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Depth Resolved Measurements of Atomic Scale Defects in Ion Irradiated Fe Alloys

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Positron annihilation spectroscopy has been established as a powerful tool for measuring atomic scale defects with high sensitivity as well as characterizing them and distinguishing between isolated vacancies, dislocations and vacancy clusters [1]. The pulsed mono-energetic positron beam (MePS) recently developed in Dresden, Germany provides a unique tool for depth resolved measurements of positron annihilation lifetime spectroscopy in metals. In this study we used MePS beam to study defect production and evolution in ion irradiated Fe and Fe alloys. Both Positron annihilation lifetime spectroscopy (PALS) and Doppler broadening spectroscopy (DBS) of annihilation radiation were carried out to provide qualitative and quantitative information about the size and density of radiation induced defects.

From PALS measurements the defect density was calculated and plotted in Fig. 1 as a function of depth and irradiation dose in pure Fe-films deposited on SiO_2 substrate and irradiated with Fe ions. The figure illustrates the change of the vacancy cluster size and density with increasing irradiation dose. Following irradiation the preexisted mono-vacancies in the films combined together and formed small vacancy clusters of 2-4 vacancies, while the original vacancy clusters have increased in size and formed larger clusters of 10-15 vacancies.

The effect of alloying Fe with 8% and 18% Cr on defect formation and accumulation was investigated by DBS measurements. The defect parameter S which represents the fraction of positrons annihilating with valence electrons, was evaluated from the measurements and presented in Fig. 2 as a function of depth, irradiation and Cr content. Since the increase of S-parameter is an indication for the increase of defect density, Fig.2 illustrates that the density of radiation induced effects decreases by alloying and the film with 8% Cr exhibits the lower defect density. PALS measurements revealed more details on the effect of alloying on the number of single vacancies, clusters and their accumulation and will be discussed. This work shows that by using PAS, one can detect single vacancies which cannot be seen by most techniques and monitor their accumulation or annihilation. The measurements also reveal the effect of alloying on defect formation and propagation.

[1] Krause-Rehberg R, Leipner HS. Positron annihilation in semiconductors: defect studies. Springer Science & Business Media; 1999.

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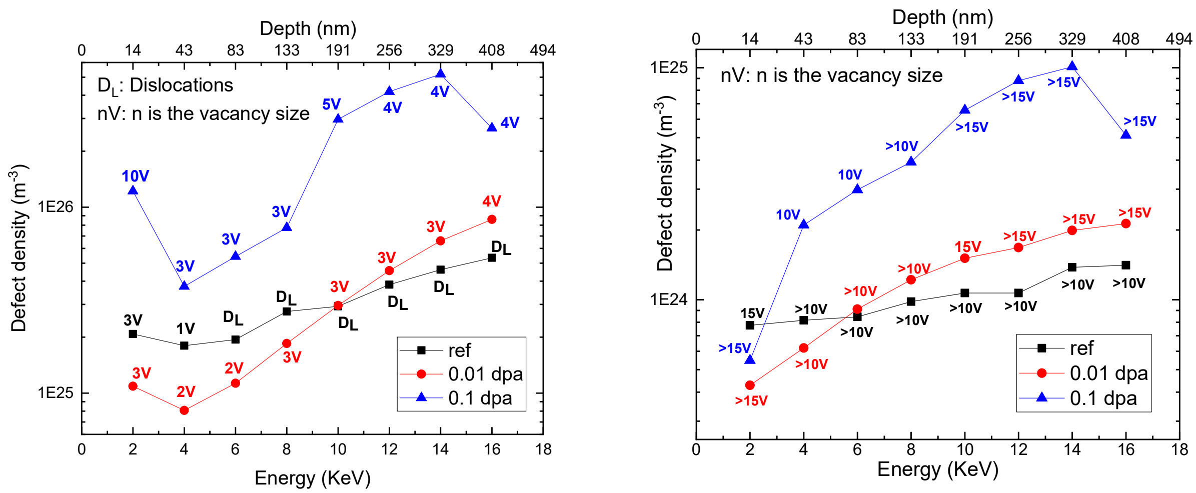

Vacancies and small clusters Large vacancy clusters

Figure 1. Defect Density of original defects and ion irradiation induced defects in pure iron film as a function of depth and irradiation dose. The lower x-axis represents positron energy.

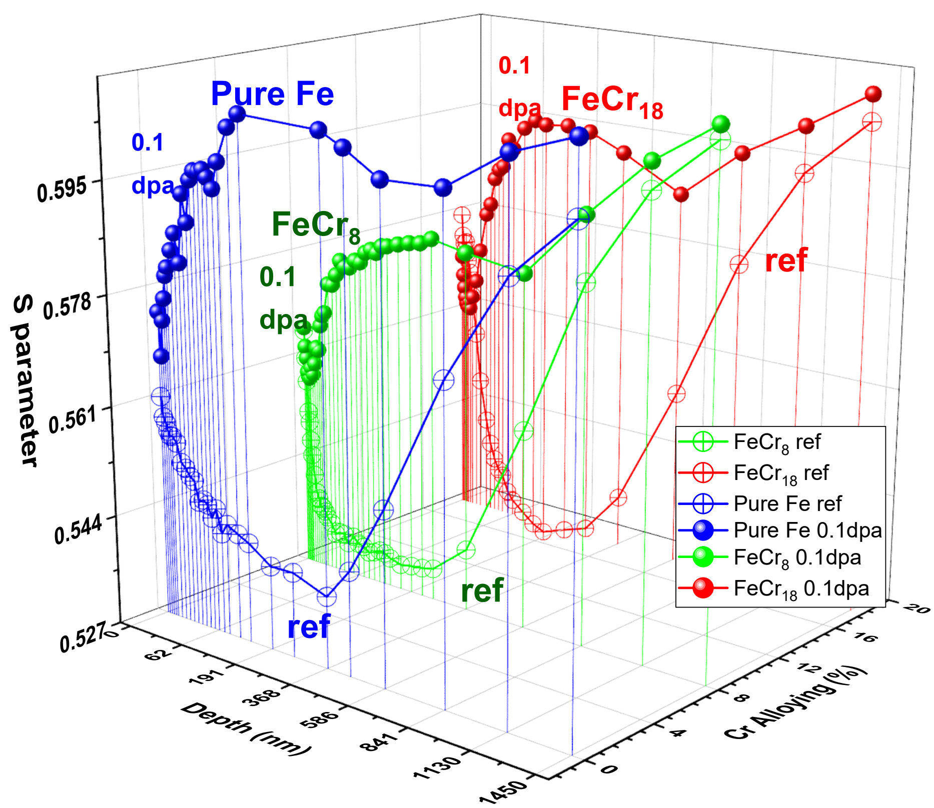

Figure 2. Depth resolved measurements of defect parameter S in reference and ion irradiated films of pure Fe, Fe-Cr (8% Cr), and Fe-Cr(18%). It shows the effect of alloying on reducing defect density.

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