# Nanoresolution BSE images created using a new type of YAG II scintillator

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Detection of backscattered electrons (BSE) in scanning electron microscopy (SEM) serves as an auxiliary method in the study of surfaces and composition of materials. Backscattered electrons have properties that are different from those of usually used secondary electrons. The achievement of the theoretical limit of resolution (0.6 – 0.8 nm for SE and 0.9 nm for BSE) depends not only on the properties of the electron source, properties of electron optics, specimen preparation technique, type of electrons, but also on the detection system efficiency.

Several types of detection systems have been designed for detecting signal electrons in SEM. Even though in the last few years the noise and time characteristics of semiconductor detectors and the properties of channel plate detectors have been considerably improved and although a great number of SEMs is equipped with semiconductor detectors for BSEs detection, the scintillator-photomultiplier still possesses the best signal-to-noise ratio and bandwidth characteristics [1]. The scintillator is the most important part of a such system. Powder P47 and yttrium aluminium garnet (YAG) single crystal are the most efficient scintillators even if powder material of P47 is suitable only for SE detectors.

It was shown [2] that BSE detectors based on YAG single crystal enable one to achieve very high detection quantum efficiency (app 0.75 at 10 keV). The efficiency of the YAG – BSE detector depends not only on the optical properties of the whole detector system but also (and especially) on the efficiency of electron – photon transfer in a scintillator. This efficiency is the limiting factor for the achievement of a high BSE resolution.

Our aim is to work out the technology for the preparation of a YAG scintillator with the highest light output after an impact of BSEs.

For crystal growth a small volume of water vapour in the growth atmosphere was used. Due to the additional treatment of the YAG discs in oxygen and hydrogen atmosphere at very high temperatures, the colour centres in the YAG crystal lattice were suppressed. Polishing process of the YAG surface was improved. It was found that this process caused penetration of the polishing microparticles into the surfaced microcracs. These particles can be removed by the washing process in a special mixture of acids only at a suitable temperature.

Thanks to these steps, the light output from the modified scintillator was increased about twice, in comparison with the older YAG (type I). The decay time 1/e was decreased and moves in the range of 60-70 ns. Long time afterglow is also shorter.

The modified single crystal named YAG II scintillator was used at design of the planar YAG-BSE detector that is placed tightly under the pole piece of the SEM. A smaller hole in the centre of the YAG has been used for the reason of higher collection of BSEs trajectories. DQE coefficient of this detector was increased from the original value of 0.75 at 10 keV to 0.85 at 10 keV.

Thanks to the improved properties of the YAG-BSE detector, it was possible to operate with lower PMT amplification, lower beam current and lower accelerating voltage. All these conditions are suitable for obtaining a higher BSE image resolution.

1. R. Autrata, R. Hermann, M. Müller, An efficient single crystal detector in SEM, Scanning 14 (1992), 127-135
2. R. Autrata, P. Schauer, Single crystal scintillator detectors for LVSEM, Proc. 14th International Congress EM, Cancun (1998) 437-438
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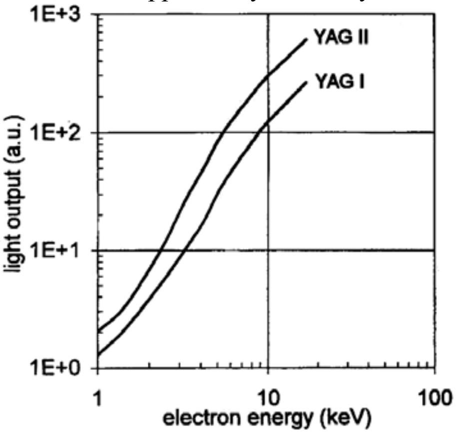


