doi: 10.1017/S1431927609092162
Microsc Microanal 15(Suppl 2), 2009

SEM contrast of semi-insulating compound materials

H.-J. Fitting[1] and J. Z. Kovacs[2]

[1] University of Rostock, Institute of Physics, Universitaetsplatz 3, D-18051 Rostock, Germany
[2] Hamburg University of Technology, Institute for Optical and Electronic Materials, Eissendorfer Str. 38, D-21073 Hamburg, Germany

The invention of the scanning electron microscopy (SEM) is concerned with Max Knoll in Berlin 1935 published in [1]. Even in this first paper charging phenomena of insulating samples are described too. In recent years the electron beam irradiation and charge injection in insulating samples have been described by means of an electron-hole flight-drift model (FDM) implemented by a computer simulation [2-4]. Ballistic scattering and transport of secondary electrons and holes is followed by drift, possible recombination and/or trapping and detrapping. In this context special surface layers have been installed to investigate charging prevention [3] and to simulate surface leakage currents, [4]. For bulk full insulating samples the time dependent secondary electron emission rate $\sigma(t)$ and surface potential $V_0(t)$ approach the final stationary state under the condition $j(x,t)$ = const = 0 and $\sigma = 1$. But in semiconducting and semi-insulating samples these relations are not fulfilled. In this context we want to remember to an old resistance model, e.g. quoted in [5]. There a certain sample resistance R_i controls a partial charging of the semiconducting or semi-insulating sample as demonstrated in Fig.1. The actual landing energy $E_v = eU_v$ of the electron beam is enhanced or diminished by the surface potential $U_s \lesseqgtr 0$:

$$E_v = e_0U_v = e_0(U_0 + U_s) = E_0 + e_0 (\sigma - 1)\, i_0\, R_i \qquad (1)$$

The interceptions of the resistance lines $\sigma(U_0,U_vR_i)$ with the SE yield curve $\sigma(E_v{=}E_0)$ result in the actual state of charging (U_s) and SE yield $\sigma(E_v)$. So we see that the (σ_0=1)–energies E_0^{I} and E_0^{II} are for the first value labile and for the second one stable (even attractive) as mostly used in simple charging models for full insulating samples $R_i = \infty$. Hence for conducting samples $R_i = 0$ we get no charging and $E_v = E_0$.

In Fig.2 an element contrast around the first (σ=1) point $E_0 \lesseqgtr E_0^{I}$ (see Fig.1) is demonstrated. The metal (Pb) islands appear darker than the silicon substrate for very low electron beam energies E_0=5 eV< E_0^{I} with a gradual contrast inversion to E_0 = 378 eV > E_0^{I}, see [6]. In Fig.3 a contrast inversion appears from the initial uncharged state (pure element contrast) to the charged-up insulating epoxy resin matrix with imbedded carbon nanotubes (CNT), [7]. The same sample shows an energy-dependent contrast inversion around E_0^{II}, shown in Fig.3.

References

[1] M. Knoll, Zeitschrift f. Technische Physik **11** (1935) 467-475.
[2] X. Meyza, D. Goeuriot, C. Guerret-Piécourt, Tréheux, H.-J. Fitting, JAP **8** (2003) 5384-5392.
[3] M. Touzin, D. Goeuriot, C. Guerret-Piécourt, et al., JAP **99** (2006) 114110.
[4] N. Cornet, D. Goeuriot, C. Guerret-Piécourt, et al., JAP **103** (2008) 064110.
[5] I. M. Bronshtein, B. S. Fraiman, "Secondary Electron Emission" (russ.), Naúka, Moscow 1969.
[6] I. Muellerova, Scanning **23** (2001) 379-394.
[7] J. Z. Kovacs, K. Andresen, J. R. Pauls, C. P. Garcia, et al., Carbon **45** (2007) 1279–1288.

