Using TRACER to Estimate the Base-Dose for Different Substrates

When first applying an established resist process to a different substrate material stack, it is necessary to determine a new base dose (the base dose of a process is defined as the required dose to expose a large grating at 50% density and remove the photoresist). Running a full dose matrix to determine the new base dose consumes time and resources. However, TRACER can be used to predict the relative change in base dose needed for different substrates for the same resist process; this can save significant experiment time.

INTRODUCTION

The point spread function (PSF) describes the energy deposited into a resist layer as a function of distance from the beam incident position. This is dependent largely on the substrate material and the beam energy. The primary function of TRACER is to compute the PSF for a given set of conditions using the Monte Carlo simulation method (see Fig. 1). An exemplary PSF is plotted in Fig. 2, showing the energy absorbed for a 100 keV electron beam in a 500 nm thick layer of PMMA on a silicon substrate.

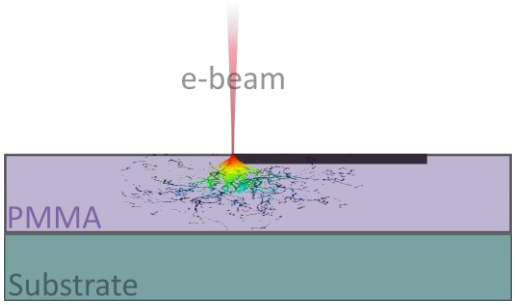

Figure 1. Electron beam exposure on a stack of PMMA on a substrate.

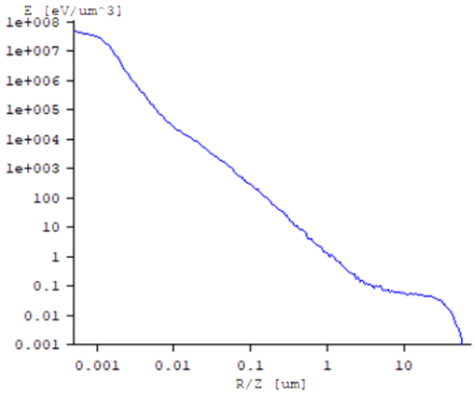

Figure 2. Point Spread Function of 100 keV beam in 500 nm thick layer of PMMA on Silicon.

Mathematical integration of the PSF over all area yields the total energy absorbed by the resist:

$$E_{PSF} = \int_0^\infty E(r) 2\pi r \, dr \qquad [1]$$

and for a given resist process, this total energy will be proportional to the Dose-to-Clear. This can be used to predict the relative change in dose needed for different substrates for the same resist process. This capability is found in TRACER's *Dose Factor* computation function.

USAGE EXAMPLE

In the following example, we will use this relationship to compute the Base Dose for the new substrate material in comparison to a former process with a different material. Using TRACER, the PSF shown above can be easily calculated; in this case, our former process makes use of the PSF for a 500 nm thick layer of PMMA on a Silicon substrate, exposed at 100 keV. For this process, let us say we have determined that a usable Base Dose is 600 $\mu C/cm^2$.

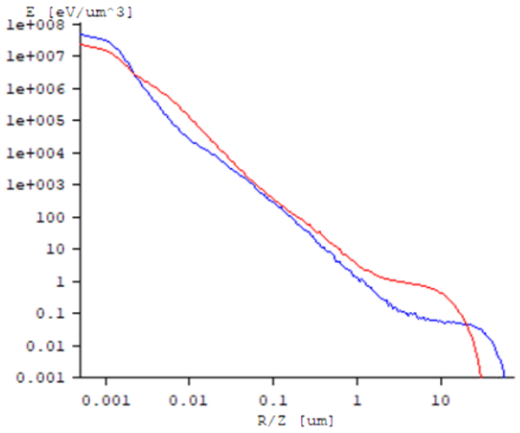

Figure 3. PSF comparison on Silicon substrate (blue) and GaAs substrate (red).

Now, what if we wanted to use this same PMMA resist process, but on a GaAs substrate? Again, this PSF is easily simulated in TRACER, and is shown in Fig. 3, in red. Let us use TRACER to determine the relative Base Dose Factor between the two PSFs representing these two different substrate materials:

1) Start with two (or more) PSFs open in TRACER, and both displayed, as indicated by the checkmark on the left side next to the name (see Fig. 4). Select the base PSF, then right-click on that PSF. Dose factors will be calculated relative to the PSF we choose; since we know the Silicon exposure conditions, we'll use that as our base PSF.

Figure 4. Two PSFs selected in TRACER. The Silicon PSF is highlighted as the base PSF.

2) In the contextual menu, choose *Dose Factor*:

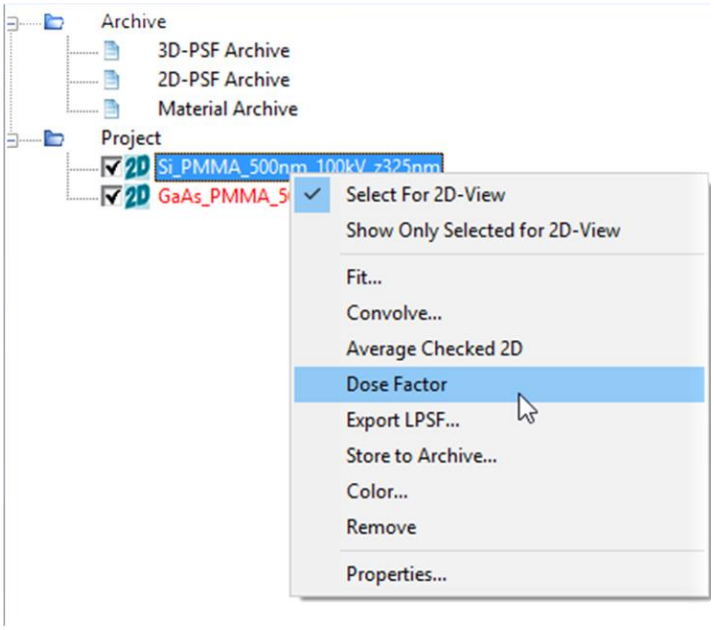

Figure 5. Right-click to select the Dose Factor calibration.

3) In the box that is displayed, we see the relative dose factors for all enabled (checked) PSFs. In this example, our GaAs substrate will use a Base Dose approximately 0.788x times that of the Silicon wafer. If our Silicon used the Base Dose of 600 µC/cm^2, then a good estimate of the Base Dose for GaAs is 0.788x600 or 473 µC/cm^2 (see Fig. 6).

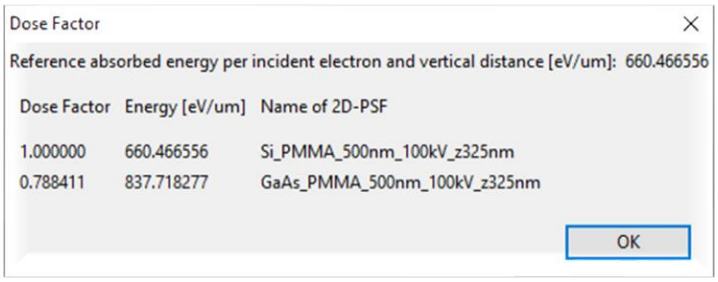

Figure 6. GaAs requires around 0.78 of the Base-Dose of reference.

ACKNOWLEDGEMENTS

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[1] The initial explanation of the Point Spread Function is due to T.H.P. Chang, JVST **12**, 1271 (1975).