Quartz Microbalance Studies of Superconductivity-Dependent Sliding Friction

The interactions which give rise to dry sliding friction, in principle, involve contributions from both electrons and phonons. Recently Dayo, Alnasrallah, and Krim (DAK) [1] presented the results of an experiment designed to study the electronic contribution to friction by probing the frictional forces between an insulator and a superconductor in the vicinity of the superconducting transition. Their experiment utilized quartz crystal microbalance measurements of solid nitrogen films on a lead substrate. Abrupt changes in the microbalance response were interpreted as changes in the frictional forces between the nitrogen and the lead at T_c, and implied a much lower frictional force in the superconducting state.

We have repeated the experiment of DAK with three important technical improvements. First, we have used a mutual inductance technique to monitor the superconducting transition in the lead film on the microbalance. Second, our experiment was mounted in a highly isothermal sealed cell [2] to eliminate the possibility of thermal gradient driven mass transport. Third, the cell was not in direct contact with the bath, but rather was suspended in vacuum which allowed us to regulate the temperature with high precision [2]. As in DAK, the lead films were prepared in a standard laboratory evaporator and transferred through air into the cryostat. Five atmospheres of ultrahigh purity nitrogen were admitted to the cell before it was sealed. As the cell was cooled from room temperature to 4 K in a period of 36 hours an equilibrium N_2 film was adsorbed on the microbalance. A heater on the microbalance could be used to remove this film to study the bare substrate. A N_2 evaporator was used to redeposit nonequilibrium films. Coverages from zero to several hundred layers were studied. In our experiment the Q of the microbalance was insensitive to the presence of the N_2 films, indicating that N_2 films do not slide on either normal or superconducting low temperature substrates. The purpose of this Comment is to report that the outcome of the DAK experiment depends on uncontrolled conditions of the sample preparation or nitrogen deposition, and is not a robust feature of N_2 lead film interfaces.

Figure 1(a) shows the response of an 8 MHz, third overtone microbalance covered with an equilibrium N_2 film. In our experiment, measurements of Q^{-1} made on bare oscillators are indistinguishable. Figure 1(b) shows the simultaneously measured mutual inductance signal as the temperature of the cell is varied between 5 and 9 K. It shows a sharp superconducting transition at 7.2 K, the bulk T_c for lead. The jump in Q^{-1} observed at the transition by DAK, 3×10^{-7}, corresponds to 1.5 major divisions in Fig. 1(a). Although the frequency of the oscillator depends on the thickness of the N_2 film, it is also insensitive to the superconducting transition.

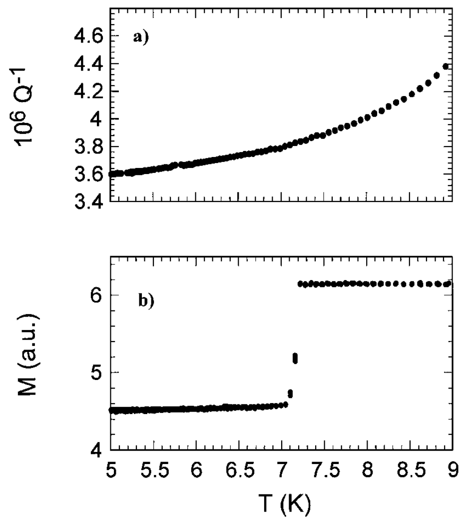

FIG. 1. Inverse Q and mutual inductance signal as a function of temperature. Panel (b) shows the behavior of Q^{-1} with an equilibrium N_2 film adsorbed. The Q^{-1} of bare substrates is identical and both are smooth through the superconducting transition. Panel (b) shows the mutual inductance signal in arbitrary units of two coils separated by the lead covered microbalance. A sharp discontinuity marks the superconducting transition. The changes in Q^{-1} reported by DAK correspond to 1.5 major divisions on our scale.

These experiments were repeated with different microbalances and different lead films and while increasing and decreasing the temperature through T_c. We also studied the effects of crossing the supernormal phase transition by applying an external magnetic field at fixed temperature, where the transition is first order. Finally, we varied the maximum velocity of the surface by more than a factor of 1000. In none of these experiments does the superconducting transition or the presence of a N_2 film affect the Q of the microbalance. Our result is consistent with the theoretical expectation that arbitrarily small amounts of surface disorder are sufficient to pin an adsorbed film at low temperature [3].

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