KYOTO UNIVERSITY
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INTEGRATED
MATERIALS SCIENCE

京都大学グローバル COE 講演会

日　時　：　2011 年 1 月 28 日（金）11:00～12:00

場　所　：　吉田キャンパス 物理系校舎 527 セミナー室

Atomic defects in ultrafine grained metals: Direct and specific studies for their characterization and their kinetics

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A complex atomic defect structure is responsible for the structural refinement and the enhanced mechanical properties of massive, ultrafine-grained metals as for example obtained after severe plastic deformation. The atomic defects comprise vacancies, vacancy clusters, dislocations, stacking faults, and grain boundaries. Every defect type is associated with a specific atomic volume also resulting in a macroscopic volume change of the solid, i.e., reduction of the mass density in comparison to its ideal counterpart [1]. The absolute concentration can be obtained by macroscopic dilatometric measurements and the different types can be distinguished due to their different annealing kinetics. It will be demonstrated that a combination of the atomistic technique of fast *in-situ* temperature dependent positron-electron annihilation and macroscopic dilatometry is a most promising way to unambiguously identify and analyse the different defect types. A study of fast defect annealing with the specific method of positron–electron annihilation was realized with the high-intensity positron beam at the NEPOMUC positron source of the research reactor FRM II (Garching, TU München, Germany) [2]. This is a first study of its kind and was combined with macroscopic, high-precision length-change measurements. The combination of these two *in-situ* methods on short time scales was applied in a comprehensive study also including calorimetry, resistometry, and electron microscopy on pure Cu, Ni and Fe after severe plastic deformation by high-pressure torsion to elucidate the basic atomistic mechanisms of grain refinement, vacancy annealing, and also removal of dislocations and recrystallization. High concentrations of athermally produced vacancies were found and the recrystallization kinetics was determined. Furthermore, it seems possible that the specific atomic volumes of vacancies and grain-boundaries can directly be determined from the results.

[1] B. Oberdorfer, B. Lorenzoni, K. Unger, W. Sprengel, M. Zehetbauer, R. Pippan, R. Würschum, Scripta Materialia **63**, 452 (2010) .

[2] B. Oberdorfer, E-M Steyskal, W. Sprengel, W. Puff, P. Pikart, C. Hugenschmidt, M. Zehetbauer, R. Pippan, R. Würschum, Physical Review Letters **105**, 146101 (2010).

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