Heat capacity and thermal conductance measurements of a superconducting/normal mixed state by detection of single 3 eV photons in a Magnetic Penetration Thermometer

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We report on measurements of the detected signal pulses in a molybdenum-gold Magnetic Penetration Thermometer (MPT) in response to absorption of one or more 3 eV photons. We designed and used this MPT sensor for x-ray microcalorimetry [1]. In this device, the diamagnetic response of a superconducting MoAu bilayer is used to sense temperature changes in response to absorbed photons, and responsivity is enhanced by a Meissner transition in which the magnetic flux penetrating the sensor changes rapidly to minimize free energy in a mixed superconducting/normal state [2]. We have previously reported on use of our MPT to study athermal phonon energy loss to the substrate when absorbing x-rays [3]. We now describe results of extracting heat capacity C and thermal conductance G values from pulse height and decay time of MPT pulses generated by 3 eV photons. The variation in C and G at temperatures near the Meissner transition temperature (set by an internal magnetic bias field) allow us to probe the behavior in superconducting/normal mixed state of the condensation energy and the electron cooling power resulting from quasiparticle recombination and phonon emission. The information gained on electron cooling power is also relevant to the operation of other superconducting detectors, such as Microwave Kinetic Inductance Detectors.

[1] "Performance of Magnetic Penetration Thermometers for X-ray Astronomy," P.C. Nagler, J.S. Adams, M.A. Balvin, S.R. Bandler, K.L. Denis, W.-T. Hsieh, D.P. Kelly, J.-P. Porst, J.E. Sadleir, G.M. Seidel, S.J. Smith, T.R. Stevenson, J. Low. Temp. Phys. 167:455-460 (2012).

[2] "Superconducting Effects in Optimization of Magnetic Penetration Thermometers for X-Ray Microcalorimeters," T. R. Stevenson, M. A. Balvin, S. R. Bandler, S. E. Busch, K. L. Denis, W.-T. Hsieh, D. P. Kelly, W. Merrell, P. C. Nagler, J.-P. Porst, J. E. Sadleir, G. M. Seidel, and S. J. Smith, IEEE Trans. Applied Superconductivity 23: 2300605 (2013).

[3] "Athermal energy loss from x-rays deposited in thin superconducting films on solid substrates," Alexander G. Kozorezov, Colin J. Lambert, Simon R. Bandler, Manuel A. Balvin, Sarah E. Busch, Peter N. Nagler, Jan-Patrick Porst, Stephen J. Smith, Thomas R. Stevenson, and John E. Sadleir, Phys. Rev. B 87:104504 (2013).