

Basic superconducting spin valves

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Abstract

© 2018, Springer International Publishing AG, part of Springer Nature. The short review is devoted to the state of the art of a booming field of research in spintronics—superconducting spintronics. The spin valve properties of hybrid structures consisting of alternating layers of superconductor (S) and ferromagnetic (F) of nanoscale thicknesses and superconducting due to the proximity effect are considered in detail. The experimental data for the weak and strong ferromagnetic materials are analyzed; the role of the domain structure of the ferromagnet and the scattering of electrons with spin flip at the SF interfaces in the magnitude of the valve effect is considered. Theoretical works describing the effects of the spin valve for diffusive and clean limits are analyzed. The necessity of consideration of the multiplicity of configurations of the superconducting order parameter in multilayer SF heterostructures is underlined.

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Keywords

Magnetism, Proximity effect, Spintronics, Superconducting spin valves, Superconductivity

References

- [1] S.A. Wolf, D. Treger, *IEEE Trans. Magn.* 36, 2748 (2000)
- [2] S.A. Wolf, D.D. Awschalom, R.A. Buhrman, J.M. Daughton, S. von Molnar, M.L. Roukes, A.Y. Chtchelkanova, D.M. Treger, *Science* 294, 1488 (2001)
- [3] M.N. Baibich, J.M. Broto, A. Fert, F. Nguen van Dau, F. Petroff, P. Etienne, G. Creuzet, A. Friederich, J. Chazelas, *Phys. Rev. Lett.* 61, 2472 (1988)
- [4] G. Binasch, P. Grünberg, F. Saurenbach, W. Zinn, *Phys. Rev. B* 39, 4828 (1989)
- [5] I. Žutić, J. Fabian, S. Das Sarma, *Rev. Mod. Phys.* 76, 323 (2004)
- [6] A. Fert, *Uspekhi Fizicheskikh Nauk* 178, 1136 (2008) [*Physics-Uspekhi (Advances in Physics Sciences)* 178, 1136 (2008)]
- [7] N.F. Mott, *Proc. R. Soc. Lond. A* 156, 368 (1936)
- [8] H. Zabel, *Superlatt. Microstruct.* 46, 541 (2009)
- [9] E.Y. Tsymbal, D.G. Pettifor, *Perspectives of giant magnetoresistance. Solid State Phys.* 56, in ed. by H. Ehrenreich, F. Spaepen (Academic Press, 2001), p. 113
- [10] P.A. Grünberg, *Physics-Uspekhi (Adv. Phys. Sci.)* 178, 1349 (2008) [*Uspekhi Fizicheskikh Nauk* 178, 1349 (2008)]
- [11] E.Y. Tsymbal, I. Žutić, *Handbook of Spin Transport and Magnetism* (CRC Press, Taylor and Francis Group, 2012), p. 808
- [12] P.G. de Gennes, *Phys. Lett.* 23, 10 (1966)
- [13] A.I. Buzdin, *Rev. Mod. Phys.* 77, 935 (2005)
- [14] G. Deutscher, F. Meunier, *Phys. Rev. Lett.* 22, 395 (1969)
- [15] J.J. Hauser, *Phys. Rev. Lett.* 23, 374 (1969)

- [16] J. Evetts, *Concise Encyclopedia of Magnetic and Superconducting Materials* (Pergamon, 1992)
- [17] M.L. Kulić, M. Endres, *Phys. Rev. B* 62, 11846 (2000)
- [18] A. Millis, D. Rainer, J.A. Sauls, *Phys. Rev. B* 38, 4504 (1988)
- [19] T. Tokuyasu, J.A. Sauls, D. Rainer, *Phys. Rev. B* 38, 8823 (1988)
- [20] A. Cottet, W. Belzig, *Phys. Rev. B* 72, 180503(R) (2005)
