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Irradiation Induced Effects In Nanocrystalline Materials

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Abstract:

Materials used in irradiation environment need to have specific properties. Nanocrystalline materials seem to have better response to irradiation than micro- or polycrystalline materials. Particle radiation is able to influence the defect structure and phase stability of structural or functional materials. Therefore, defect formation and stability have been studied systematically on nanocrystalline ceramic (ZrO_2) and metal (Pd) samples.

Experiments focusing on defect formation in nano and course grained ZrO_2 and Pd showed agglomeration of defect clusters (vacancies or interstitials) triggered by heavy ion irradiation. The density of the clusters clearly depends on temperature and grain size. A dependence on the ion dose was also observed. Near grain-boundary areas free of defects were observed. From the evaluation of the defect free regions different diffusion mechanisms could be determined. Electron irradiation experiments were also performed to investigate a different process of defect cluster formation. In this case, defect clusters could not be formed immediately by the irradiation, but only after short-range diffusion. This is a consequence of the lower displacement rates of the atoms during electron irradiation.

Additionally, systematic experiments have been performed to investigate the phase stability of the, for many applications important, tetragonal phase of nanocrystalline ZrO_2 samples after the unexpected phase transition from monoclinic ZrO_2 to tetragonal ZrO_2 under heavy ion irradiation at room temperature. A dependence of the relative volume of the tetragonal phase on the ion dose was observed. In order to investigate the thermal stability of the tetragonal phase, heat treatments of similar samples have been performed up to 1300℃. For samples that had been irradiated with high doses ($1 \cdot 10^{16}$ ions/cm^2 and higher) the tetragonal phase was stable up to 900℃ which is in good agreement with the sintering temperature. At higher temperatures a residual content of the tetragonal phase of less than 5% was observed. Significant grain growth could be observed only in the case of Pd after the irradiation procedure.