Spin injection, transport and detection technology in ferromagnet/MgO/Si devices

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Spin metal-oxide semiconductor field-effect transistors (spin-FETs) [1, 2], whose source and drain electrodes consist of ferromagnetic materials, are expected to lead to a new logic-in-memory architecture. Recently, many studies of silicon (Si) spintronics for realizing the spin-FETs have been reported because of the observation of room-temperature spin signals in Si. [3-9,12,13] However, in order to realize the spin-FETs, it is necessary to improve injection and detection efficiencies of electrical spin in semiconductors [10-13]. We have been observing spin accumulation signals in Si with relatively long spin relaxation time by measuring three-terminal and four-terminal Hanle signals for CoFe/MgO/n^+-Si(100) and Heusler Co_2FeSi/MgO/n^+-Si(100) devices [4, 7-13], and observing local magnetoresistance (MR) and nonlocal (NL)-MR signals up to room temperature. [9, 11-13] However, the estimated spin polarization using standard spin diffusion theory was a small value of ~ 0.16. [8, 9, 11] The spin polarization in n^+-Si estimated by other gropes using standard spin diffusion theory has also exhibited small values, for example: ~ 0.05 for Fe/MgO/n^+-Si at 8 K [6] and ~ 0.15 for CoFe/n^+-Si devices at room temperature. [5] It is therefore necessary to improve the spin polarization (spin injection and detection efficiency) in Si to achieve large spin signals in Si. Recently, we have been succeeded in improving the spin polarization in Si. [12, 13] The estimated spin polarization (P) and spin life time (τ) are P ~ 40% and τ ~ 1 nsec, respectively at room temperature. The large spin injection and detection efficiency into Si and relatively long spin relaxation time even at room temperature and spin signals at room temperature along with its robustness up to 400^{o}C are observed.

In this invited talk, we review the resent progress and our current status of Ferromagnet/MgO/n^+-Si junction technology for increasing the spin signals in Si. This work was partly supported by ImPACT Program of Council for Science, Technology and Innovation (Cabinet Office, Government of Japan) and Grant-in-Aid for Scientific Research from JSPS.

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