Time-Resolved X-Ray Scattering Investigation of Al-Y-Ni Metallic Glass Crystallization

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Introduction

The discovery of high specific strength Al-Y-Ni metallic glass alloys[1,2] has spurred interest in their development and study. A lot of attention has been devoted to studying the crystallization behavior of these metallic glasses. These materials undergo different sequences of crystallization stages and phase transitions which strongly depends on their stochiometry, annealing rates and annealing times. This report summarizes our investigation of the crystallization of these materials as studied by time-resolved X-ray scattering.

Methods and Materials

This work is part of an ongoing project at McGill University to study high-tensile strength Al-rich metallic glasses[3-5]. These measurements were performed using a spectrometer optimized for time-resolved X-ray diffraction recently commissioned on the side station of 8-ID beamline. This 2-circle goniometer is equipped with a photo-diode linear array detector which can be used for acquiring powder diffraction measurements as fast as every 5 ms over a range of as much as 20° of 2θ. In-situ time resolved x-ray scattering provides an ideal tool to study these types of problems as we can quickly explore large regions of this phase space. The setup also allows to easily switch from the linear array detector to a sensitive point detector in order to measure conventional 2θ powder diffraction patterns. The alloys we studied had a composition of $Al_{85}Y_{10}Ni_5$ and were prepared by arc melting and melt-spinning to produce uniform ribbons 2 mm wide and ≈50 μm thick. These ribbons were mounted in a furnace equipped with a Be window covering approximately 200° in 2θ. The ribbons were heated by flowing a current of a few amps through them and temperature was monitored using a pyrometer. The samples were probed with monochromatic X-rays coming off a diamond (111) monochromator at 7.66 keV. The X-ray beam had a dimension of 0.6×0.9 mm^2 and a flux just above 10^{12} photons per second for a storage ring current of 100 mA..

Results

Figure 1 shows the temporal evolution of the X-ray scattering for a sample of $Al_{85}Y_{10}Ni_5$ which is being heated by a linear temperature ramp. It shows the transformation from the initial amorphous state of the metallic glass into three subsequent crystal phases. Figure 1 (a) is a false-color contour plot of the X-ray scattering intensity while Fig. 1 (b) shows instantaneous diffraction patterns taken at different intervals. The two main peaks in this figure are Al fcc peaks. The first transformation from amorphous to crystalline is clearly visible at t≈50 s. The following two transformations are easily seen at t≈230 s and t≈380 s where a diffraction peak at q=2.67 Å^{-1} appears and disappears.

