Acoustic measurements of crystalline Aluminium and of an Aluminium alloy (Al 5056)

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Crystalline metals with a certain degree of structural disorder very often exhibit acoustic low temperature properties which are quite similar to those of metallic or dielectric glasses. In glasses the low temperature properties are caused by atomic two-level tunneling systems with a widely distributed spectrum of excitation energies [1]. The microscopic origin of these tunneling systems, however, is not known. To approach this problem at least for crystalline matter we studied the acoustic properites of Aluminium with various degrees of disorder. Our goal was to find correlations between the properties below 1 K where the influence of tunneling systems usually dominates and the properties at higher temperatures where other effects like thermally activated motions of dislocations become important. Such a comparison has not been done in earlier measurements [2-4].

We employed a vibrating reed technique with a special sample geometry to reduce clamping losses. All samples were machined to the same dimensions with a fundamental frequency of about 2.5 kHz. Our samples were i) a single crystal of Aluminium, which we measured in a state as machined as well as after an annealing process, ii) a polycrystalline sample of Al, and iii) a sample of the the alloy Al 5056. Al 5056 is the metallic material with the lowest known mechanical loss and Q^{-1} values of $2 \cdot 10^{-8}$ have been reported [5].

Some of our results may be summarized in the following way: Evidence for the existence of 'glass-like' two-level tunneling systems is only observed for the polycrystalline sample. The internal friction Q^{-1} of the single crystal is almost temperature independent between 30 mK and 1 K and has a maximum around 7 K which we attribute to the thermally activated motion of dislocations. Q^{-1} between 30 mK and 20 K can be reduced by about 20% by annealing. Q^{-1} of our Al 5056 specimen is more than an order of magnitude smaller than Q^{-1} of the Aluminium single crystal. Moreover, Q^{-1} is almost temperature independent up to 10 K, corresponding to a very small variation of the sound velocity. Although Al 5056 is considerably disordered the influence of tunneling systems on its acoustic properties is negligibly small compared to metallic glasses.

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