using a poly(dimethylsiloxane) stamp. Cobalt oxide ALD proceeds on the exposed oxide surface.

For the first time, we illustrate a path to selectively deposit ultrathin magnetic cobalt films. Finally, we explore the dependency of film coercivity with the reduction conditions and demonstrate control over the tunability of the coercivity of the resultant films by controlling the reduction conditions and interface quality.

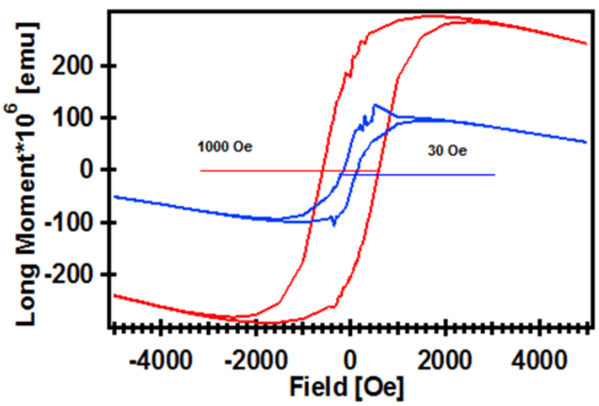

Fig. 1. SQUID measurements of SrO/Co/MgO(001) (blue color), and SrO/Co/CoO/MgO(001) (red color) heterostructures as a function of applied magnetic field measured at 300 K.

1. T. Q. Ngo, A. Posadas, H. Seo, H. Son, M. D. McDaniel, D. Utess, D. H. Triyoso, C. B. Mullins, A. A. Demkov, J. G. Ekerdt, *J. Appl. Phys*. **114**, 08491 (2013).

C14: Silicon Spintronics

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The sustainable increase in performance of integrated circuits is continuously supported by the miniaturization of electronic components and interconnects. The state-of-the art 14nm technology recently adopted by the semiconductor industry allows manufacturing multi-gate three-dimensional transistors [1]. Although single devices with the gate length as short as a few nanometers have been demonstrated [2], fabrication, control, and integration costs combined with reliability issues will gradually bring the CMOS scaling to an end.

The principle of the MOSFET operation is fundamentally based on the charge of an electron interacting with the electrostatic field. Another intrinsic electron characteristic, the electron spin, attracts at present much attention as a possible candidate for complementing or even replacing the charge degree of freedom in future electronic devices [3]. The electron spin is characterized by two projections on an axis and could be potentially used in digital information processing. It takes an amazingly small amount of energy to invert the spin orientation. The key advantages of all spin-based computing are zero static power, small device count, and low supply voltage [4].

However, spin injection, detection, and propagation were not demonstrated until recently. The fundamental reason preventing spins from a ferromagnetic metal being injected into a semiconductor is a spin impedance mismatch problem [5]. A solution is the introduction of a potential barrier between the metal and semiconductor [6]. The problem of making good contacts with low resistance per area is critical for spin injection. Tunnel contacts made of a single layer graphene [7] have been shown to be close to optimal [8].

The excess spin injected is not a conserved quantity: While diffusing, it gradually relaxes to its equilibrium value which is zero in a nonmagnetic semiconductor. Spin can propagate 350 μm through a silicon wafer at 77K [9]. The spin diffusion length in silicon at room temperature is around 200nm [8]. In a confined electron structure the spin lifetime is further reduced due to the additional spin relaxation at the interfaces [10]. This shortens the spin diffusion length, and technologies to boost the spin lifetime are needed.

In (001) silicon films the spin lifetime is controlled by the intervalley scattering processes between the equivalent valleys. Uniaxial stress along [110] direction lifts the degeneracy thus reducing the spin relaxation [11]. This results in a large spin lifetime enhancement [12]. As strain is now routinely used to increase the electron mobility, it is straightforward to apply the same technique to boost the spin lifetime.

A purely electrical spin manipulation was recently demonstrated in an InGaAs heterostructure with point contacts at low temperature [13]. Due to the difficulty to manipulate spin in silicon channels by voltage-dependent spin-orbit interaction, the only option to add spin in nanoscale CMOS technology is to introduce ferromagnetic source and drain contacts [13]. The current then depends on the relative orientation of the magnetizations of source and drain paving the path towards reprogrammable non-volatile logic [13].

The most viable option for practical spin-driven applications in the near future is to use magnetic tunnel junctions (MTJs). MTJ-based spin transfer torque memory is CMOS compatible, fast, and non-volatile. In addition, the combination of an MTJ with a MOSFET opens an opportunity to build non-conventional non-volatile logic-in-memory computational architectures [15].

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[1] S. Natarajan et al., IEDM 2014., pp. 71–73 (2014).

[2] B. Doris et al., IEDM 2002, pp. 267–270 (2002).

[3] I. Zutic et al., Rev.Mod.Phys. 76, 323 (2004); J. Fabian et al., Acta Physica Slovaca 57, 565 (2007).

[4] J. Kim et al., Proceedings of the IEEE, 103, 106 (2015).

[5] G. Schmidt et al., Phys.Rev.B 62, R4790 (2000).

[6] E.I. Rashba, Phys.Rev.B 62, R16267 (2000).

[7] O.M.J. van t'Erve et al., Nature Nanotechnology 7, 737 (2012).

[8] R. Jansen, Nature Materials 11, 400 (2012).

[9] B. Huang et al., Phys.Rev.Lett. 99, 177209 (2007).

[10] J. Li and I. Appelbaum, Appl.Phys.Lett. 100, 162408 (2012).

[11] V. Sverdlov, Strain-induced effects in advanced MOSFETs. Wien - New York. Springer 2011.

[12] V. Sverdlov and S. Selberherr, Physics Reports 585, 1 (2015).

[13] P. Chuang et al., Nature Nanotechnology 10, 35 (2015).

[14] S. Sugahara and J. Nitta, Proceedings of the IEEE, 98, 2124 (2010).

[15] H. Mahmoudi et al., Solid-State Electron. 84, 191 (2013).

C15: Efficient spin injection in metallic hybrid structures

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Generation, manipulation and detection of spin currents are important issues in the operation spintronic devices because a spin current plays an important role in spin-dependent transport and spin-transfer switching. Especially, pure spin current which is the spin current without accompanying the charge current is an attractive quantity for utilizing the spin current efficiently. Nonlocal spin valve measurements in laterally configured ferromagnetic metal (FM)/nonmagnetic metal (NM) hybrid nanostructures is a powerful means for evaluating the intriguing properties of pure spin current precisely. In this talk, I will introduce materials for the efficient generation and detection of the pure spin current and a structure for efficient control of the absorption property of the pure spin current.

In the first part, I will introduce the results on the efficient generation of pure spin current using CoFeAl. We show that CoFeAl alloy is an excellent material not only for the electrical spin injection but also thermal spin injection because of its favorable band structure as schematically shown in Fig. 1.[1] Moreover, the wireless microwave irradiation in the ferromagnetic metal is found to