- [21] M. Eschrig, *Rep. Progr. Phys.* 78, 104501 (2015)
- [22] A. Cottet, *Phys. Rev. B* 76, 224505 (2007)
- [23] B. Li, N. Roschewsky, B.A. Assaf, M. Eich, M. Epstein-Martin, D. Heiman, M. Münzenberg, J.S. Moodera, *Phys. Rev. Lett.* 110, 097001 (2013)
- [24] D. Lenk, R. Morari, V.I. Zdravkov, A. Ullrich, G. Obermeier, C. Müller, A.S. Sidorenko, H.-A. Krug von Nidda, S. Horn, L.R. Tagirov, R. Tidecks, *Phys. Rev. B* 96, 184521 (2017) (Appendix A)
- [25] Y. Zhu, A. Pal, M.G. Blamire, Z.H. Barber, *Nat. Mater.* 16, 195 (2017)
- [26] A.A. Golubov, M.Yu. Kupriyanov, *Nat. Mater.* 16, 156 (2017)
- [27] B.I. Kochelaev, L.R. Tagirov, and M.G. Khusainov, *Sov. Phys. JETP* 49, 291 (1979) [*Zh. Eksp. Teor. Fiz.* 76, 578 (1979); 79, 333E (1980)]
- [28] B.I. Kochelaev, L.R. Tagirov, *Solid State Commun.* 53, 961 (1995)
- [29] B.I. Kochelaev, L.R. Tagirov, *Sov. Phys. JETP* 62, 787 (1985) [*Zh. Eksp. Teor. Fiz.* 89, 1358 (1985)]
- [30] L.R. Tagirov, *IEEE Trans. Magn.* 23, 2230 (1987)
- [31] V.L. Ginzburg, *Sov. Phys. JETP* 4, 153 (1957) [*Zh. Eksp. Teor. Fiz.* 31, 202 (1956)]
- [32] P. Fulde, R. Ferrell, *Phys. Rev.* 135, A550 (1964)
- [33] A.I. Larkin, Yu.N. Ovchinnikov, *JETP* 47, 1136 (1964)
- [34] P. Fulde, *Adv. Phys.* 22, 667 (1973), Fig. 22
- [35] P.G. de Gennes, E. Guyon, *Phys. Lett.* 3, 168 (1963)
- [36] N.R. Werthamer, *Phys. Rev.* 132, 2440 (1963)
- [37] P.G. de Gennes, *Rev. Mod. Phys.* 36, 225 (1964)
- [38] B.Y. Jin, J.B. Ketterson, *Adv. Phys.* 38, 189 (1989)
- [39] A.S. Sidorenko, *Low Temp. Phys.* 43(7), 366-371 (2017)
- [40] C.L. Chien, D.H. Reich, *J. Magn. Magn. Mater.* 200, 83 (1999)
- [41] Yu.A. Izyumov, Yu.N. Proshin, M.G. Khusainov, *Usp. Fiz. Nauk* 172, 113 (2002) [*Physics-Uspekhi* 45, 109 (2002)] (see also comment by Ya.V. Fominov, M.Yu. Kupriyanov, and M.V. Feigel'man, *Physics-Uspekhi* 46, 105 (2003))
- [42] A.A. Golubov, M.Yu. Kupriyanov, E. Il'ichev, *Rev. Mod. Phys.* 76, 411 (2004)
- [43] I.F. Lyuksyutov, V.L. Pokrovsky, *Adv. Phys.* 54, 67 (2005)
- [44] K.B. Efetov, I.A. Garifullin, A.F. Volkov, K. Westerholt, in *Magnetic Heterostructures. Advances and Perspectives in Spinstructures and Spintransport*. Springer Tracts in Modern Physics, vol. 227 ed. by H. Zabel, S.D. Bader (Springer, Berlin, Heidelberg, 2008), Chap. 5, pp. 251-289
- [45] F.S. Bergeret, A.F. Volkov, K.B. Efetov, *Rev. Mod. Phys.* 77, 1321 (2005)
- [46] M. Eschrig, *Phys. Today* 64, 43 (2011)
- [47] M.G. Blamire, J.W.A. Robinson, *J. Phys.: Condens. Matter* 26, 453201 (2014)
- [48] J. Linder, J.W.A. Robinson, *Nat. Phys.* 11, 307 (2015)
- [49] L.R. Tagirov, *Phys. Rev. Lett.* 83, 2058 (1999)
- [50] A.I. Buzdin, A.V. Vedyayev, N.V. Ryzhanova, *Europhys. Lett.* 48, 686 (1999)
- [51] B. Dieny, V.S. Speriosu, S.S.P. Parkin, B.A. Gurney, D.R. Wilhoit, D. Mauri, *Phys. Rev. B* 43, R1297 (1991)
- [52] K.D. Usadel, *Phys. Rev. Lett.* 25, 507 (1970)
- [53] M.G. Khusainov, Yu.N. Proshin, *Phys. Rev. B* 56, R14283 (1997).
