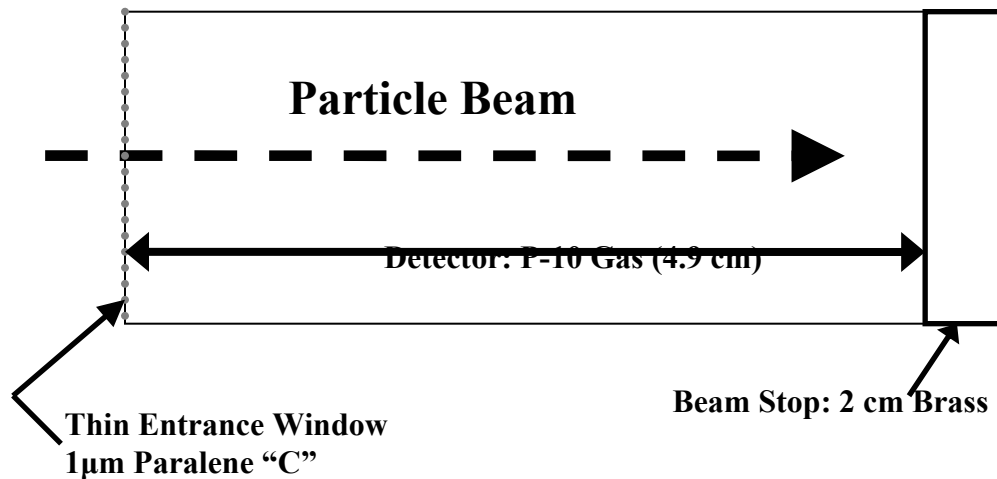# .   *Tutorial #3 – Building Complex Targets*

.   *Mixed Gas/Solid Targets – Gas Ionization Chamber*

Previous Tutorials have covered how to setup TRIM, determine which ion and energy to specify for a semiconductor n-well implantation, and how to evaluate the damage during an implantation into a semiconductor. This Tutorial will show how to build a complex target: a Gas Ionization Detector for energetic ions with both Gas and Solid volumes.

Particle Beam

Detector: P-10 Gas (4.9 cm)

Beam Stop: 2 cm Brass

Thin Entrance Window
1μm Paralene "C"

The apparatus consists of a long cylinder. It has a very thin entrance window, on the left, made of a polymer called Paralene "C". This thin film is only 1 μm thick, and it allows the beam to enter the detector with minimal energy loss. The detector itself is made of a special gas called P-10, which is a mixture of 10% Methane (CH_4) and 90% Argon. The argon is ionized by the particles, and the ejected electrons are swept off by electric fields (not shown). There is a chance that the stream of ionized gas might lead to breakdown, and the 10% methane "quenches" any excessive charge buildup. Finally, there is a "Beam Stop" at the end. The beam should stop entirely within the P-10 gas, but a thick end plate is usually included for safety.
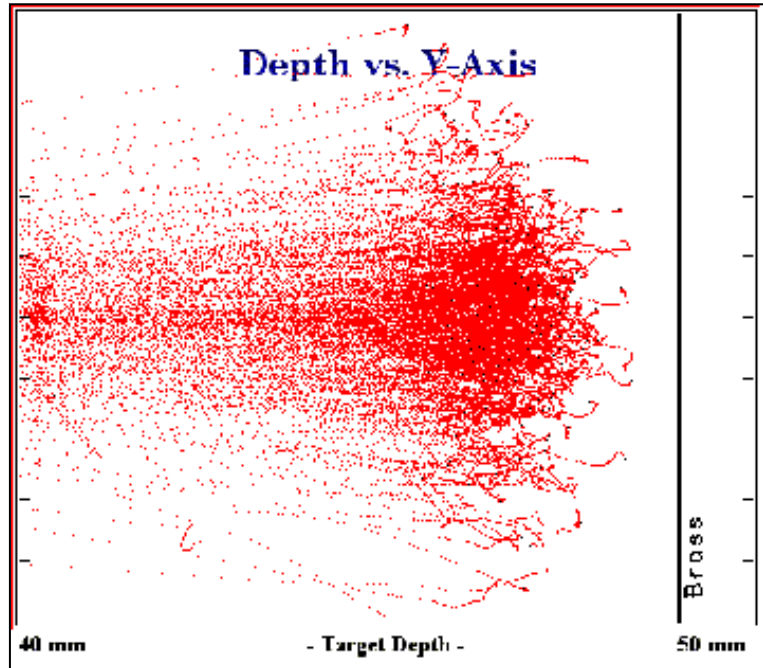
We wish to build this detector in SRIM so that we can evaluate what happens when a beam enters the detector. This is an exercise in building a complex target, and we are only using the detector as an example.

