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Report on Radiation Damage Effects in a Titanium Target under Photon Irradiation

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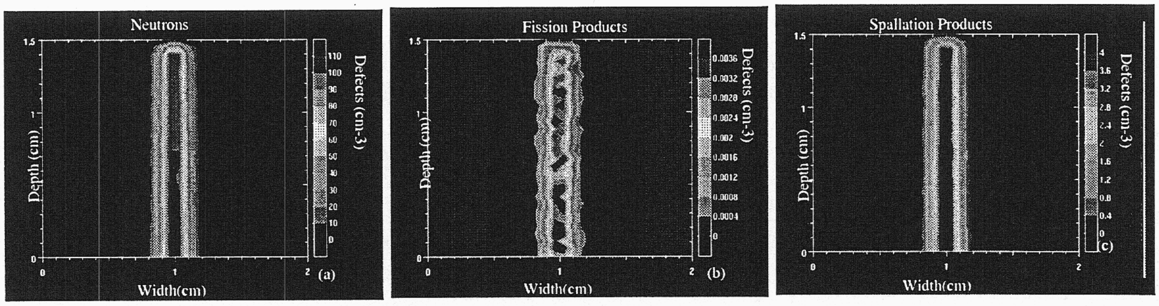

Figure 2: Defects per cm^3 due to (a) neutrons (b) fission products and (c) spallation products.

For comparison we show the total number of defects for the Ti target under photon irradiation together with the results of the NLC W-Re target under electron irradiation in Figures 3(a) and (b) respectively.

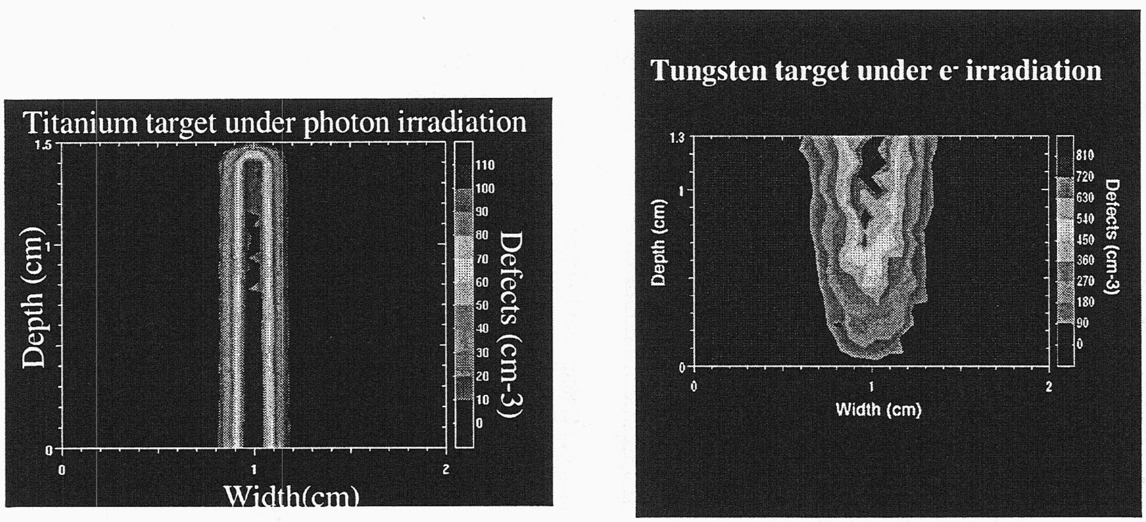

Figure 3: Defects per cm^3 produced (a) per photon in a Titanium target and (b) per electron in a W-Re target.

Several significant differences are observed between the irradiation with electrons and with photons. In the case of electrons most of the damage is produced at the back surface of the target, due to cascade effects. In the case of photons the damage is higher in the front surface and there is no much dispersion. The maximum number of defects per incident electron is larger than the maximum number of defects per photon, (~8x higher defects in the electron irradiation).

Report on Radiation Damage effects in aTitanium Target Under Photon Irradiation

M.J. Caturla, 08/30/02

Following the same approach as with the W-Re targets [1], we have calculated the damage induced by photon irradiation (22.1 MeV average energy) in titanium targets. Stefan Roesler calculated, using FLUKA [2] the spallation products, neutrons and fission products from the interaction of the photons with the titanium target.

Using these initial values of energies and positions, we calculated the number of defects produced per incoming photon. It should be noted that the threshold displacement energy for defect production of Titanium as measured experimentally is between 21 and 30 eV [3]. We used a value of 25eV. This is a much lower value than for the case of W-alloys (90 eV) which implies a larger defect production for the same deposited energy in the case of Titanium.

The number of defects for different neutron energies was calculated using SPECTER [4] Figure 1(a) shows the number of defects as a function of energy for the case of Ti as compared to W, in Figure 1(b). The number of defects is much larger in the Ti case due to the low threshold displacement energy as explained above.

