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Superconductivity in cubic U-Mo alloys prepared by splat cooling

Nhu-T.H. Kim-Ngan[1,*], I. Tkach[2], L. Havela[2]

[1] Institute of Physics, Pedagogical University, Podchorążych 2, 30-084 Kraków, Poland

[2] Faculty of Mathematics and Physics, Charles University, Ke Karlovu 5, 12116, Prague

[*] Email: tarnawsk@up.krakow.pl

Uranium metal exhibits three allotropic phases, namely α (orthohombic)-, β (tetragonal)- and γ (body-centered cubic). Electronic properties are known only for α-U, stable below room temperature. Superconductivity with $T_c = 0.78$ K was reported for α-U, although recently it was suggested that the fully developed CDW state prohibits the superconductivity [1,2].

The β and γ-U may have different electronic properties, as their density is lower (18.06 g/cm^3 for γ-U comparing to 19.04 g/cm^3 for α-U). The interest in these phases dwells mainly in metallurgy of possible nuclear fuels. For instance the *bcc* phase was considered to be much more resistant to irradiation effects. γ-U is stable only in the range 1049-1408 K, and/or it can be preserved by quenching if U is doped by e.g. Mo on the level of 8-10 weight % [3].

We undertook a study of (meta) stabilization of the *bcc* phase corresponding to γ-U using the splat-cooling technique and using a variable Mo concentration (015 at % Mo, i.e. $\mathrm{U}_{1-x}\mathrm{Mo}_x$ with $x = 0 \div 0.15$). The samples were prepared by arc-melting of appropriate amounts of U (99.8 % purity) and Mo (99.95 % purity) on a water-cooled copper hearth in an argon atmosphere. The as-cast samples were then transfered to a high-vacuum splat cooling system (Vakuum Praha) giving the effective cooling rate of $\sim 10^6$ K/s. The resulting splat-cooled discs had a diamater of 20 mm and a thickness below 100 μm.

The XRD analysis revealed that the splat-cooled pure uranium specimen consists of mixed (α+γ) phases. It opens a new possibility of stabilising the γ-phase at room temperature in uranium by ultrafast cooling. The γ^o -phase and the pure cubic γ-phase can be already stabilised in the uranium alloys contained respectively of 11 at % Mo and 15 at % Mo.

The superconducting transition was investigated by low-temperature resistivity measurements (down to 0.3 K) by means of PPMS in various magnetic fields up to 5 T. We found that also the splats become superconducting. T_c =1.71 K (the width of the resisivity jump $\Delta T_c = 0.5$ K) and 1.91 (ΔT_c =0.3 K) were determined, respectively, for splat-cooled U-Mo samples with $x = 0.11$ and 0.12. We observed neither the quadratic dependence of $H_{c2}(T)$ as the temperature approaches 0 K (as it was revealed for α-U single crystal expected for type-I superconductors) nor a linear dependence exhibited for e.g. superconductor $\mathrm{U}_6\mathrm{Fe}$ [4]. The polynomial (up to 2nd order) fit of the data implies the magnitude of $\mu_0 H_{c2}(T \to 0)$ of 5.1T and 6.0 T, respectively, for x = 0.11 and x = 0.12. These values are quite large for the alloys with $T_c < 4$ K. The slope -$(d\mu_0 H_{c2}/dT)_{T_c}$ was estimated to be 4.06 T/K and 3.97 T/K respectively for x = 0.11 and x = 0.12, respectively. These values are close but higher than those found for e.g. the strongly interacting Fermi liquid superconductor $\mathrm{U}_6\mathrm{Fe}$ (-$(d\mu_0 H_{c2}/dT)_{T_c} = 3.42$ T/K) and within the limit for the extreme high-field A15 and Chevrel-phase superconductors.

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