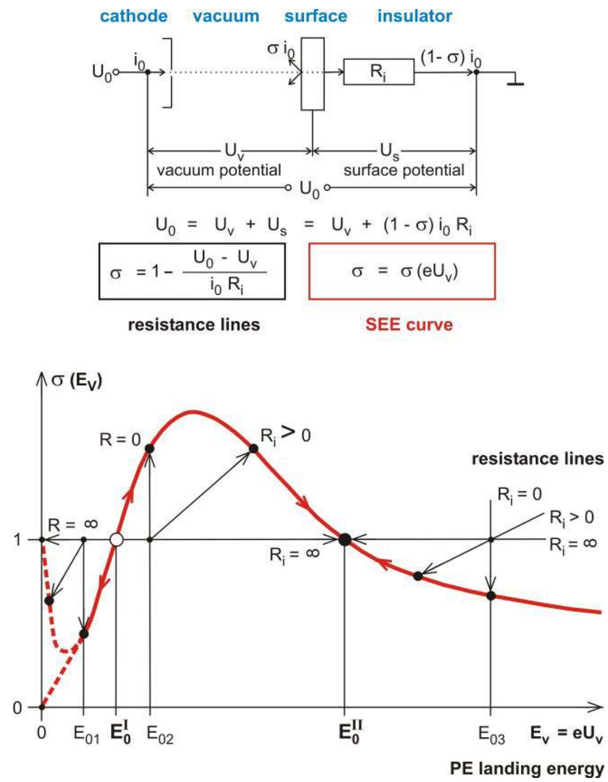

Fig.1 SEE resistance model for semiconductors and insulators; R_i internal sample resistance.

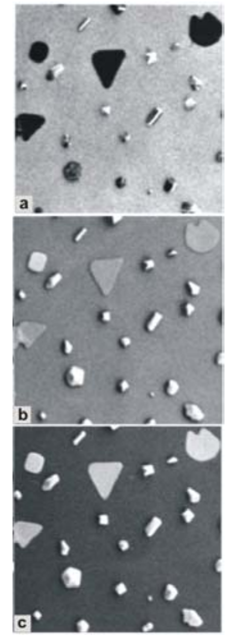

Fig.2 Element contrast inversion of Pb islands on Si substrate at very low beam energies $E_0 \lesssim E_0^I$: E_0=5 eV (a); 42.5 eV (b); 378 eV (c), with courtesy of I. Muellerova (ISI Brno) [6].

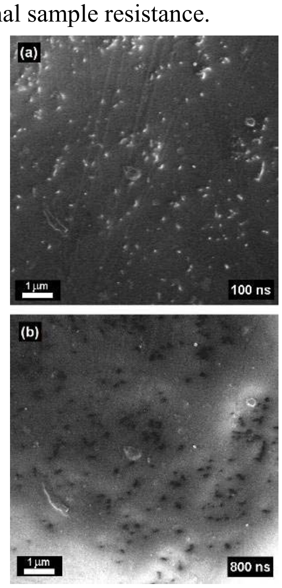

Fig. 3 Time-dependent charge contrast inversion from short (100 ns above) to longer irradiation times t = 800 ns (below) of CNT in epoxy resin; E_0 = 0.6 keV.

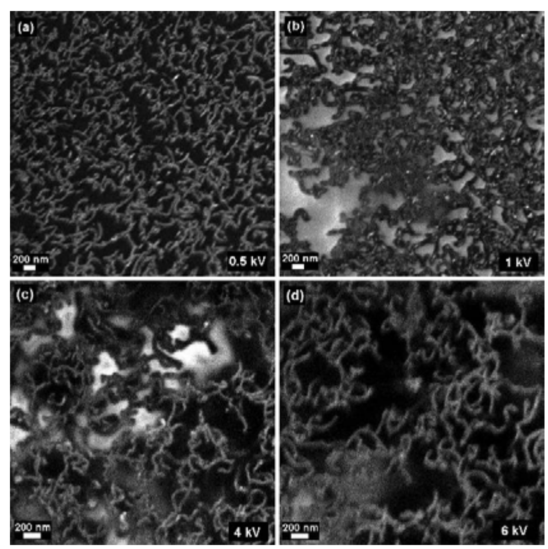

Fig. 4 Energy-dependent charge contrast inversion of CNT in epoxy resin around $E_0 \lesssim E_0^{II}$, E_0=0.5; 1.0; 4.0; 6.0 keV.

https://doi.org/10.1017/S1431927609092162 Published online by Cambridge University Press