Tunneling States and Defects in Quasicrystals

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Quasicrystals present a long range order but, contrary to crystals, they don't have any periodic order. Hence, they appear as intermediate materials between simple crystals and glasses. It is known that the low temperature (T<1K) properties of amorphous materials differ from those of simple crystals[1]. In the phenomenological tunneling states (TS's) model, these specific properties are explained by the presence of two-level systems arising from a tunneling effect of atoms between nearly degenerated configurations. The existence of such low energy excitations in quasicrystals is therefore an interesting issue.

The first experimental study of this question was performed in the system AlLiCu and revealed the presence of TS's with a very low density of states in comparison to amorphous metals[2]. They were ascribed to particular structural defects, called phason strains, which are specific to quasicrystals. These observations were not confirmed by recent studies on better quasicrystalline samples free of phason strains which showed the presence of TS's with a density of states similar to what is found in amorphous metals[3,4]. At this point it seems important to re-investigate in detail the occurrence of TS's in the special case of defective quasicrystals.

Therefore we have studied the acoustic properties at low temperature of three samples of the ternary alloy AlLiCu: (a) a monocrystal of the cubic approximant, (b) a polygrain of the related icosahedral phase and (c) an other polygrain extracted from the same ingot which was annealed to improve its structural quality[5]. Thus, we hope to avoid any possible effect of a different sample preparation or composition[6].

The acoustic velocity variation in all samples is qualitatively in agreement with the predictions of the TS model with a small density of states of the TS's as compared to amorphous metals. Besides, the TS's density of states increases from sample (a) to sample (c).

Our results gives a coherent view of the existence of TS's in quasicrystals: the TS's density of states increases with the perfection of the quasicrystalline order. It reaches, in perfect quasicrystals a value similar to what is found in amorphous metals. Moreover the icosahedral symmetry seems to be critical for the occurrence of TS's since any departure from this one reduces drastically the TS's density of states.

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