4G IRT: Detecting powder diffraction peaks from Gd-based magnetic quasicrystals

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It had been a long-standing issue if magnetic quasicrystal can host magnetic long-range order. Until recently, no quasicrystalline magnet shows long-range magnetic order. Just recently, it has been found in the bulk magnetic measurement that Au-Ga-RE (RE = Tb and Gd) quasicrystals exhibit sharp anomalies in the magnetic susceptibility measurement [1], suggesting the existence of the magnetic long-range order. To confirm, and also to obtain details of the spin arrangement, we performed neutron diffraction experiment on Au-Ga-Tb quasicrystal using ECHIDNA powder diffractometer at ANSTO (Australia) [1]. We obtain sharp Bragg peaks which can only be indexed by the six-dimensional indices, indicating that they are form the quasicrystalline phase. Nonetheless, at the same time, there appear many reflections that can be indexed by usual three-dimensional indices, and are attributed to the contaminating 1/1 approximant phase in the measured sample. From the material science characterization results, it is indicated that Au-Ga-Gd sample has much better quality (i.e. less impurity contamination), and hence it is highly desired to measure the magnetic diffraction in the Au-Ga-Gd magnetic quasicrystal.

The obstacle is, of course, the huge absorption cross-section of Gd. Generally, the stable isotope is used to reduce the absorption, however, for the present sample preparation method, using the costly stable isotope is not reasonable. Therefore, we utilized an elaborated sample setting technique, developed at Chalk River [2], and successfully obtained magnetic diffraction signal in Au-Ga-Gd.

The neutron scattering experiment on Au-Ga-Gd was performed using the 4G-GPTAS triple axis spectrometer in the trip-axis mode with the collimations 20-20-20-40. The incident neutrons of the energy 30.5 meV were selected using the pyrolytic graphite monochromator and analyzer. The powder sample (approximately 50 microns) was pasted on the single crystal Si wafer to reduce the absorption to the reasonable level, and also to reduce unwanted background. The sample was cooled down to low temperatures using standard 4K GM refrigerator, and the temperature was measured using a thermometer placed on the Si wafer.

Figure 1 shows the resulting powder diffraction patterns at two temperatures. At the higher temperature, the nuclear Bragg reflections from the quasicrystalline sample (6D indices) are clearly observed. By lowering the temperature, the 111000 reflection intensity grows, indicating that magnetic scattering appears on top of the nuclear reflection. This is consistent with the ferro- or ferrimagnetic order suggested in the bulk measurement, and is a clear evidence of the first magnetic long-range order in the quasicrystals [1].

[1] R. Tamura *et al*., J. Am. Chem. Soc. **143**, 19938-19944 (2021).
[2] Ryan *et al*., J. Appl. Crystallogra. **41**, 198 (2008)

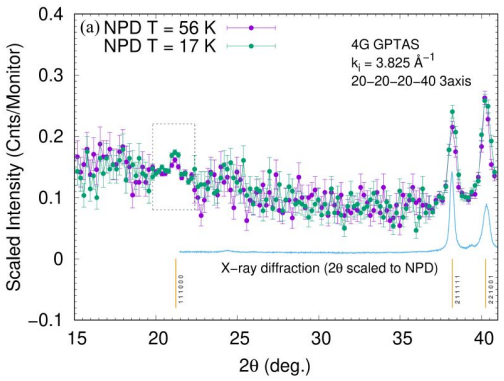

Fig. 1. Neutron diffraction patterns in Au-Ga-Gd quasicrystal at 56K and 17K. Only in the squared region, the scattering was counted for sufficiently long time. Xray diffraction data are also plotted for comparison.