Temperature and intensity dependence of the acoustic properties of normal- and superconducting amorphous metals at low temperatures

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The apparent discrepancy between the experimental observations of the low-temperature acoustic properties of the metallic glass PdSiCu and the behavior expected from the tunneling model have been traced back to different considerations of strain-dependent effects. By studying the intensity dependence of the internal friction Q^{-1} and of the relative change of sound velocity $\Delta v/v$ of the amorphous metal PdSiCu [M.A. Ramos *et al.*, Phys. Rev. B **61**, 1059 (2000)], we succeeded – for the first time – in unveiling the predictions of the tunneling model for the temperature dependence of the acoustic properties, but only in the limit of zero strain.

The different contributions of the interaction of the tunneling systems (TS) with phonons and electrons on the acoustic properties of an amorphous metal can be separated in studies of the sound velocity and internal friction of superconducting materials. Depending on the position of the superconducting transition temperature T_C, the condensation of the quasiparticles into Cooper pairs differently affects the behavior of the acoustic properties below T_C. We have studied this effect on two samples of the amorphous metal Zr_xCu_{1-x} with zirconium concentrations $x = 0.3$ and $x = 0.4$ using the vibrating reed technique at frequencies of about 1kHz and in the temperature range $0.1\text{mK} < T < 1\text{K}$. The rather low transition temperatures of $T_C = 95\text{mK}$ ($x = 0.3$) and 0.28K ($x = 0.4$) and the corresponding low critical magnetic fields enable us to switch between the normal- and superconducting states of these samples and to study the electron- and/or phonon-TS interaction separately down to temperatures into the microkelvin range. Thus, our studies clearly demonstrate the importance of experiments on amorphous materials performed at ultralow temperature.

In line with the conclusions we have drawn from the investigations of PdSiCu, we are able to assign our main results to the zero strain extrapolated values of the acoustic properties obtained from measurements of their strain dependence at various constant temperatures. At temperatures above 3mK, the expectations of the Tunneling Model for the sound velocity are unveiled, and concerning the internal friction of the sample in the normal state we observe a plateau at zero strain extending to temperatures far into the microkelvin temperature range. However, we will also discuss the problems which we encounter in our analysis: this applies, in particular, to the observed saturation of the sound velocity (at zero strain) in the normal and superconducting range below 3mK, and to the astonishing similarities in the strain dependence of the internal friction in both states.