# Chemical potential investigations of the surface of ferromagnetic-superconducting multilayers

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Chemical potential $\mu$ is the only one thermodynamical parameter which can be easy measured on low-dimensional systems like thin films or a two-dimensional electron gas. It is especially useful for multilayers because the properties of the topmost layer with thickness about the Debye screening length are investigated.

The method to measure the change of the chemical potential $\Delta\mu = \mu(H) - \mu(0)$ is based on the determination of the change in charge on the measuring capacitor consisting of the sample under investigation and the reference electrode. The idea is closely related to Lord Kelvin's investigations of the contact potential difference. In general, the contact potential difference differs from the chemical potentials difference by the magnitude of the potential difference of the double charged layers present at the surface of bulk metals. If the influence of a magnetic field on the capacitance $C$ and in the work function of the reference electrode is negligibly small then $\Delta Q = -C\Delta\mu/e$, where $e$ is the charge of current carriers.

Measurements of the chemical potential of superconducting and ferromagnetic films in stationary magnetic field were published many years ago [1]. The purpose of the present work is to investigate heterostructures consisting of superconducting and ferromagnetic layers [2]. The heterostructures were characterized by magnetic and transport measurements. Chemical potential investigations were done using the field-modulation technique that significantly increases the sensitivity of the method. Field was modulated at frequency 13.7 Hz with amplitude about 0.015 T. Charge was measured by the Keithley 642 Electrometer. For lock-in detection Signal Recovery 7265 and Signal Recovery 7225 were used.

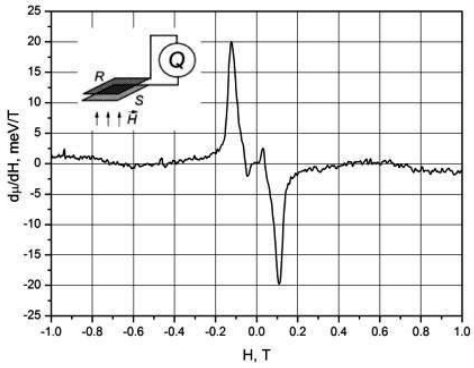


Figure on the left shows the results for $La_{0.7}Sr_{0.3}MnO_3$ epitaxial 90 nm film. Peculiarities observed in dependence of $d\mu/dH$ on magnetic field result from the behavior of magnetization and magnetostriction.

[1] V. I. Nizhankovskii, S. G. Zybtsev, Phys. Rev. B **50**, 1111 (1994).
[2] P. Przyslupski et al., Phys. Rev. B **69**, 134428 (2004).