Posters - Magnetic Structures

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MAGNETISM IN RARE EARTH QUASICRYSTALS: RKKY INTERACTIONS AND ORDERING

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We take a two-step theoretical approach to study magnetism for simple models of rare earth quasicrystals by considering Ising spins on quasiperiodic tilings, coupled via RKKY interactions [1]. First, we compute RKKY interactions from a tight-binding Hamiltonian defined on the two-dimensional quasiperiodic tilings. We find that the magnetic interactions are frustrated and strongly dependent on the local environment. This also results in the formation of clusters with strong bonds at certain patterns of the tilings, which repeat quasiperiodically. In the second part, we examine the statistical mechanics of Ising spins with these RKKY interactions, using extensive Monte Carlo simulations. Although the wide range of interactions is often associated with spin glass behaviour, we show that the spin system has a phase transition to a low-temperature state with long-range quasiperiodic magnetic order. Additionally, we find that in some of the systems clusters can fluctuate much below the ordering temperature.

1. S. Thiem and J. T. Chalker, to appear in EPL (arXiv:1407.5868).

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SYNTHESIS AND MAGNETIC PROPERTIES OF Au-Al-Gd APPROXIMANTS

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Various Tsai-type quasicrystals and crystalline approximants have been found in a variety of systems. These compounds are made of the common Tsai-type icosahedral cluster. The Tsai-type cluster contains a rare-earth icosahedron shell. Recently, the existence of a long-range magnetic order was reported in Cd_6Tb and Au-SM-R (SM=Si,Ge,Sn) approximants [1-3]. Therefore, it is of interest to investigate the magnetic properties of other Tsai-type compounds that are also composed of the same Tsai-type clusters. In the present work, we have studied the phase constitution and magnetic properties in the Au-Al-Gd systems.

Polycrystalline alloys of nominal compositions of Au-Al-Gd were prepared by arc-melting high-purity(>99.9 wt%) Au, Al, Gd. The alloys were annealed under an Ar atmosphere. The phase purity of the samples was examined by powder X-ray diffraction using CuK radiation. The temperature and field dependence of the magnetization were measured using a SQUID or VSM magnetometer in the temperature range between 1.8 and 300 K and fields of up to 9T.

Powder X-ray diffraction studies have shown that a single phase is obtained in an extraordinarily wide Au/Al range with 14 at% Gd. Also, the lattice parameter is found to increase with increasing the Au/Al ratio. Magnetic measurements have exhibited a salient composition-driven spin-glass to ferromagnetic transition in the approximant crystal for the first time. An interesting feature for Au-Al-Gd is that the paramagnetic Curie temperature, $_p$, is clearly dependent on the Au/Al ratio. $_p$ increases significantly from a large negative value to a large positive value as the Au content increases. Detailed results of the magnetic properties will be reported in the presentation.

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PHASE TRANSITION TO THE MODULATED STRUCTURE IN HEMIMELLITIC ACID COMPOUND

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1,2,3-Benzenetricarboxylic acid (hemimellitic acid) is rather uncommon tricarboxylic acids with three carboxylic units close together in 1,2,3 positions of benzene ring. The studied compound is a inhibitor of the citrate carriers in liver mitochondria and inhibitor of pyruvate carboxylation in small animals like rat, mice and rabbit [1]. It is also used in cosmetology.

Studied compound was obtained in oxidation reaction of 1,5 dimethylnaphthalene with $KMnO_4$ in water suspension at boiling temperature. The reaction is an interesting example of the disintegration of the aromatic ring (naphthalene) in a fairly mild conditions for this type of reaction. In the literature there are similar reactions, but they occurred in more drastic conditions (high temperature, high pressure). The crystals were prepared from a solution of D_2O directly in a test tube for performing NMR measurements. The H^1 NMR spectrum is consistent with the invention and expectations.

Good quality single crystals were preselected under stereoscopic polarization Zeiss microscope and mounted on quartz glass capillary. X-ray diffraction measurements were performed using Agilent Technologies SuperNova 4-circle Kappa diffractometer using both Cu and Mo radiation. X-ray diffractometer was equipped with Atlas CCD camera and Cryostream 700 low temperature attachment. Studied compound crystallizes in the monoclinic crystal system in C2/c space group. There are 8 hemimellitic acid molecules per average unit cell.