- [54] Erratum: *Phys. Rev. B* 62, 6832E (2000)
- [55] L.R. Tagirov, *Physica C* 307, 145 (1998)
- [56] Ya.V. Fominov, A.A. Golubov, M.Yu. Kupriyanov, *JETP Lett.* 77, 510 (2003) [*Pis'ma v ZhETF* 77, 609 (2003)]
- [57] I. Baladié, A. Buzdin, *Phys. Rev. B* 67, 014523 (2003)
- [58] S. Tollis, *Phys. Rev. B* 69, 104532 (2004)
- [59] J.Y. Gu, C.-Y. You, J.S. Jiang, J. Pearson, Ya.B. Bazaliy, S.D. Bader, *Phys. Rev. Lett.* 89, 267001 (2002)
- [60] C.-Y. You, Ya.B. Bazaliy, J.Y. Gu, S.-J. Oh, L.M. Litvak, S.D. Bader, *Phys. Rev. B* 70, 014505 (2004)
- [61] A. Potenza, C.H. Marrows, *Phys. Rev. B* 71, 180503(R) (2005)

- [62] J. Zhu, I.N. Krivorotov, K. Halterman, O.T. Valls, Phys. Rev. Lett. 105, 207002 (2010)
- [63] M. Fauré, A.I. Buzdin, A.A. Golubov, M.Yu. Kupriyanov, Phys. Rev. B 73, 064505 (2006)
- [64] M. Fauré, A.I. Buzdin, D. Guskova, Physica C 454, 61 (2007)
- [65] M.Yu. Kupriyanov, V.F. Lukichev, Sov. Phys. JETP 67, 1163 (1988) [Zh. Eksp. Teor. Phys. 94, 139 (1988)]
- [66] L.R. Tagirov, N. Garcia, Superlatt. and Microstr. 41, 152 (2007)
- [67] J. Aarts, C. Attanasio, C. Bell, C. Cirillo, M. Flokstra, J.M. v. d. Knaap, Nanoscience and Engineering in Superconductivity (Springer, Berlin, Heidelberg, 2010), p. 323
- [68] Y. Luo, K. Samwer, Eur. Phys. Lett. 91, 37003 (2010)
- [69] V.I. Zdravkov, J. Kehrle, G. Obermeier, S. Gsell, M. Schreck, C. Müller, H.-A. Krug von Nidda, J. Lindner, J. Moosburger-Will, E. Nold, R. Morari, V.V. Ryazanov, A.S. Sidorenko, S. Horn, R. Tidecks, L.R. Tagirov, Phys. Rev. B 82, 054517 (2010)
- [70] V.I. Zdravkov, J. Kehrle, G. Obermeier, A. Ullrich, S. Gsell, D. Lenk, C. Müller, R. Morari, A.S. Sidorenko, V.V. Ryazanov, L.R. Tagirov, R. Tidecks, S. Horn, Supercond. Sci. Technol. 24, 095004 (2011)
- [71] V.I. Zdravkov, J. Kehrle, D. Lenk, G. Obermeier, A. Ullrich, C. Müller, H.A. Krug von Nidda, R. Morari, A.S. Sidorenko, L.R. Tagirov, S. Horn, R. Tidecks, J. Appl. Phys. 114, 033903 (2013)
- [72] V.I. Zdravkov, D. Lenk, R. Morari, A. Ullrich, G. Obermeier, C. Müller, H.-A. Krug von Nidda, A.S. Sidorenko, S. Horn, R. Tidecks, L.R. Tagirov, Appl. Phys. Lett. 103, 062604 (2013)