Start SRIM by clicking on its icon.

- Select TRIM Calculation

- In the upper left, press **TRIM Demo**

- Select the target at the bottom of the 2nd column:

   He (5 MeV) into Gas Ionization Detector

- Press **Save Input and Start TRIM.** You may get a warning about the target density. Press **Yes** to keep the value suggested.

- TRIM starts using this target

This setup will give you the target details of a Gas Ionization Detector. Several things to note:

o The ions all stop just before they reach the brass Beam Stop at the bottom.

o The plot shows only part of the target. Note the abscissa shows depths from 40 mm to 50 mm. That is, you have expanded this deep part of the target so that you see the final ion paths in greater detail.

o The thin entrance window is not shown. It is there, but when we expand the deep section, this first layer no longer shows on the plot.

You might look at several of the calculation plots. There are no recoils or sputtering atoms because we have omitted these for this calculation. When you are done looking at plots, **close TRIM without saving the data**. This puts you back in the TRIM setup screen.

We shall build an identical setup manually to show how to build a complex target in TRIM. Down at the bottom of this window is a button to clear all entries. Press **Clear All**.

Enter the **ION DATA**:

• In the line called Ion Data, enter Helium, atomic number 2. You may use the **PT** button.

• Enter the Ion Energy (keV) as 5000 (5 MeV)

• The angle of incidence is "normal" so leave this angle as zero.

Enter the **TARGET DATA.** The target will have three layers: the surface thin film, the long cylinder of gas, and the brass Beam Stop.

• The first layer is a plastic film made of Paralene "C". There is a short-cut for entering this complex material. On the right of the TARGET DATA is a button called **Compound Dictionary**. Press this.

o Listed in this directory are more than 300 compounds. Paralene "C" is a trade name, and you either have to know its real name or else look through the long listing of trade names. Click on *PLASTICS / POLYMERS*.

o The listing expands, and down this list you will find: "*Polychloro-p-xylylene / Paralene-C*". Note that the listing tells you that it contains C_8H_7Cl, and it has a density of 1.289. In the yellow window in the bottom is a long description of the material, including a chemical diagram of its structure. (If the yellow window contains weird characters, then the font *Linedraw* has not been installed on your computer. See note at end of this lesson.) **Important**: the description includes a correction for the stopping of He ions in

this substance, +3.5%, based on the bonding of the compound. Select Paralene-C by clicking on it. Then press the button **Add to Current Layer**. You will be asked if you want to use the Stopping Correction for this compound. Answer **Yes**

- You will see that Layer #1 is fully filled in. The layer is now described as Paralene-C, and the atomic structure is included. The only item left is the *Width*, which is 10000 Angstroms. This is the default, so for a 10 μm thickness it does not have to be changed. We can now construct the second layer.

- Press the button **Add New Layer**. You will be asked for a short Layer Name. Enter: **P-10 Gas**

- We will construct this gas directly. Go to the right part of the TARGET DATA window and get the Periodic Table by pressing **PT**. Find **Ar** and click on it. The first element is specified as argon.

- We now need to add Methane to this gas. Press the button **Add New Element to Layer**. For this second element, again press **PT**. Select **H** and click on it. This enters hydrogen as part of the target.

- Press the button **Add New Element to Layer**. For this third element, again press **PT**. Select **C** and click on it. This enters carbon as part of the P-10 Gas.

- Now we have to specify the amounts of each. P-10 gas is 90% Ar and 10% methane, CH_4. These percentages are by weight, and SRIM uses atomic percents. Use the relative number of atoms as: *Ar:64, C:7, H:29*. Find the target column labeled **Atom. Stoich**. Enter the stoichiometries of the three atoms, placing **64** next to Argon, **29** next to Hydrogen, and **7** next to Carbon. SRIM will automatically normalize these to the correct ratios.

- Next, on the left side, for this second layer (***P-10 Gas***), there is a small box marked **Gas**. You need to check this box. This modifies the stopping calculations since gases have higher stopping powers than solids. Now we need to change the layer **Density (g/cm^3)**. SRIM calculates a density assuming a solid. However, P-10 is a gas. Change the Density to read: **.00125**.

- The last item to enter is the target width. We wish this width to be 49 mm. There is a drop-down menu next to the *Width* column. Click on this and specify "***mm***". Then under Width, enter: **49**.

- Press the button **Add New Layer**. You will be asked for a short Layer Name. Enter: ***Brass***

- To simplify this entry, again open **Compound Dictionary**. Click on ***METAL / ALLOYS***.

