Variation of Proximity Effect Correction Parameters with Density

David A. Czaplewski, Leonidas E. Ocola
Center for Nanoscale Materials, Argonne National Laboratory, Argonne, IL 60439
dczaplewski@anl.gov, ocola@anl.gov

We present measurements of the backscattered range and coefficient for proximity effect correction for several materials and have found an inverse relationship with material density that can be used to predict PEC parameters for any substrate with a known density. These results will be very useful for researchers that work with unconventional materials such as complex oxides, II-VI or III-V materials, and multilayer heterostructures.

Proximity effect correction (PEC) for electron beam lithography has been used to ensure high fidelity pattern creation of structures ranging in size from microns down to nanometers. The parameters used in the PEC finite element analysis (FEA) have been measured since the early 1980s [1]. Recently, the values used in PEC have been measured with an accuracy of 0.2% [2]. The method used to determine the parameters to this accuracy is independent of processing variations. A set of tori are patterned on the substrate with varying inner radii and a fixed outer radius. At the center of the tori patterns, a 100 nm line is patterned. The doses of the tori, with various inner radii, are adjusted until the thickness of the inner line is constant for all tori radii. The dose adjustments as a function of inner tori radii are fit using a least squares method to obtain the backscatter range. To measure the backscatter coefficient, the thickness of the inner pattern for two different tori doses is measured and converted to dose using the contrast curve for the resist.

One problem with PEC adjusted patterns is that they are substrate dependent. The values used in the PEC correction for silicon substrates are different than the values used for GaAs substrates. Finding values of PEC parameters in literature that covers the range of materials is difficult. However, in this work, we present data that should provide a way to calculate the values for all materials encountered in electron beam lithography. Using the above described method, the backscatter range and coefficient of 100 keV electrons were measured for substrates such as Si (density = 2.3 g/cm^3), GaAs (density = 5.3 g/cm^3), and Cu (density = 8.9 g/cm^3). The dose assignments versus inner tori radii are shown for Si and GaAs. We find that the backscatter range (Fig. 2) is inversely proportional to the density of the material; this is consistent with the increased stopping power of higher density materials. The functional form of this data can then be used to predict the backscatter range and coefficient for different materials with densities in this range. The data range will be expanded to include materials with higher densities such as Au or Pt.

---

[1] L. D. Jackel, R. E. Howard, P. M. Mankiewich, H. G. Craighead, and R. W. Epworth, Appl. Phys. Lett. **45**, 698 (1984).
[2] D. A. Czaplewski, L. E. Ocola, Appl. Phys. Lett. **99** 192105 (2011).

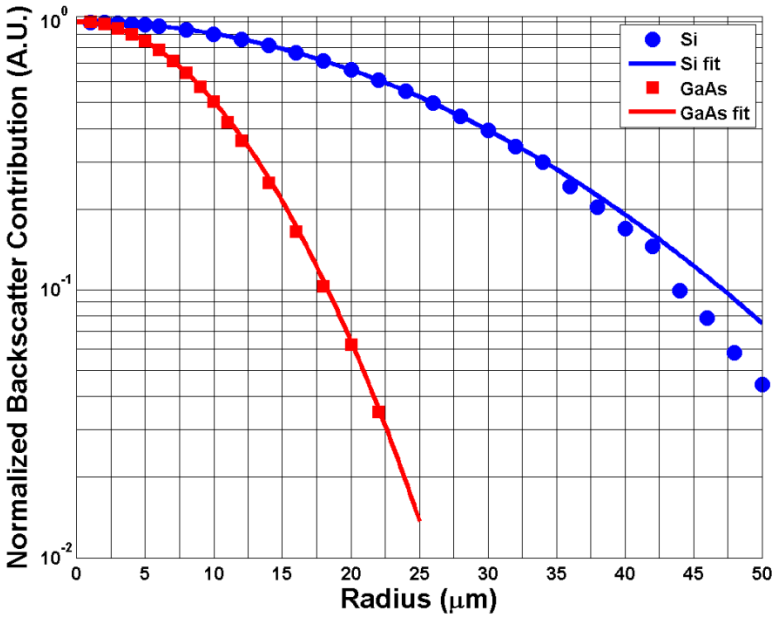

Figure 1: Graphs showing the contribution of backscattered electrons as a function of radius for silicon and GaAs.

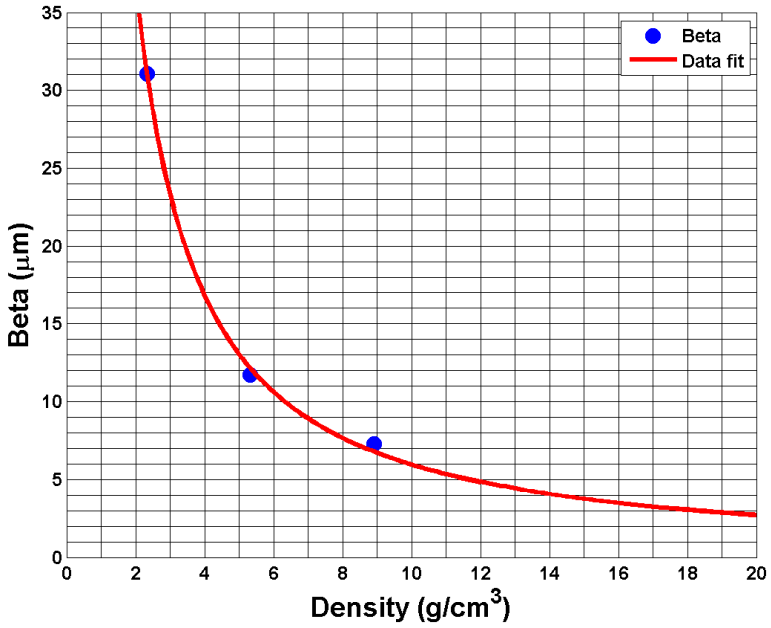

Figure 2: Graph showing the backscattered range (beta) as a function of density for Si, GaAs, and Cu substrates.

Use of the Center for Nanoscale Materials was supported by the U. S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357.