Physical properties of Henanobubbles investigated by EELS

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Cavities (filled or not) are extended defects usually resulting from the incorporation of inert gas or hydrogen in solids by high fluence implantation or transmutation reactions in nuclear reactors. While these defects are of major interest in several domains, from materials for microelectronics and energy, to more fundamental fields (study of plasmon excitations or nanofuidics), there are serious gaps in the understanding of their mechanisms of formation and evolution under external solicitations such as thermal annealing or irradiation. Such an understanding is however the prerequisite to tune the characteristics of the cavities, which is essential for all applications. STEM-EELS has been shown to be an invaluable tool to investigate the physical properties of individual He bubbles embedded in metals or alloys [1 and references therein] and in elemental semiconductors [2].

In this work, we focus on the use of EELS to study the evolution of the physical properties of nanometricHe bubbles embedded in Si or Ge, under *in situ* thermal annealing or irradiation. We demonstratethat the He density can be modified in single bubbles by using the electron beam of a STEM as a multifunctional tool: a measurement probe for imaging and chemical analysis and an irradiation source to modify the He density(Fig.1) in a controllable way,depending on the electron beam parameters. Moreover, Hedetrapping from bubbles under *in situ*electron and ion irradiation are compared and the underlying physical mechanisms are discussed; our experimental observations suggest thatHe detrapping could be interpreted in terms of direct ballistic collisions. In a second part, we focus on Hedetrapping during themal annealing. For that purpose, we are currently developing a method to determine He density in bubbles using EFTEM. Initial results have allowed us to establishconditions and procedures for the acquisition, treatment and extraction of data from thesamples. Density and pressure maps are obtained overseveral bubbles simultaneously (Fig.2). The *in situ* thermal annealing experiments clearly showHedetrapping from bubblesbetween room temperature and 800°C, and movement and shape alteration in the same range. Acquisitions were performed with various annealing temperatures and time steps, allowing for the detailed study of the bubble behaviorrelative to those parameters.

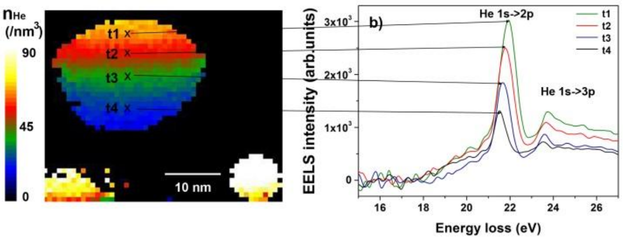

Fig. 1.He bubbles in Ge showing He detrapping under the electron beam.(a)He density map determined using STEM-EELS.(b) He-K edge extracted at different times in the largest bubble,

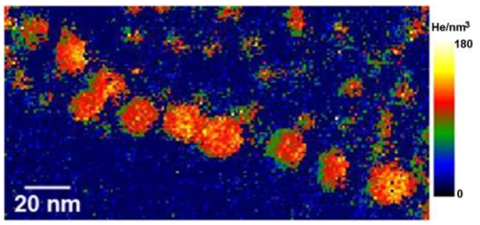

Fig. 2. He bubbles in Si. He density map determined using EFTEM after an in situ annealing at 500°C, 10min.

Références

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