light guide. Cheaper organic glass types show different light absorption in this wavelength region. In the case of long organic glass light guides, the advantage of higher efficiency is eliminated by the loss of the light output signal due to an imperfect light transmission in the light guide. Another unfavourable effect is the self-absorption of light in YAP (20% for 5 mm length) which is the reason for further losses of the light output signal if the generated light is to be propagated along a long path in the scintillator. YAP is therefore suitable for BSE detectors with smaller scintillators and with short organic glass light guides.

YS is a new type of scintillation single crystal. It shows a high quantum efficiency (8%), short decay time (20 ns), acceptable self-absorption of light (9% for 5 mm length), and a maximum of light emission at the 400 - 410 nm wavelength. The technology of growth of YS crystals is still associated with some problems which limit the scintillator size to a diameter of 10 mm.

Owing to a high index of refraction of all single crystal scintillators, the scintillator light guide part of the BSE detector is optically adapted to provide a maximum light output signal from the light guide (2). From the optical point of view, the most advantageous shape of the scintillation BSE detector is a disc with a hole to allow the passage of an electron beam. The disc is attached to the light guide by one half of its peripheral area. The scintillator and light guide are coated with a system of conducting, reflecting, anti-reflecting and diffusion layers.

The shape of the light guide can significantly influence the light output signal. Generally, it holds that the most advantageous shape of the light guide is a cylinder of circular cross-section tapered at one end to allow the attachment of a scintillator (3). The magnitude of the light losses occurring during the transport depends on the ratio of the length and diameter of the light guide, on the perfectness of the mirror surface and on the absorption properties of the light guide. The values DQE = 0.8 - 0.9 at an electron beam energy of 15 keV and DQE = 0.5 - 0.6 at an electron beam energy of 5 keV can be achieved using an optically modified planar YAG-BSE detector.

FIGURE IS MISSING

Figure 1. Light output signal of single crystal, plastic and powder scintillators plotted as a function of incident electron energy.

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