- Find the entry ***Brass (typical).*** Click on this. Then click on **Add New Element to Layer**. You will be asked if you want to add "Brass to *Brass*". It is asking you if you want to add Brass to the current layer, which you called *Brass*. If you say NO, then you could place it in a different layer. But we wish to include it in the 3rd layer, called *Brass*, so press **YES**.

- Brass contains Cu, Zn and Pb. All the details are filled out for you, except the layer width. Go to the *Width* column, and enter *2.5 mm*. Remember to pull down the units menu to specify "**mm**".

This completes the setup for the calculation. Note that we have not changed the "***Type of TRIM Calculation***" at the upper right of the window as we did before (Lesson #2). We are using

"Quick Calculation of Damage" for now since we want to see what happens when we run the calculation. Specifically, we are not sure that we have made the gas thick enough to stop all the ions, and we will run TRIM to see what happens and then adjust the dimensions.
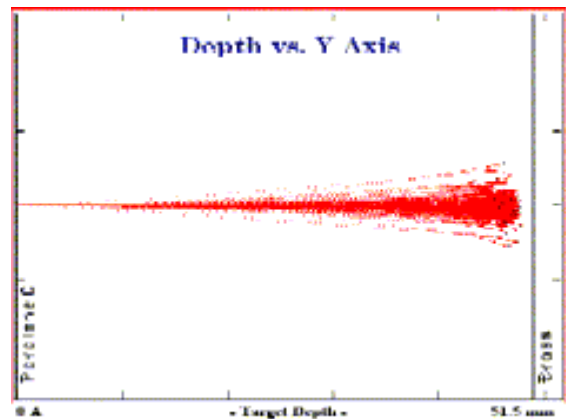
You have completed the entry of a target with three layers and a total of nine elements. Good job!

Press **Save Input and Run TRIM**.

You should see a plot that looks like ➔➔➔

If you don't see this, you have put in a wrong entry. You must go back to the beginning and review all the entries.

When you get this plot, you will then modify the calculation to see more details.

- Press **PAUSE** at the top of the TRIM window.

- Press **Change TRIM**.

- We want to see the details at the very end of the range of ions. To do this we will expand the window of the plot. On the left hand side you can find a table called *PLOT Window*. Under this are the numbers **0 A - 515010000 A**. This means that the plot shows the target from the surface, 0 Angstroms, to the deepest target point, 51.5 mm. Change the *left window* to read 40 mm = **400000000 A** (there are 8 zeroes). Change the right window to read 50 mm = **500000000 A**. (8 zeroes). This will make a window that concentrates on the very end of range.

- At the top of the window, press **End Edit**. A window will pop up saying that you will have to restart TRIM. Press **YES**.

- Press **Continue** . TRIM should restart. [There is a chance of a crash. If so, you will be put back in the TRIM Setup window. Just press **SAVE Input and Run TRIM**. Then repeat the above commands to change the plot-window depths.]

At this point your plot should be identical to that of the DEMO that you executed. Note that the ions are well behaved until the very end of their travel. Their initial high velocity prevents strong interactions with the target. Conduction electrons in a target have velocities equivalent to about 25 keV/amu (the velocity of He ions at 100 keV, since He ions have a mass of 4 amu). This is energy that has the maximum strength of interaction between He and the target electrons. The interactions between He and the target nuclei are only significant below this energy. So the He beam remains tightly focused until the He energy drops below 100 keV, or 2% of its original energy of 5 MeV.
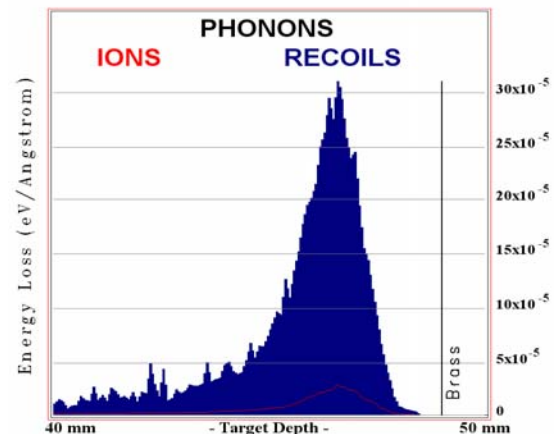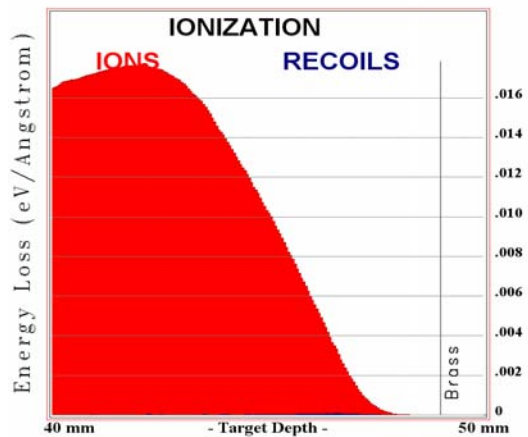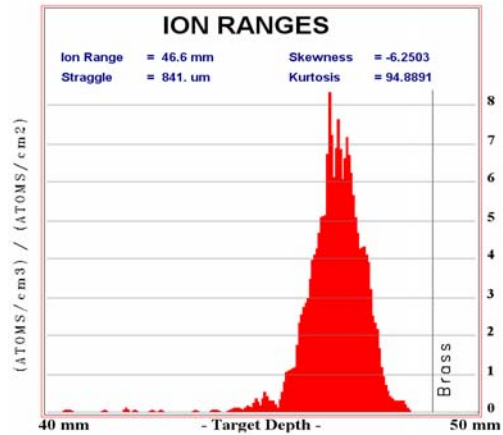
Let's look at a couple of plots. Press Pause TRIM ,