**Figure 1.** Relative light output of single crystals versus energy of incident electrons.

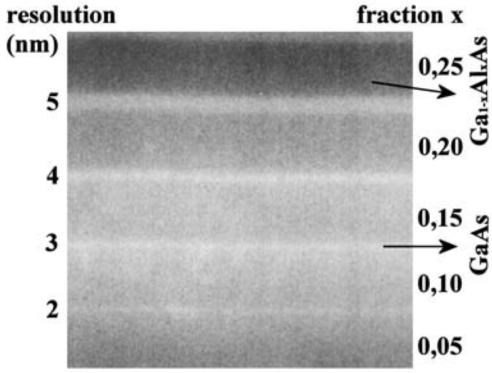


**Figure 2.** Superlattice structure of GaAs and $Ga_{1-x}Al_xAs$ recorded with planar YAG-BSE detector.

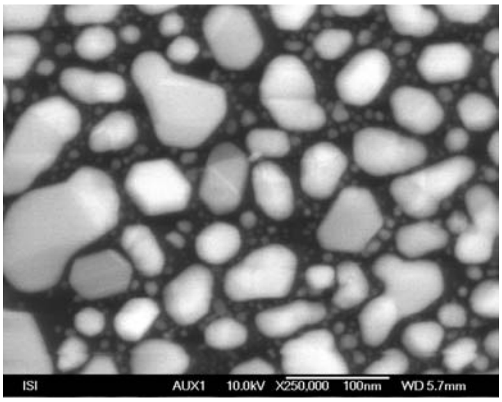


**Figure 3.** Gold particles on Carbon.

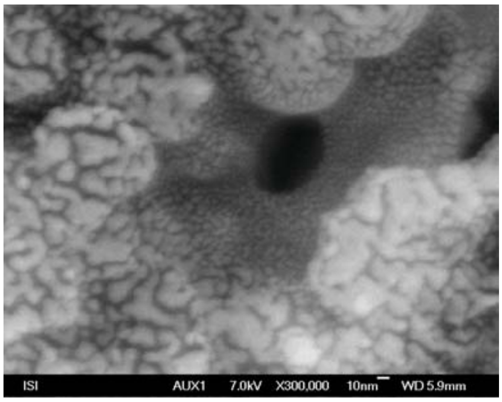


**Figure 4.** Gold coated magnetic tape.

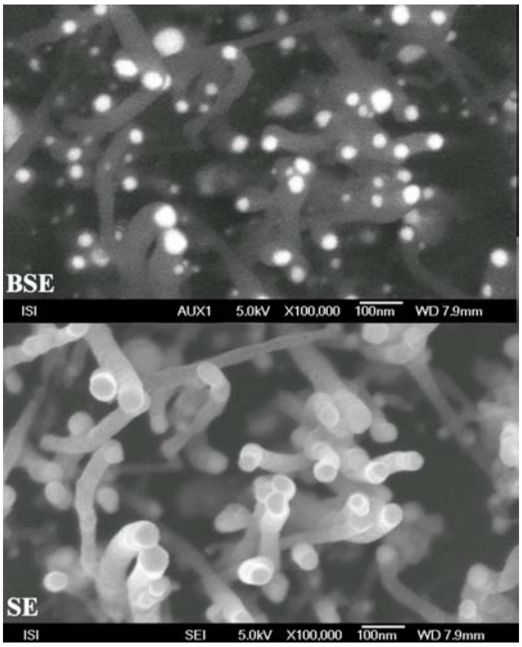


**Figure 5.** Carbon nanotubes.

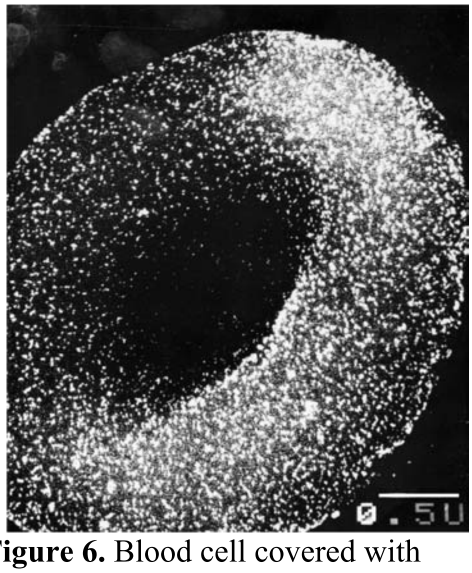


**Figure 6.** Blood cell covered with protein particles A marked with colloidal gold 5-10 nm.