- [73] E. Antropov, M. Kalenkov, A. Zaikin, J. Kehrle, V. Zdravkov, R. Morari, A. Socrovisciuc, C. Müller, G. Obermeier, S. Horn, L.R. Tagirov, A. Sidorenko, H. Hahn, R. Tidecks, Supercond. Sci. Technol. 26, 085003 (2013)
- [74] I.C. Moraru, W.P. Pratt Jr., N.O. Birge, Phys. Rev. Lett. 96, 037004 (2006)
- [75] I.C. Moraru, W.P. Pratt Jr., N.O. Birge, Phys. Rev. B 74, 220507(R) (2006)
- [76] A.S. Sidorenko, V.I. Zdravkov, A. Prepelitsa, C. Helbig, Y. Luo, S. Gsell, M. Schreck, S. Klimm, S. Horn, L.R. Tagirov, R. Tidecks, Annalen der Physik (Leipzig-Berlin) 12, 37-50 (2003)
- [77] V.N. Kushnir, S.L. Prischepa, C. Cirillo, C. Attanasio, Eur. Phys. J. B 52, 9 (2006)
- [78] D. Mancusi, E.A. Ilyina, V.N. Kushnir, S.L. Prischepa, C. Cirillo, C. Attanasio, J. Appl. Phys. 110, 113904 (2011)
- [79] V.N. Kushnir, M.Yu. Kupriyanov, Low Temp. Phys. 42, 900 (2016) [Fiz. Nizk. Temp. 42, 1148 (2016)]
- [80] G.-X. Miao, A.V. Ramos, J.S. Moodera, Phys. Rev. Lett. 101, 137001 (2008)
- [81] J. Aarts, J.M.E. Geers, E. Brück, A.A. Golubov, R. Coehoorn, Phys. Rev. B. 56, 2779 (1997)
- [82] A.Yu. Rusanov, S. Habraken, J. Aarts, Phys. Rev. B. 73, 060505(R) (2006)
- [83] J. Aarts, A.Yu. Rusanov, Comptes rendus—Physique 7, 99 (2006)
- [84] S. Takahashi, H. Imamura, S. Maekawa, Phys. Rev. Lett. 82, 3911 (1999)
- [85] V. Peña, Z. Sefrioui, D. Arias, C. Leon, J. Santamaria, J.L. Martinez, S.G.E. te Velthuis, A. Hoffmann, Phys. Rev. Lett. 94, 057002 (2005)
- [86] D. Stamopoulos, E. Manios, M. Pissas, Phys. Rev. B 75, 014501. (2007)
- [87] M.G. Blamire, M. Ali, C.-W. Leung, C.H. Marrows, B.J. Hickey, Phys. Rev. Lett. 98, 217202 (2007)
- [88] D. Stamopoulos, E. Aristomenopoulou, A. Lagogiannis, Supercond. Sci. Technol. 27, 095008 (2014)
- [89] R. Steiner, P. Ziemann, Phys. Rev. B 74, 094504 (2006)
- [90] E.B. Sonin, Sov. Tech. Phys. Lett. 14, 714 (1988). [Pis'ma Zh. Tekh. Fiz. 14, 1640 (1988)]
- [91] E.B. Sonin, Phys. Rev. B 66, 100504R (2002)
- [92] V.V. Ryazanov, V.A. Oboznov, A.S. Prokof'ev, S.V. Dubonos, JETP Lett. 77, 39 (2003) [Pis'ma v ZhETF 77, 43 (2003)]
- [93] I.S. Burmistrov, N.M. Chtchelkatchev, Phys. Rev. B 72, 144520 (2005)
- [94] D.H. Kim, T.J. Hwang, Physica C 455, 58 (2007)
- [95] J. Zhu, X. Cheng, C. Boone, I.N. Krivorotov, Phys. Rev. Lett. 103, 027004 (2009)