- Click on **Ion Distribution**. You will see a nice Gaussian shape, centered on 46.6 mm. It is very narrow with the straggling being less than 2% of the depth.

- Click on **Ionization**. This plot shows the energy dissipated to target electrons. Note that at the very bottom of the plots is the tiny ionization contribution from the recoils (blue line). More than 99% of the energy loss to electrons is by direct interaction with the ions.

- Click on **Phonons**. This plot shows the exact opposite trend for the production of target phonons. The target recoils now dominate this energy loss. However, one should note the units on the ordinate. The phonon energy loss is about 1% of the ion's energy loss to the target electrons. In fact, the contribution of the recoils to the target electrons is about the same as to phonons (loss to the target atoms). The energy loss by the ions to phonons is almost zero (see faint red dotted line on plot). If you look at the table on the right of the window called **"%
ENERGY LOSS"**, you will see the relative distribution of energy loss. Direct losses to the target electrons accounts for 99% of the ion's energy loss, and everything else is rather insignificant.

You are now done with this example. Close TRIM. When asked to SAVE the calculation, answer **YES**. Save the calculation in the ***Default SRIM Directory***.

When you return to the TRIM setup window, press **Clear All** to begin a new session.

You may restart the last calculation by clicking on the small box in the lower-right marked "**Resume saved TRIM calc**". Try this now. When asked, say "**Restore TRIM from SRIM Directory**". A new box will pop up showing where you stopped the last calculation. Press OK.

Now resume the calculation by pressing the pink box: Resume Saved TRIM. The calculation will resume where it last left off. The plot of the ions will start over, since this plot is not saved. (If you get an error message, try this step a second time.)

NOTE: Only the last saved TRIM can be restored unless you save the calculation in a location different from the SRIM default location, the SRIM subdirectory: "**../SRIM Restore**". If you save it elsewhere, you can always restart the calculation from its last point.

. *Special Notes about the TRIM Setup Window*

- At the lower-left is a command "*AutoSave at Ion #*" with an entry box. TRIM automatically saves the calculation after a certain number of ions. Often, TRIM is run overnight, and this feature makes sure that some information is saved even if there is a power failure. The default is *10,000* ions. You can see what has been calculated by using the command Resume Saved TRIM.

- Next is the command *Total Number of Ions* (default = *99999*). This command is useful to compare identical calculations with slight ion or target differences. When the calculation finishes the complete set of ions, it saves the calculation and stops.

- Next is the command *Random Number Seed* (default = blank). It is possible for an artifact (weird event) to be calculated. For example, there may be only one chance in 10,000 that the ion will have a hard collision with a surface atom, creating a large cascade. If you want to save typical plots, sometimes these rare events make abnormal plots. Enter any number (*1* is OK) and you will get a totally different calculation. The default seed if no number is entered is 16381, which is a number of mythical reverence to those who delve deeply into random number theory.

Note: The font "*LineDraw*" is required to view some of the details of the TRIM setup program. If you find that part of the TRIM setup uses the wrong font, follow these directions.

You can find a copy of the missing font in the directory: *..SRIM 2003/Data/Linedraw.ttf*. All you need to do is to copy this file, *Linedraw.ttf*, into the system font folder: C:/Windows/Fonts. For Windows XP systems, the font will be automatically activated. In prior Windows systems, the Font directory may be in a different location, and you may have to manually activate the font by (1) moving the font *Linedraw.ttf* into the system font directory and (2) in Windows Explorer, double click on the font name. A window will open asking if you wish to install this font.