Influence of sample preparation on the glass-like acoustic properties of pure crystalline tantalum

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The rather surprising similarities of the low-temperature acoustic properties of some pure crystalline metals with those found in glasses remain still a puzzle. Although the acoustic behavior can be phenomenologically explained in terms of the existence of tunneling systems (TS) which interact with phonons, little is known about the nature of these entities (apart from some special samples in which the tunneling systems are indeed identified as atoms or a group of atoms). Searching further for the origin of the glass-like acoustic properties in crystalline metals, we have studied the internal friction and the relative change of sound velocity of a series of well-characterized crystalline tantalum samples of very high purity in the temperature range 0.1mK < T < 10K.

All samples were obtained from Ta foils with 5 at.-ppm (C,N,O) as interstitials and less than 11 at.-ppm substitutional impurities. The tantalum foils were decarbonized and degassed in a UHV system at 2500°C and at a pressure of 10^{-10}-10^{-11} Torr. In order to study the possible influence of hydrogen on the low temperature acoustic properties, the foils have been – in addition to this heat treatment – differently prepared to obtain samples with and without an oxidized surface as protection against the penetration of hydrogen into the material. The Ta sample without oxidized surface (labeled No. 390) contains about 100ppm hydrogen as interstitial impurities; those with surface protection (Nos. 391, 393) contain a maximum of 10ppm hydrogen. All samples were further cold-rolled (390c: 10-15% deformation; 391c: 10% deformation; 393c: 15-20% deformation) in order to study the influence of dislocations on the acoustic properties.

The measurements of the acoustic properties of the samples performed at kHz frequencies by means of the vibrating reed technique reveal a different behavior already prior to their deformation by cold-rolling. The sample with the large hydrogen content (Nr. 390) shows a shallow peak in the internal friction and a saturation of the sound velocity below 100mK. In contrast, the samples with an oxidized surface (small H content) show a maximum in the sound velocity at ~1K with a logarithmic temperature dependence below it accompanied by a glass-like behavior in the internal friction. The parameter $C = P_0\gamma^2/\rho v^2$ obtained from the temperature dependence of the relative change of sound velocity is similar to that obtained for amorphous PdSiCu. After deformation the acoustic properties depend on whether the samples had been previously oxidized or not. The experimental findings are discussed in terms of the influence of the hydrogen content and dislocations on the acoustic properties.