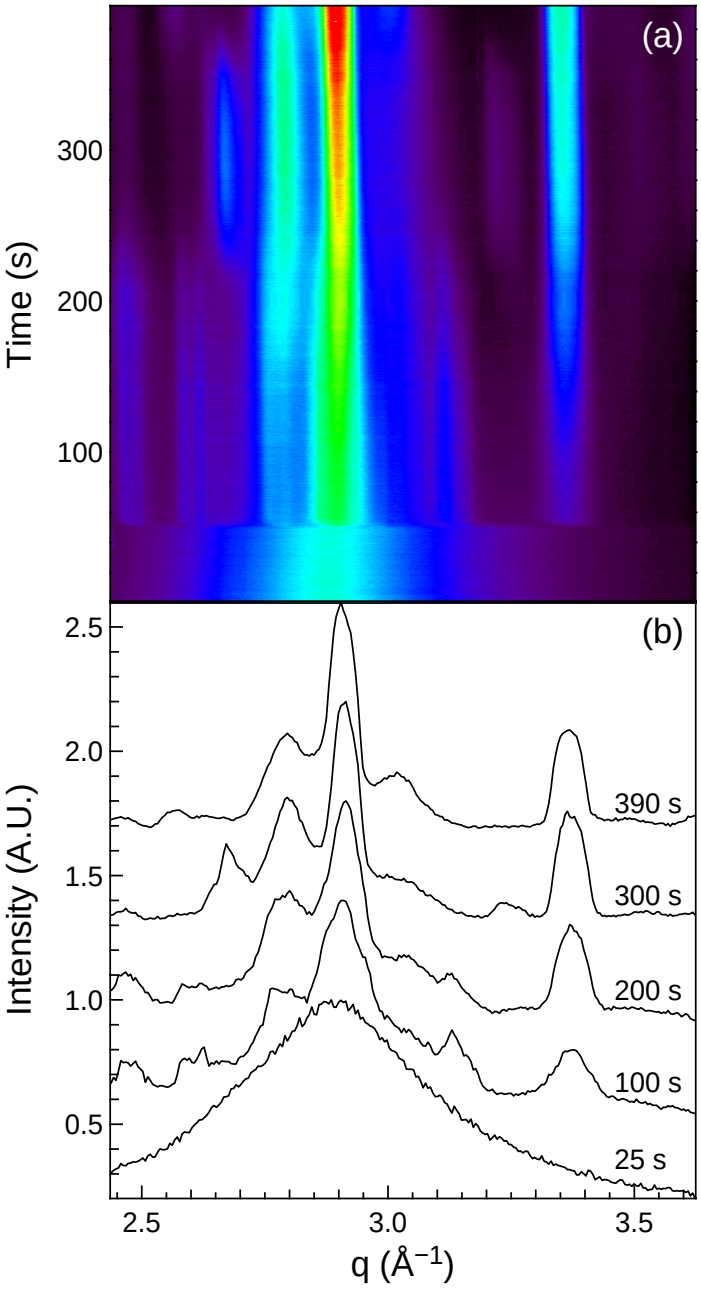

Fig. 1 Temporal evolution of the X-ray scattering for a sample of $Al_{85}Y_{10}Ni_5$ being heated by a linear temperature ramp. (a) false-color contour plot of the X-ray scattering intensity, (b) instantaneous diffraction patterns taken at different intervals.

The crystallization sequence for this composition are numerous and relatively complicated. To investigate these transitions further we have carefully followed the crystallization dynamics of one sample and quenched it as soon as a transition was observed. The linear array detector used to obtain time-resolved scattering patterns was then temporarily replaced with a sensitive point detector in order to measure a conventional 2θ powder diffraction pattern between 20 and 100° of 2θ. In total, we have observed that this sample goes through five different crystallization stages before reaching its final product. Figure 2 presents high-resolution powder diffraction patterns measured for each crystallization stage. Careful analysis of these patterns has confirmed that an Al_4Y phase appears briefly in the second stage and that the final crystallization products are β-Al3Y and $Al_{16}Ni_3Y$. However, the combination of higher resolution data with dynamic measurements of the first stage formation has revealed a more complicated scheme than expected. Analysis of this data is still underway at this point.

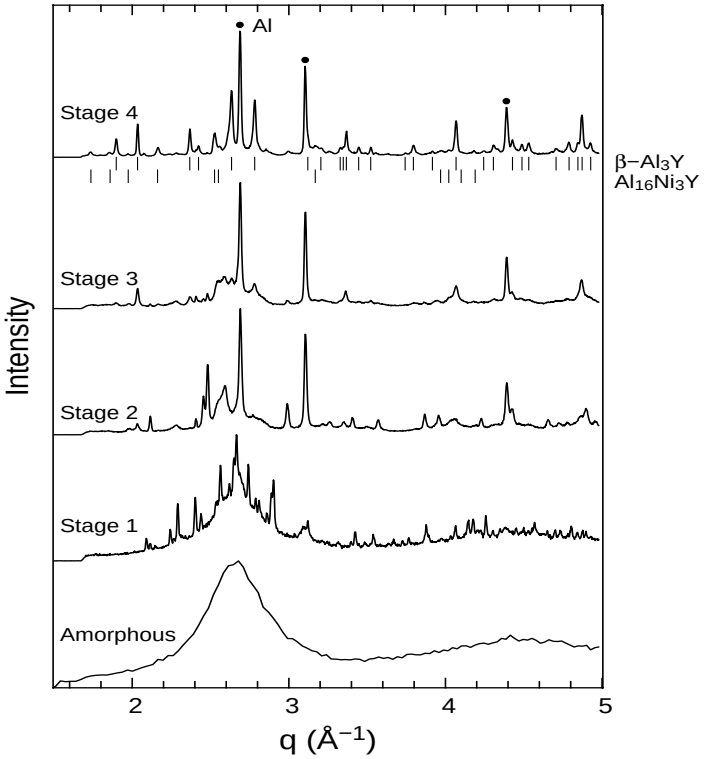

Fig. 2 High-resolution powder scattering patterns showing the sequence of crystallization stages observed for $Al_{85}Y_{10}Ni_5$.

Discussion

The crystallization history of $Al_{85}Y_{10}Ni_5$ has been investigated by mean of wide-angle time-resolved X-ray scattering. A recently commissioned spectrometer dedicated to this purpose has proven to be the ideal tool to study the complex crystallization sequences observed for this particular kind of Al-rich alloys. Analysis of these results should be completed soon an a publication will be submitted by the end of this year.

Acknowledgments

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