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STUDIES THE ALL-OPTICAL SWITCHING AS THE APPLICATION OF OPTO-SPINTRONICS.

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Abstract:

In the field of Opto-spintronics, this research leads to the advancement of the memory circuit and computation technology with the spinning degree of electrons. The femtosecond optical laser pulse is most relevant to trigger the quick change in the magnetic state of the material, which leads to the possibilities of higher speed and energy-efficient opto-spintronic devices and memory.

The all-optical switching of magnetization shows that how light-spin interaction playing an important role to the improvement of memory devices. So, this paper focuses on optical control of magnetization by transient non-equilibrium state. Finally, all-optical magnetization switching with the magnetic domain access reliable higher-power memory devices will be developed for magnetic writing with a least dissipative method. It is investigated that the effect of spin Hall effect is driven motion of magnetic domains indicates single-pulse All-optical switching.

Key Words: Magnetic writing, Opto-Spintronics, Hall effect, (AOS)All optical-switching, Domain wall, Ferrimagnetic racetrack

Introduction: The traditional charge carriers of electronic and semiconductor devices are electrons and holes whereas the emerging spintronic technology is based on the intrinsic spinning of electrons and their magnetic moment because electrons can rotate either anticlockwise or clockwise direction at fixed frequency around its axis. So, their states spin up and spin down can be represented by 0 or 1. The ferromagnetic material is useful to show the effect of spinning properties because its spin up and spin-down magnetic moments can not be cancelled due extra accumulation spin in the region, called magnetic domain. Nowadays, spintronic technology is the most important and driving technology with optical signals to develop ultra-fast and ultra-modern photonic memory devices. For the last five decades, the miniaturization of semiconductor devices going on but in this paper, the effect of the combination of applications of nanotechnology, spintronics, and optical signal technology is used to develop the photonic memory device. In this case, the spin polarization is created by the application of circularly polarized optical pulse and excited spin-polarized electrons as per the optical selection rule and then the current of spin-polarized electrons is used for spin generation [1-7].

The Seebeck and Nearnst effect of spin caloritronics is also considered the cause of spin-polarized carrier current due to thermal gradient as the proper and useful energy harvesting. So many magnetic memory devices launched in the market, but with the improvement of its

characteristics like low power operation, stochastic computing, and energy harvesting, this research will provide new aspects for the Opto-spintronic racetrack memory device [8-13].
In 1988, the birth of spintronics through the discovery of giant-magneto resistance in the multi-layers of magnetic materials, which further led in 1994, to the tunnel magnetoresistance by a thin insulating condition between two consecutive magnetic layers, this effect is preferred here to develop the improved memory device. The mixing of spin-up and spin-down electronic states by spin-orbit coupling induces the scattering of conduction electrons anisotropically in the sample under the application of an external magnetic field. So, the anisotropic magnetoresistance (AMR) of the AMR sensor used to record the information of the applied magnetic field as per its direction and magnitude since 2018.

Due to the high-power potential of nano optical circuits behaves as all-optical switching (AOS) that allows one light signal to transmit from its input port to the output port under optical control for fast and energy-efficient memory devices without change in electrical voltage. That is, the AOS can directly store the optical data in magnetic bits as shown in the fig-1. It makes maximization of the switching speed and the minimization of network equipment at minimal operating power. The switching energy is approximately 35 fJ and the switching rate is approximately 260 fsecs. attended in this nano-scale integrated optical device [14-17].