- [96] C. Bell, S. Turşucu, J. Aarts, Phys. Rev. B 74, 214520 (2006)
- [97] M. Flokstra, J. M. van der Knaap, J. Aarts, Phys. Rev. B 82, 184523 (2010)
- [98] A.Yu. Rusanov, T.E. Golikova, S.V. Egorov, JETP Lett. 87, 175 (2008) [Pis'ma v ZhETF 87, 204 (2008)]
- [99] T. Trunk, M. Redjfal, A. Kákay, M.F. Ruane, F.B. Humphrey, J. Appl. Phys. 89, 7606 (2001)
- [100] M. Houzet, A.I. Buzdin, Phys. Rev. B 74, 214507 (2006)
- [101] T. Champel, M. Eschrig, Phys. Rev. B 71, 220506 (2005)
- [102] T. Champel, M. Eschrig, Phys. Rev. B; 72, 054523 (2005)
- [103] A.Yu. Rusanov, M. Hesselberth, J. Aarts, A.I. Buzdin, Phys. Rev. Lett. 93, 057002 (2004)
- [104] P.V. Leksin, R.I. Salikhov, I.A. Garifullin, H. Vinzelberg, V. Kataev, R. Klingeler, L.R. Tagirov, and B. Büchner, JETP Lett. 90, 59 (2009). [Pis'ma v ZhETF 90, 64 (2009)]

- [105] M. Flokstra, J. Aarts, Phys. Rev. B 80, 144513 (2009)
- [106] K. Halterman, O.T. Valls, Phys. Rev. B 65, 014509 (2001)
- [107] K. Halterman, O.T. Valls, Phys. Rev. B 72, 060514(R) (2005)
- [108] K. Halterman, P.H. Barsic, O.T. Valls, Phys. Rev. Lett. 99, 127002 (2007)
- [109] K. Halterman, O.T. Valls, P.H. Barsic, Phys. Rev. B. 77, 174511 (2008)
- [110] M. Božović, Z. Radović, Europhys. Lett. 70, 513 (2005)
- [111] C.-T. Wu, O.T. Valls, K. Halterman, Phys. Rev. B 86, 014523 (2012)
- [112] G. Eilenberger, Z. Phys. 214, 195 (1968)
- [113] J. Linder, M. Zareyan, A. Sudbø, Phys. Rev. B 79, 064514 (2009)
- [114] S.V. Mironov, A. Buzdin, Phys. Rev. B 89, 144505 (2014)
- [115] A. Buzdin, M. Daumens, Europhys. Lett. 64, 510 (2003)
- [116] S. Tollis, M. Daumens, A. Buzdin, Phys. Rev. B 71, 024510 (2005)
- [117] X. Montiel, D. Guskova, M. Daumens, A. Buzdin, Europhys. Lett. 86, 67002 (2009)
- [118] J.Y. Gu, G.B. Halász, J.W.A. Robinson, M.G. Blamire, Phys. Rev. Lett. 115, 067201 (2015)
- [119] V.N. Kushnir, E.A. Ilyina, S.L. Prischepa, C. Cirillo, C. Attanasio, Superlattices Microstruct. 43, 86 (2008)
- [120] V.N. Kushnir, S.L. Prischepa, C. Cirillo, C. Attanasio, J. Appl. Phys. 106, 113917 (2009)
- [121] V.N. Kushnir, S.L. Prischepa, C. Cirillo, A. Vecchione, C. Attanasio, M.Yu. Kupriyanov, J. Aarts, Phys. Rev. B 84, 214512 (2011)
- [122] J. Jensen, A.R. Mackintosh, Rare Earth Magnetism. Structures and Excitations (Clarendon Press, Oxford, 1991)
