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An Order-Disorder Phase Transition in Al-Ni-Co Decagonal Quasicrystals by Anomalous-X-Ray Scattering

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Introduction

Al-Ni-Co (ANC) system is well known to be decagonal quasicrystals, which have two-dimensional quasiperiodic planes. From the point of view of an order-disorder transformation, the atomic short-range order (SRO) diffuse scattering study in $Al_{72}Ni_{20}Co_8$ has been recently performed at high temperatures [1,2]. Furthermore, quantitative SRO analysis was performed by anomalous-X-ray diffuse scattering [3]. Very recently, a local anomaly of the Debye-Waller (DW) factor was detected by in-situ observations using HAADF-STEM (electron microscopy) in $Al_{72}Ni_{20}Co_8$ decagonal quasicrystals [4]. It is thought that local dynamic fluctuations, which correspond to atomic flips, are excited at high temperature.

In this study, we report that the anomalous DW factor is also found at high temperature using X-ray diffraction. This implies that local atomic flipping occurs even on the macroscopic scale.

Experimental

The diffuse scattering measurements were performed on the BL-4C of the Photon Factory at the High Energy Accelerator Research Organization in Japan. A cylindrical focusing mirror is placed in front of a double monochromator of Si (111). The specimen was mounted on a four-circle diffractometer (Huber 5010). Air scattering was minimized by He filled beam paths. Fluorescence of the scattered beam from the specimen was reduced using a curved highly orientated pyrolytic graphite (002) (Panasonic Co.). The incident X-ray energy was calibrated to within 1 eV using Co foil. The incident X-ray energy was chosen at 7.686 keV near Co K-edge. A high temperature furnace (Mac Science Co.) has two hemispherical Be windows, whose thickness is 1 mm each. In order to analyze the diffuse scattering quantitatively (electron units per atom), we measured the several integrated intensities of a powder sample of Ni.

Results and Discussion

Figure 1 shows a $|\mathbf{G}^{\perp}|^2$ dependence of the Bragg intensities ratio between high temperature and room temperature, T_{rt} ($T_1<T_c$, $T_c<T_2$), where $-\ln(I(T_1)/I(T_{rt}))$ equals to $2\Delta B|G|^2$. Thus, we can estimate $\Delta<u^2>$, that is, the difference of the mean square displacement from the average lattice sites. It is found to be 19.0×10^{-4} nm^2. This value is comparable to that obtained by HAADF-STEM.

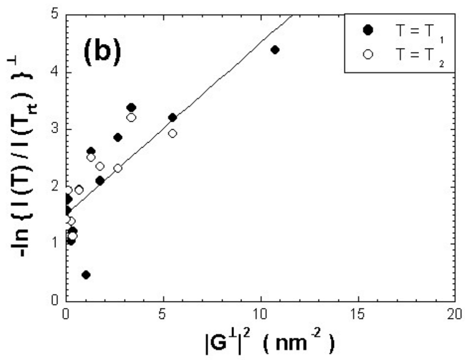

Fig. 1 $|\mathbf{G}^{\perp}|^2$ dependence of the intensity ratio between room temperature (T_{rt}) and high temperature.

We confirm that the anomalous attenuation of the Bragg intensities by the anomalous DW factor at high temperature is connected with the local vibration anomaly as pointed out in HAADF-STEM experiments. In particular, the $|\mathbf{G}^{\perp}|^2$ dependence of Bragg intensities ratio between room temperature and high temperature implies that the fluctuations are related to phason flips. It should be noted that X-ray experiments provide information about the average of the local fluctuations in the bulk state. In contrast, electron microscopy experimental results correspond to direct local fluctuations on the microscopic scale.

References

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