Nano-Scale Spin Conversion Science

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Spin conversion science is a generic term for the research field treating a variety of angular momentum transfer phenomena mediated by electronic spins. This can be classified into 4 types such as magnetic, electronic, optical, and thermo kinetic conversions. The magnetic and electronic conversions were initiated by the theoretical and experimental demonstrations of spin transfer torque[1, 2] and its reverse effect, i.e. spin pumping[3, 4]. These two phenomena have separately evolved as means to manipulate magnetic switching and domain wall displacement, or to inject dynamic spin currents into adjacent materials. When the adjacent materials exhibit strong spin-orbit interaction, spin currents can be converted into charge currents and vice versa via the direct (DSHE) and inverse spin Hall effects (ISHE)5). Important to note is that the ISHE enabled us to detect the spin currents and to discover a variety of spin conversion phenomena including the thermo kinetic spin conversion, Spin Seebeck effects in metals[6] and insulators[7]. The same is true for the optical conversion where the optical angular momentum of circularly polarized light can be transferred to the magnetic moment and eventually switch its direction[8].

In this symposium we will show our recent experimental and theoretical efforts to understand the spin conversion phenomena in terms of the above mentioned 4 types of conversions. In this talk, the overview of the spin conversion science is given and then some of representative magnetic spin conversion phenomena such as SHEs in random spin systems[9] and spin torque ferromagnetic resonance studies are presented.

Reference

1) L. Berger, J. Appl. Phys. **3** (1978) 2156; L. Berger, J. Appl. Phys. **3** (1979) 2137; J.C. Slonczewski, J. Magn. Magn. Mater. **159** (1996) L1.
2) T. Ono, Y. Ooka, S. Kasai, H. Miyajima, N. Nakatani, N. Hayashi, K. Shigeto, K. Mibu, T. Shinjo, Mater. Sci. Eng. B **84** (2001) 126; M. Tsoi, R.E. Fontana, S.S.P. Parkin, Appl. Phys. Lett. **83** (2003) 2617.
3) Y. Tserkovnyak, A. Brataas, G.E.W. Bauer, Phys. Rev. Lett. **88** (2002) 117601.
4) S. Mizukami, Y. Ando, T. Miyazaki, Phys. Rev. **B 66** (2002) 104413.
5) E. Saitoh, M. Ueda, H. Miyajima and G. Tatara, Appl. Phys. Lett. **88** (2006) 182509; S. O. Valenzuela and M. Tinkham, Nature **442** (2006) 176; T. Kimura, Y. Otani, T. Sato, S. Takahashi, and S. Maekawa, Phys. Rev. Lett. **98** (2007) 156601.
6) K. Uchida, S. Takahashi, K. Harii, J. Ieda, W. Koshibae, K. Ando, S. Maekawa and E. Saitoh, Nature **455** (2008) 778.
7) K. Uchida, J. Xiao, H. Adachi, J. Ohe, S. Takahashi, J. Ieda, T. Ota, Y. Kajiwara, H. Umezawa, H. Kawai, G. E. W. Bauer, S. Maekawa and E. Saitoh, Nature Matter. **9** (2010) 894.
8) C. E. Graves, A. H. Reid, T. Wang, B. Wu, S. de Jong, K. Vahaplar, I. Radu, D. P. Bernstein, M. Messerschmidt, L. Müller, R. Coffee, M. Bionta, S. W. Epp, R. Hartmann, N. Kimmel, G. Hauser, A. Hartmann, P. Holl, H. Gorke, J. H. Mentink, A. Tsukamoto, A. Fognini, J. J. Turner, W. F. Schlotter, D. Rolles, H. Soltau, L. Strüder, Y. Acremann, A. V. Kimel, A. Kirilyuk, Th. Rasing, J. Stöhr, A. O. Scherz and H. A. Dürr, Nature Materials **12** (2013) 293.
9) D. H. Wei, Y. Niimi, B. Gu, T. Ziman, S. Maekawa and Y. Otani, Nature Comm. **3** (2012) 1058.
10) L. Berger, J. Appl. Phys. **3** (1978) 2156; L. Berger, J. Appl. Phys. **3** (1979) 2137; J.C. Slonczewski, J. Magn. Magn. Mater. **159** (1996) L1.
11) T. Ono, Y. Ooka, S. Kasai, H. Miyajima, N. Nakatani, N. Hayashi, K. Shigeto, K. Mibu, T. Shinjo, Mater. Sci. Eng. B **84** (2001) 126; M. Tsoi, R.E. Fontana, S.S.P. Parkin, Appl. Phys. Lett. **83** (2003) 2617.
12) Y. Tserkovnyak, A. Brataas, G.E.W. Bauer, Phys. Rev. Lett. **88** (2002) 117601.
13) S. Mizukami, Y. Ando, T. Miyazaki, Phys. Rev. **B 66** (2002) 104413.
14) E. Saitoh, M. Ueda, H. Miyajima and G. Tatara, Appl. Phys. Lett. **88** (2006) 182509; S. O. Valenzuela and M.

Tinkham, Nature **442** (2006) 176; T. Kimura, Y. Otani, T. Sato, S. Takahashi, and S. Maekawa, Phys. Rev. Lett. **98** (2007) 156601.

15) K. Uchida, S. Takahashi, K. Harii, J. Ieda, W. Koshibae, K. Ando, S. Maekawa and E. Saitoh, Nature **455** (2008) 778.

16) K. Uchida, J. Xiao, H. Adachi, J. Ohe, S. Takahashi, J. Ieda, T. Ota, Y. Kajiwara, H. Umezawa, H. Kawai, G. E. W. Bauer, S. Maekawa and E. Saitoh, Nature Matter. **9** (2010) 894.

17) C. E. Graves, A. H. Reid, T. Wang, B. Wu, S. de Jong, K. Vahaplar, I. Radu, D. P. Bernstein, M. Messerschmidt, L. Müller, R. Coffee, M. Bionta, S. W. Epp, R. Hartmann, N. Kimmel, G. Hauser, A. Hartmann, P. Holl, H. Gorke, J. H. Mentink, A. Tsukamoto, A. Fognini, J. J. Turner, W. F. Schlotter, D. Rolles, H. Soltau, L. Strüder, Y. Acremann, A. V. Kimel, A. Kirilyuk, Th. Rasing, J. Stöhr, A. O. Scherz and H. A. Dürr, Nature Materials **12** (2013) 293.

18) D. H. Wei, Y. Niimi, B. Gu, T. Ziman, S. Maekawa and Y. Otani, Nature Comm. **3** (2012) 1058.