- [123] J.Y. Gu, J.W.A. Robinson, M. Bianchetti, N.A. Stelmashenko, D. Astill, F.M. Grosche, J.L. MacManus-Driscoll, M.G. Blamire, APL Mater. 2, 046103 (2014)
- [124] A. Tesauro, A. Aurigemma, C. Cirillo, S.L. Prischepa, M. Salvato, C. Attanasio, Supercond. Sci. Technol. 18, 1 (2005)
- [125] I. Sosnin, H. Cho, V.T. Petrashov, A.F. Volkov, Phys. Rev. Lett. 96, 157002 (2006)
- [126] V.N. Kushnir, M.Yu. Kupriyanov, Pis'ma Zh. Exp. Teor. Fiz 93, 597 (2011) [JETP Lett. 93, 539 (2011)]
- [127] D. Movshovitz, N. Wiser, Phys. Rev. B 41, 10503 (1990)
- [128] G. Brammertz, A.A. Golubov, P. Verhoeve, R. den Hartog, T. Peacock, H. Rogalla, Appl. Phys. Lett. 80, 2955 (2002)
- [129] V.N. Kushnir, S.L. Prischepa, Dokl. NAN Belarusi 56, 60 (2012)
- [130] S. Oh, D. Youm, M.R. Beasley, Appl. Phys. Lett. 71, 2376 (1997)
- [131] K. Westerholt, D. Sprungmann, H. Zabel, R. Brucas, B. Hjörvarsson, D.A. Tikhonov, I.A. Garifullin, Phys. Rev. Lett. 95, 097003 (2005)
- [132] G. Nowak, K. Westerholt, H. Zabel, Supercond. Sci. Technol. 26, 025004 (2013)
- [133] Ya.V. Fominov, A.A. Golubov, T.Yu. Karminskaya, M.Yu. Kupriyanov, R.G. Deminov, L.R. Tagirov, JETP Lett. 91, 308 (2010). [Pis'ma v Zh. Exp. Teor. Fiz 91, 329 (2010)]
- [134] T.Yu. Karminskaya, A.A. Golubov, M.Yu. Kupriyanov, Phys. Rev. B. 84, 064531 (2011)
- [135] C.-T. Wu, O.T. Valls, K. Halterman, Phys. Rev. B 86, 014523 (2012)
- [136] P.V. Leksin, N.N. Garif'yanov, I.A. Garifullin, J. Schumann, H. Vinzelberg, V. Kataev, R. Klingeler, O.G. Schmidt, and B. Büchner, Appl. Phys. Lett. 97, 102505 (2010)
- [137] P.V. Leksin, N.N. Garif'yanov, I.A. Garifullin, J. Schumann, V. Kataev, O.G. Schmidt, B. Büchner, Phys. Rev. Lett. 106, 067005 (2011)
- [138] P.V. Leksin, N.N. Garif'yanov, I.A. Garifullin, J. Schumann, V. Kataev, O.G. Schmidt, B. Büchner, Phys. Rev. B 85, 024502 (2012)
- [139] P.V. Leksin, N.N. Garif'yanov, I.A. Garifullin, J. Schumann, V. Kataev, O.G. Schmidt, B. Büchner, Phys. Rev. Lett. 109, 057005 (2012)
- [140] P.V. Leksin, A.A. Kamashev, N.N. Garif'yanov, I.A. Garifullin, Ya.V. Fominov, J. Schumann, C. Hess, V. Kataev, B. Buchner, JETP Lett. 97, 478 (2013) [Pis'ma v ZhETF 97, 549 (2013)]
