Ann. Phys. (Leipzig) **12**, No. 1–2, 37 – 50 (2003) / **DOI** 10.1002/andp.200310005

Oscillations of the critical temperature in superconducting Nb/Ni bilayers

A. S. Sidorenko*[1,2], V. I. Zdravkov[2], A. A. Prepelitsa[2], C. Helbig[1], Y. Luo[3], S. Gsell[1], M. Schreck[1], S. Klimm[1], S. Horn[1], L. R. Tagirov[1,4], and R. Tidecks[1]

[1] Institut für Physik, Universität Augsburg, 86135 Augsburg, Germany
[2] Institute of Applied Physics, LISES, 2028 Kishinev, Moldova
[3] I. Physikalisches Institut, Universität Göttingen, 37073 Göttingen, Germany
[4] Kazan State University, 420008 Kazan, Russia

Received 20 November 2002, accepted 5 December 2002 by U. Eckern
Published online 21 March 2003

Key words Superconductor/ferromagnet proximity effect, FFLO pairing.
PACS 74.80.Dm, 74.50.+r, 74.62.-c

We investigated Nb/Ni bilayers prepared by magnetron sputtering on glass subtrates. The quality of the films was characterized by small-angle X-ray diffraction analysis. The thickness of the layers was determined by the Rutherford backscattering spectrometry (RBS). For specimens with constant Nb layer thickness we observed distinct oscillations of the superconducting critical temperature upon increasing the thickness of the Ni layer. The results are interpreted in terms of Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) like inhomogeneous superconducting pairing in the ferromagnetic Ni Layer.

1 Introduction

Since the work of Ginzburg [1] the problem of coexistence of two long-range orders, superconductivity (S) and ferromagnetism (F), has been intensively discussed. Ginzburg concluded that the two antagonistic orders cannot coexist in a homogeneous material, because superconductivity requires conduction electrons to form Cooper pairs, i.e. pairs of electrons with antiparallel spins, whereas ferromagnetism forces the electron spins to align parallel. If superconductivity and ferromagnetism cannot be reconciled, they may appear spatially separated in the nanoscale range to form a natural or artificially layered material. This scenario has been realized in the multicomponent magnetic superconductors [2] and in artificially produced S/F bilayers and multilayers [3]. The latter system has the advantage that the thickness and/or sequence of the S and F layers can be varied during fabrication.

Wong et al. [4] observed a non-monotonic dependence of the superconducting transition temperature, T_c, on the thickness of the iron layer in V/Fe multilayers. Based on this observation, Buzdin et al. [5,6] predicted a realization of a Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) [7,8] like inhomogeneous pairing in the ferromagnetic layers of S/F structures leading to oscillating behavior of T_c. This prediction stimulated intense studies of artificially layered S/F systems (Refs. [9]- [25]), to observe oscillations of T_c. The results appeared to be controversial: in some investigations T_c oscillations were observed [10,12–15,19–21,23,24], but in others not [9,11,16–18,22,25], even when using the same S/F couples. Careful analysis shows that molecular beam epitaxy (MBE) grown samples [9,11,16–18,21,25] do not reveal T_c oscillations, whereas magnetron sputtered samples demonstrate this behavior [10,12–15,19,20,23,24].

* Corresponding author E-mail: anatoli.sidorenko@physik.uni-augsburg.de, Phone: +49 821 598 3308, Fax: +49 821 598 3225

© 2003 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim 0003-3804/03/1–201-0037 $ 17.50+.50/0