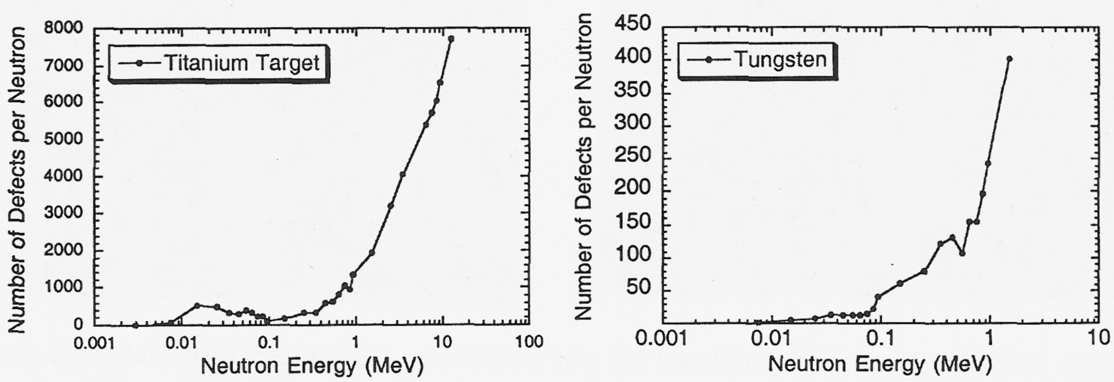

Figure 1. Defects per Neutron as a function of neutron energy as obtained by SPECTER for (a) Titanium and (b) Tungsten.

The contour plots of the number of defects for the width (0.75 mm spot radius) and depth (1.5 cm) of the target are presented in Figure 2, for the case of (a) the defects produced by neutrons, (b) defects produced by spallation products and (c) defects produced by fission products. The number of spallation and fission products in this case is very small and only the neutrons produce a significant amount of defects. This was also the case in electron irradiation and W targets but it is even more pronounced in this case.

We have calculated the total damage produced in the titanium target for 1 year operation, considering that 1 spot receives 1 pulse per second with 190 bunches per pulse and a 1.1×10^{12} photons per bunch. This results in a total of 6.59×10^{21} photons/year. As a comparison, a W-Re target spot receives 1.22×10^{20} electrons in 3 years for the NLC configuration. The dose in a year in the Ti target is 54x higher than the dose in the W-Re target in 3 years. From the analysis above, the damage per photon is only 1 order of magnitude smaller than the damage per electron. This lower damage does not compensate for the higher dose that this target will receive, resulting in a much higher damage level in the Ti targets. Figure 4(a) shows the damage for the Ti target in a year as compared to the previously calculated damage in the W-Re target for the NLC configuration in 3 years (Figure 4(b)). The damage is calculated in DPA (displacements per atom). The DPA is calculated as:

[number of defects per photon (defects/cm^3) x dose (number of photons)] / density (atoms/cm^3).

The density used for Ti in these calculations is 5.6×10^{22} atoms/cm^3.

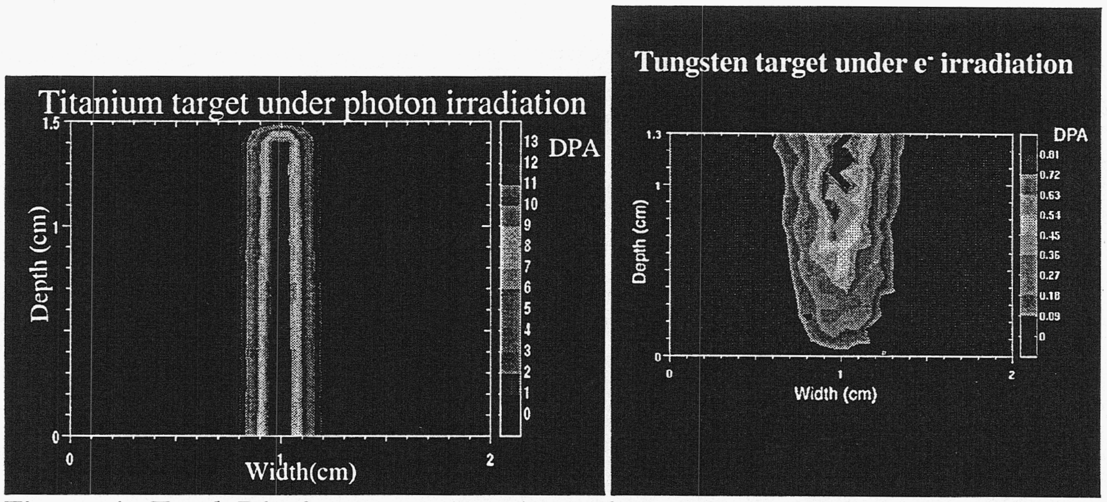

Figure 4: Total Displacements Per Atom for a (a) Titanium target under photon irradiation for 1 year and a (b) W-Re target under e-irradiation for 3 years.

The maximum DPA expected in the Ti target is on the order of 13 dpa while the W target maximum values obtained were below 1 dpa. Values near 1 dpa have been shown to result in material damage and brittleness in SLAC W-26%Re material targets .

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References:

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