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A Neutron Small-Angle Scattering Study of the HfPd System

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Abstract

The HfPd system exhibits a fast amorphization reaction. A series of specimens has been prepared by mechanical alloying (MA). X-ray diffraction (XRD) and small angle neutron scattering (SANS) were used to characterise the structural transformations during the amorphization reaction. Contrast-matching technique was used to isolate the powder surface effects and obtain the scattering from the bulk of the specimens. The structural transformations observed by the wide-angle measurements are reflected in the large-scale structure and this was detected by SANS. A strong SANS intensity profile is obtained for the parent specimen relative to those obtained for the MA treated specimens. More interesting is that the SANS intensity profiles for both the amorphous HfPd obtained by MA and that obtained by fast quenching (FQ) are almost identical, indicating similar structure on a large scale. However, the structure of particles within the amorphous phase obtained by MA is of more convoluted surfaces compared to those produced by FQ. Graphs of the log[I(Q)] vs. log(Q) are linear over a wide range of scattering vector Q indicating the fractal nature of the structure in these specimens. The fractal dimensions D were obtained as a function of MA time.

1. Introduction

Amorphous alloys prepared by mechanical alloying (MA) were reported for the first time by Koch et al [1] in NiNb system. Since then, a variety of amorphization reactions produced by MA have been observed in many other systems [2]. During the MA reaction, complicated processes occur such as the repetitive cold welding, destruction, deformation of crystallites as well as the interdiffusion of atoms among crystallites [3]. These processes produce random fluctuations in the atomic density of the samples investigated which should be detected by small angle neutron scattering (SANS). These severe structural transformations are of fractal nature [4]. We have recently studied the amorphization reaction in the $Hf_{63}Pd_{37}$ system prepared by MA technique. On an atomic scale the amorphization reaction in this system has been studied using X-ray diffraction (wide-angle) and differential thermal analysis (DSC) measurements [5]. This system was found to have a very fast amorphization reaction. A full amorphous phase was obtained after 6 h of MA time. Such a behavior was observed in some other early-late transition metal alloys [e.g. 6,7]. In the present work, we investigate the large-scale structure of $Hf_{63}Pd_{37}$ system by SANS. This was done to see whether the structural transformations observed on the atomic scale are reflected on the large scale, and if so a try was made to address the question about the nature of such transformations.

2. Experimental Procedure

The parent powders of hafnium (99.6 wt % purity), and palladium (99.9 wt % purity) were prepared. Samples of composition $Hf_{63}Pd_{37}$ were MA treated for 0 (parent), 0.5, 1, 2, 3, 4, 6, and 8 hours, in a hardened steel vial of a Spex Mixer/Mill Model 8001. Milling was carried out under an argon atmosphere to prevent oxidation. An extra $Hf_{63}Pd_{37}$ sample was prepared using Hf and Pd