- [141] P.V. Leksin, N.N. Garif'yanov, A.A. Kamashev, Ya.V. Fominov, J. Schumann, C. Hess, V. Kataev, B. Büchner, I.A. Garifullin, Phys. Rev. B 91, 214508 (2015)
- [142] A.A. Jara, C. Safranski, I.N. Krivorotov, C.-T. Wu, A.N. Malmi-Kakkada, O.T. Valls, K. Halterman, Phys. Rev. B 89, 184502 (2014)
- [143] M.G. Flokstra, T.C. Cunningham, J. Kim, N. Satchell, G. Burnell, S.J. Bending, P.J. Curran, S.J. Langridge, C. Kinane, J.F.K. Cooper, N. Pugach, M. Eschrig, S.L. Lee, Phys. Rev. B 91, 060501(R) (2015)
- [144] X.L. Wang, A. Di Bernardo, N. Banerjee, A. Wells, F.S. Bergeret, M.G. Blamire, J.W.A. Robinson, Phys. Rev. B 89, 140508(R) (2014)

- [145] V.I. Zdravkov, J. Kehrle, G. Obermeier, D. Lenk, H.-A. Krug von Nidda, C. Müller, M.Yu. Kupriyanov, A.S. Sidorenko, S. Horn, R. Tidecks, L.R. Tagirov, Phys. Rev. B 87, 144507 (2013)
- [146] D. Lenk, V.I. Zdravkov, J.-M. Kehrle, G. Obermeier, A. Ullrich, R. Morari, H.-A. Krug von Nidda, C. Müller, M.Yu. Kupriyanov, A.S. Sidorenko, S. Horn, R.G. Deminov, L.R. Tagirov, R. Tidecks, Beilstein J. Nanotechnol. 7, 957 (2016)
- [147] A. Ruotolo, C. Bell, C.W. Leung, M.G. Blamire, J. Appl. Phys. 96, 512 (2004)
- [148] Yu.N. Proshin, Yu.A. Izyumov, M.G. Khusainov, Phys. Rev. B 64, 064522 (2001)
- [149] K. Halterman, O.T. Valls, Phys. Rev. B 69, 014517 (2004)
- [150] K. Halterman, O.T. Valls, Phys. Rev. B 70, 104516 (2004)
- [151] Y.N. Proshin, A. Zimin, N.G. Fazleev, M.G. Khusainov, Phys. Rev. B 73, 184514 (2006)
- [152] P.H. Barsic, O.T. Valls, K. Halterman, Phys. Rev. B 75, 104502 (2007)
- [153] V.N. Kushnir, M.Yu. Kupriyanov, JETP Lett. 93, 539 (2011)
- [154] V.N. Kushnir, S.L. Prischepa, C. Cirillo, A. Vecchione, C. Attanasio, M.Yu. Kupriyanov, J. Aarts, Phys. Rev. B 84, 214512 (2011)
- [155] I.A. Golovchanskiy, V.V. Bolginov, N.N. Abramov, V.S. Stolyarov, A. Ben Hamida, V.I. Chichkov, D. Roditchev, V.V. Ryazanov, Journ. Appl. Phys. 120, 163902 (2016)
- [156] M.Yu. Kupriyahov, A.A. Golubov, M. Siegel, Proc. SPIE 6260, 62600S (2006)
- [157] L.S. Uspenskaya, A.L. Rakhmanov, L.A. Dorosinskii, A.A. Chugunov, V.S. Stolyarov, O.V. Skryabina, S.V. Egorov, JETP Lett. 97, 155 (2013)
- [158] N.G. Pugach, M.Yu. Kupriyanov, E. Goldobin, R. Kleiner, D. Koelle, Phys. Rev. B 84, 144513 (2011)