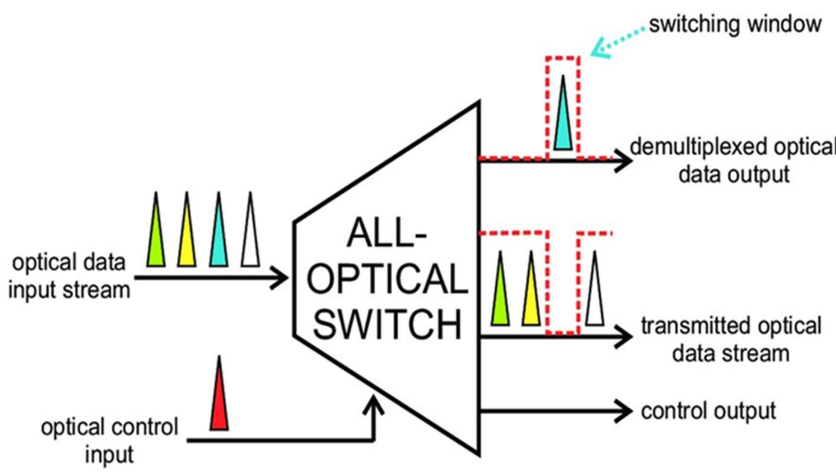

Figure. 1

The photonic and spintronic research fields benefited with a further boost when AOS is obtained in the ferromagnetic thin films and the structure of multilayers. Using a thermal single pulse All-optical switching mechanism, spintronic integration became successful. Whereas multilayers of Pt/Co/Gd for single pulse AOS are investigated and this structure has perpendicular magnetic isotropy in the Pt layer, interfacial anti-ferromagnetic coupling between co and Gd layers with greater demagnetization time between them. This experiment indicated that Pt/Co/Gd racetrack is the successful integration of AOS and spintronics for the opto-spintronic memory devices. The spin Hall effect (SHE) and DW chirality verified these facts by showing the movement of the domain wall of the optically written domain coherently throughout this racetrack. That is, the written magnetic domain transmitted through this single pulse all-optical switching (AOS) over electrical current of spin wave in the Pt/Co/Gd racetrack[18-19]

Result (Analysis of SHE Efficiency and DW Chirality):

The Pt/Co/Gd racetrack is prepared by DC magnetron sputtering at room temperature in the deposition chamber at 10^{-9} mbar and then lithography is used, the size of the sample is 90 μm long and 5 μm width developed on SiO_2 coated Si Substrate.

By the field-driven spin hall effect-based measurement of domain wall (DW) velocity, it is observed that domain wall velocity is either supported or opposed by the spin Hall effect depending upon the polarity of the current. The domain wall velocity as a function of driving field amplitude with 0 mA and +1 mA direct current through the sample is shown in Figures 2 and 3 respectively. This satisfies the creep law and shows the domain wall chirality of the optically written domain, which shows the independence of domain wall velocity with respect to DW polarity.

Now, the Spin Hall effect efficiency is calculated and its value is 9.73 ± 0.08 mT, as the current density to effective field conversion factor which shows the agreement with theoretical value as per global fit parameters [18-19]