1. M. Shimoni, J. Azran, O. Buchman, *Journal of Labelled Compounds and Radiopharmaceuticals*, **25** (1987), 685.

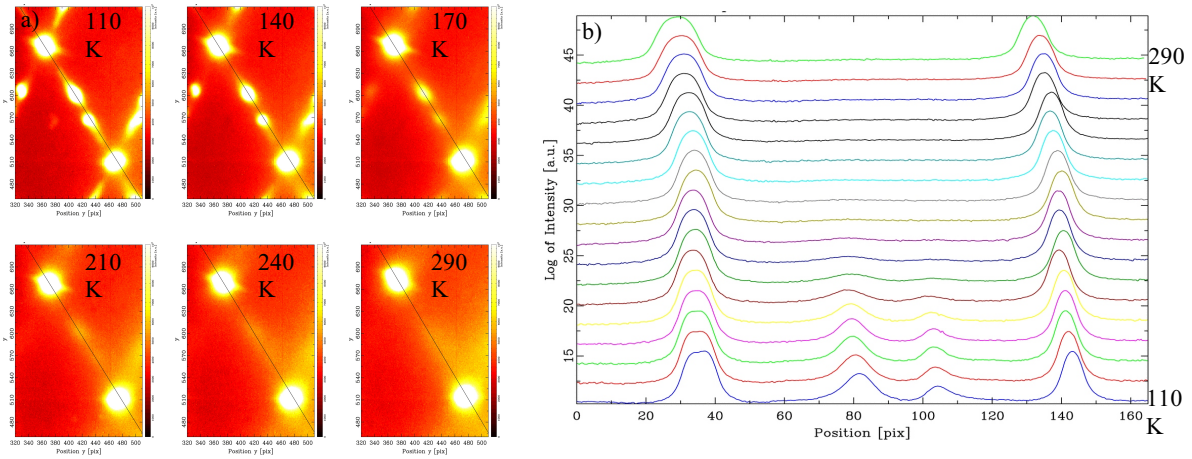

Figure 1. a) Cuts thru reciprocal space showing temperature evolution of satellite reflections and diffuse scattering. b) Cuts thru reciprocal space in logarithmic scale.

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IMPORTANCE OF THE INTERSTITIAL REGION FOR PRODUCING MAGNETISM IN NANOSTRUCTURED i-$Al_{64}Cu_{23}Fe_{13}$ APERIODIC CRYSTAL

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In past decades, a large number of research papers have been developed both in the understanding and applications of aperiodic crystals [1, 2]. However, many questions about their physical properties are still without conclusive and satisfactory answers. In particular, the magnetic properties of these new materials are controversial because these systems have revealed different magnetic responses. It is important to note that the chemical order is also relevant to define the properties of quasicrystals. The case of the quasicrystalline i-$Al_{64}Cu_{23}Fe_{13}$ is particularly important since a small variation in the chemical composition form a new crystalline (periodic) structure like w-$Al_{70}Cu_{20}Fe_{10}$. Moreover, the nanostructuration of these complex samples give us the opportunity to improve their physical properties as a function of the grain size [3].

In the context indicated above, we study the formation and growing of a magnetic interstitial region after reducing the grain size of the aperiodic i-$Al_{64}Cu_{23}Fe_{13}$ phase and the periodic w-$Al_{70}Cu_{20}Fe_{10}$ phase. For this purpose, samples of Al-Cu-Fe were prepared by the arc-furnace technique and then nanostructured by mechanical milling. The results indicate that the solid sample shows a weak ferromagnetism at 300K, with a saturation magnetization of 0.124 emu/g for the i-$Al_{64}Cu_{23}Fe_{13}$ phase and 0.449 emu/g for the w-$Al_{70}Cu_{20}Fe_{10}$ phase. These low values indicate that only a small percentage of Fe atoms carry magnetic moments. The magnetic response for the nanostructured w-$Al_{70}Cu_{20}Fe_{10}$ phase increased up to 3.5 times more than its solid counterpart. Surprisingly, in the case of the i-$Al_{64}Cu_{23}Fe_{13}$ phase, this increase is about 16 times, which implies a greater magnetic interstitial region. Moreover, the rate of change of the physical parameters studied after reducing the grain size has been obtained from the exponent of a power law fit of the experimental data. The values of such exponent, corresponding to the magnetic response, are slightly different in each phase, which should be related to the different chemical composition and/or the type of long range order. Additionally, we also search for a critical grain size. However, this critical value has not been observed in the studied samples.

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