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Optimization of Poly-(Methylphenylsilylene) Specimens for Cathodoluminescence Measurement

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Two possibilities of photon collection from the luminescence centra can be applied at cathodoluminescence (CL) measurement of transparent specimens. The CL emission can be collected both from the side of excitation and substrate using a lens and a light guide, respectively. To choose the better alternative, one has to study optical properties and electron-interactive volumes of specimen materials. Based on this knowledge, optimized geometry, dimension and arrangement of the specimen can be designed. The object of our interest was the CL study of Poly-(Methylphenylsilylene), i.e. PMPhSi, which is an interesting material both from the application and the basic research point of view. The PMPhSi was prepared by the Wurtz coupling polymerization [1]. The low-molecular weight fractions were extracted with boiling diethyl ether. The layers for the CL measurements were prepared from a toluene solution by casting on quartz disk substrates.

The optical transmittance of 500 nm thick PMPhSi layer was measured using the Varian Cary 5E spectrophotometer in the wavelength range from 200 to 1600 nm. The measurement (not corrected for Fresnel's reflections) is plotted in Fig. 1. After correction, the absorption coefficient of approximately 0.2 μm^{-1} can be calculated in the region of the CL emission (360 nm). So, the optical selfabsorption of PMPhSi is high enough to require a thickness optimization at CL measurements. To look for the optimal thickness of the PMPhSi, the size and shape of the electron interaction volume must be known. Therefore, the Monte Carlo (MC) simulation of electron trajectories and energy deposition in the bulk PMPhSi has been executed using the single scattering algorithm with the screened Rutherford elastic cross-section and the Bethe continuous slowing-down energy loss[2]. At the primary electron energy of 10 keV, the deposited energy distribution in the PMPhSi (penetrated from the surface to the depth) has been obtained (Fig. 2). It can be taken from the plot the 75 % of energy is converted to photons below the depth of 2 μm, and only remaining energy is absorbed above 2 μm up to the terminal penetration of 3 μm. So, photon collection from the side of substrate using a light guide seems to be a better choice. To minimize the losses due to the photon selfabsorption, the PMPhSi should be optimized to the thickness of 2 μm for CL measurements at 10 keV excitation electron beam.

The PMPhSi layer is non-conductive and hence it is necessary to provide its surface with a thin conductive coating. The coating must be thin enough not to absorb the energy of signal electrons and at the same time thick enough to be conductive and to show high optical reflection. Therefore, Al and Ag films have been investigated to find their optical reflection and e-beam energy losses at the sufficient electrical conductivity. Thickness dependance of the internal optical reflection at the PMPhSi-(Al|Ag) boundary (Fig. 3) has been obtained by matrix method [3] calculation. Although Ag film is known as an excellent optical mirror, its reflection in the region of the CL emission band (360 nm) is poor, and only Al can be considered as an optically suitable film. Using the same MC method mentioned above, the dependance of the thickness of Al and Ag films on the electron energy

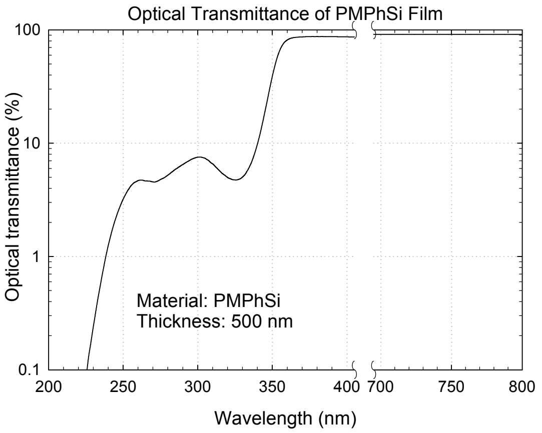

Fig. 1. Optical transmittance of the 500 nm thick PMPhSi layer. Measurement is not corrected for Fresnel's reflections.

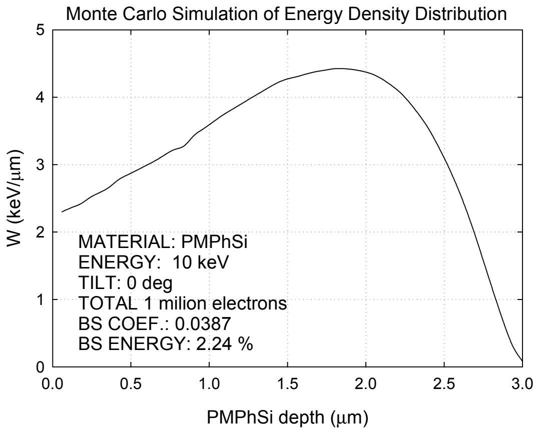

Fig. 2. Distribution of the electron energy absorbed in the bulk PMPhSi. The Monte Carlo simulation of 1 million electron trajectories of 10 keV primary energy.

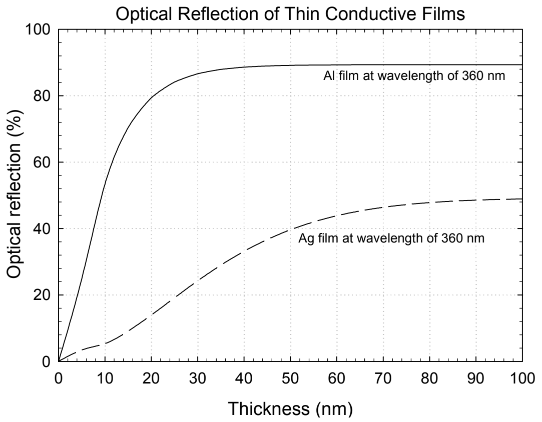

Fig. 3. Internal optical reflection for the perpendicular incidence at the PMPhSi→conductive film boundary at the wavelength of 360 nm.

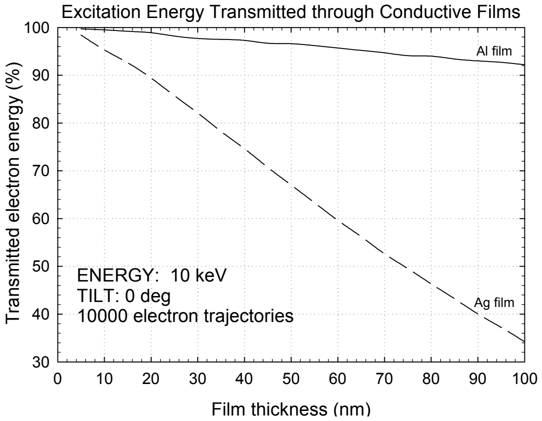

Fig. 4. MC simulation of the excitation electron energy transmitted through the thin conductive film deposited on the PMPhSi layer.

transmitted at 10 keV (Fig. 4) has been obtained. As shown, Ag possesses high losses at the electron penetration, and only Al film is again acceptable. As the best solution of high optical reflection and low penetration losses of electrons, 50 nm thick Al film with electrical resistivity lower than 10 Ω/□ was accepted. Owing to the increased refraction index and to the smooth and parallel bases of the disk specimens the total reflection of photons of some directions causes significant loses at photon collection from the output base. Using analytical 3D geometry, the efficiency of photon collection from an ideal transparent PMPhSi disk having one ideal reflective base can be easily derived as $\eta=1-(n^2-1)^{1/2}/n$, where n is the refraction index of the material used. This gives the poor collection efficiency of only 25 % for PMPhSi disks. So, it is strongly recommended to matte the output base of the disk, which results in much higher photon collection efficiency.

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