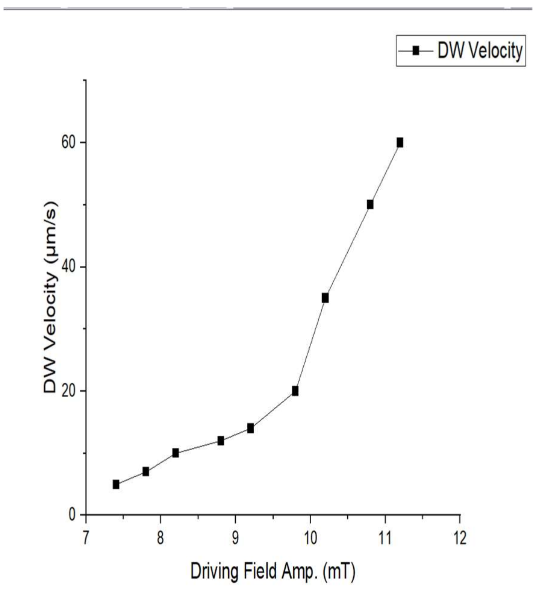

Fig. 2a

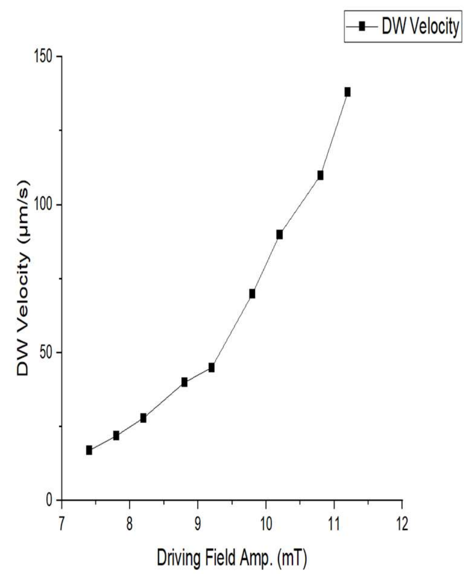

Fig. 2b

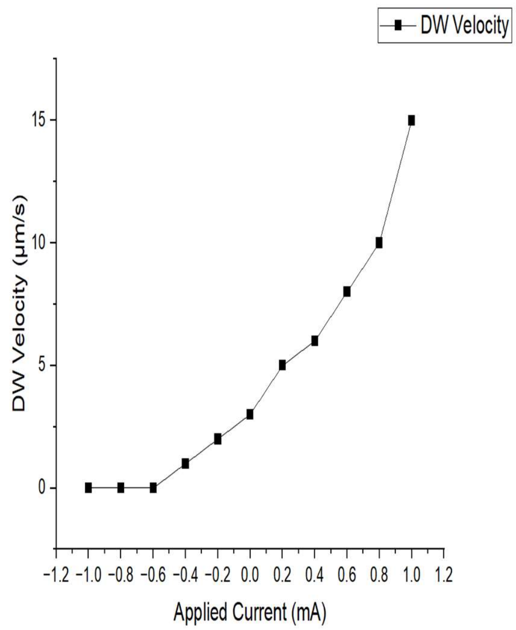

Fig -3a

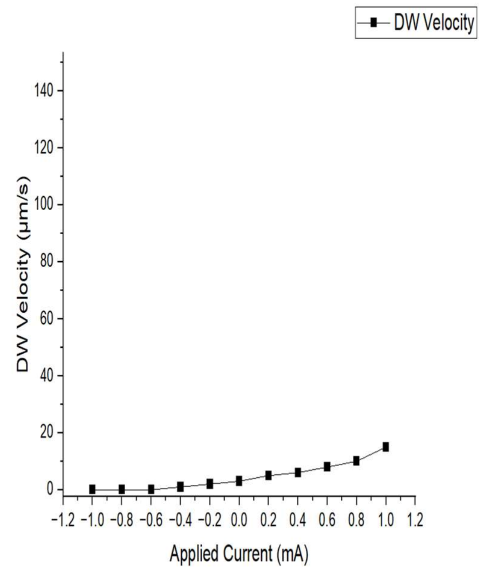

Fig.-3b

For the obtained value of spin Hall effect efficiency in this developed racetrack, the effective out-of-plane field strength is 280 mT [19]. Graph figures 3a and 3b show that with the increase in temperature DW velocity curve not only shifts up but also its exponential nature changes due to thermal activation.

Conclusion:

The use of more specific magnetization by minimizing Co thickness or proper development of synthetic-ferrimagnet of sample racetrack, domain wall velocity must be attending its higher value. Furthermore, the domain wall motion induced by the spin Hall effect with perpendicular anisotropy of Pt/Co/Gd racetrack and thermal single pulse AOS can be combined, and controlled over efficient motion of optically written domains and chirality of domain wall. Therefore, the integrated photonic memory devices will become effective through the integration of all-optical switching (AOS) and racetrack memory. Finally, the sensitivity of this integrated photonic memory can be improved by a quantum mechanical approach. That is, this memory device of the next generation not only increases memory power, and processing capabilities but also reduced power consumption. Again, the quantum mechanical study will lead to the miniaturization and efficiency of this device.

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