Tuning the Neel temperature of α-$TbAlB_4$ by alteration of Fe:Tb ratio in multi-phase Al-Cu(B, Fe, Tb) alloys

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One of the prospective materials for ultrafast magnetic switching memory are rare-earth–transition-metal antiferromagnetic alloys. There are only limited reports describing Al-Cu alloys with more than three alloying components that include both d- and f-electron elements. Here we investigate one such alloy family, Al–Cu with variable amounts of $TbAlB_4$ boride. The magnetic properties of analogous end member β-$YbAlB_4$ were described by Nakatsui *et al.* [1] as a heavy-fermion system that exhibits a low-temperature superconducting transition and quantum criticality.

Four Al-Cu(B, Fe, Tb) alloy compositions with Fe:Tb atomic ratios of 3:1, 1:1, 1:3 and 0:1 were considered in the current study, and were referred as S1, S2, S3 and S4, respectively. The dominant phase by volume in all studied alloys is Al_8Cu_4Tb, isostructural with $ThMn_{12}$ (space group 139), which appears to be non-magnetic. The accompanying precipitates of Al_2Cu (s.g. 69) in composition S1 and Al_3Tb (s.g. 221) in mixes S2–S4 are not expected to significantly contribute [2] to antiferromagnetic response of the samples. In the alloys S1-S3, the boride has the structure of TbB_4, isostructural with UB_4 (s.g. 127), while in S4 it is β-$TbAlB_4$.

For alloys S2, S3 and S4, the Neel temperatures T_N are 8 K, 15 K and 23-28 K, respecitvely, forming a broad maximum in FC-ZFC magnetization versus temperature in the case of S4. It may be that Cu and Fe substitute for some fraction of the boron atoms sandwiched between Al and Tb layers in β-$TbAlB_4$. If so, this would lead to unit cell expansion, affecting the exchange interactions. In VSM data measured up to 1 kHz, no frequency dependence is observed in magnetic AC susceptibility versus temperature. The alloys exhibited no magnetic DC hysteresis, showing clearly antiferromagnetic behavior.

The case of alloy S1 is more complex. A Curie-Weiss fit to inverse susceptibility versus temperature revealed T_N as high as 67.3 K, which we ascribe to the TbB_4 (s.g. 127) phase. But there is also a ferromagnetic phase present, monoclinic Fe_4Al_{13} (s.g. 12). A Curie law fit to inverse susceptibility shows that the coexisting phase has T_C of 46.2 K. No magnetic DC hysteresis is observed at $T > 75$ K, while H_c changes with decreasing temperature from very narrow at $T = 50$ K to about 4 kOe at $T = 3$ K, illustrating dominantly ferromagnetic interactions in the lowest temperature regime.

References:

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The research described was funded by the National Science Centre, Poland (NCN) within the research grant No. 2020/36/C/ST5/00007.