Investigation of spin dynamics in Ni-Pd alloys

using extreme ultraviolet radiation

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Application Note

Introduction

Controlling magnetization alignment using femtosecond light pulses may be the next possible approach to store binary information in magnetic materials. Nevertheless, to proceed towards this goal a deeper understanding of the non-equilibrium ferromagnetism and interaction of laser light with complex ferromagnetic materials is required. In our experimental approach we investigate optically triggered spin dynamics in magnetic alloys and multilayers to discern the underlying physical processes. Measuring the material's optical response with ultrashort extreme-ultraviolet pulses permitting resonant probing and element selectivity has proven to be a decisive feature for providing crucial insights about spin currents and exchange breakdown in a broad set of technologically relevant materials [1,2].

Experimental setup

Figure 1 shows our experimental setup. The extreme ultraviolet (XUV) light is generated by focusing ultrashort laser pulses (1.57 eV, 2mJ per pulse at 3 kHz, pulse duration 35 fs) into a glass capillary filled with neon gas. The outgoing XUV radiation is separated from the fundamental laser light by two 150 nm thick Al foils in order to block the visible light. Due to the high absorption of XUV in air all components after the XUV capillary source are mounted inside vacuum (10^{-5} mbar). After passing the Al filters, the XUV beam is directed at the sample and the light is dispersed during reflection using optical grating etched into the substrate surface. The reflected light is then recorded by a XUV-sensitive low-noise cooled CCD camera (Newton DO920P-BEN with 1024 x 255 x 26 µm pixels from Andor Technology). In order to register the magnetic signal, resonant reflectivity in the XUV range [3,4] covering the Ni and Pd absorption edges was recorded.

Strong increase of magneto-optic signal at these resonances allowed element-selective tracing of the Ni and Pd signal separately. To study spin dynamics, the Ni-Pd thin film was excited using near-infrared light from the same laser source.

Results

In our work we fabricated a set of Ni-Pd thin films to study spin dynamics in alloys consisting of a *3d* metallic ferromagnet (Ni) and a *4d* non-magnetic metal (Pd). Earlier studies have shown that an increase of the Pd concentration leads to a reduction of the Curie temperature (TC) as well as to a slight decrease of the average magnetic moment µ [5]. At the same time, the material modifications lead to a change of the spin-flip probability which is expected to result in a variation of the demagnetization time τ_m [6]. In order to gain insight into the possible dynamical interplay between the involved material subsystems we employ extreme ultraviolet (XUV) light [7] tuned near the $M_{2,3}$ absorption edge of Ni (68 eV) and the $N_{2,3}$ edge of Pd (51 eV) to get the separate contributions of Ni and Pd, employing transversal magneto-optical Kerr effect geometry. Magnetic contrast in this configuration has been registered by measuring the reflectivity of a p-polarized XUV light at two magnetic fields aligned in opposite directions and magnetic asymmetry was then obtained as a normalized difference of reflected intensities corresponding to the two fields. Figure 2(a) clearly demonstrates that the Ni-Pd alloy shows magnetic asymmetry near the expected resonances corresponding to Ni and Pd absorption edges. Magnetic contrast of up to 35% for Ni near the Brewster angle indicates that tracing the time evolution of the magneto-optical asymmetries at the elemental resonances is well within the experimental capabilities of the setup (Figure 2(b)).

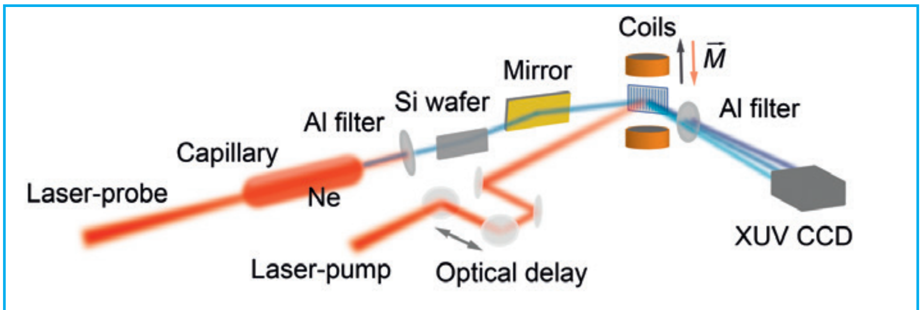

Fig.1 Schematics of a resonant magnetic scattering experiment using high-order laser harmonic source and Andor Newton SO 920 camera as XUV detector.

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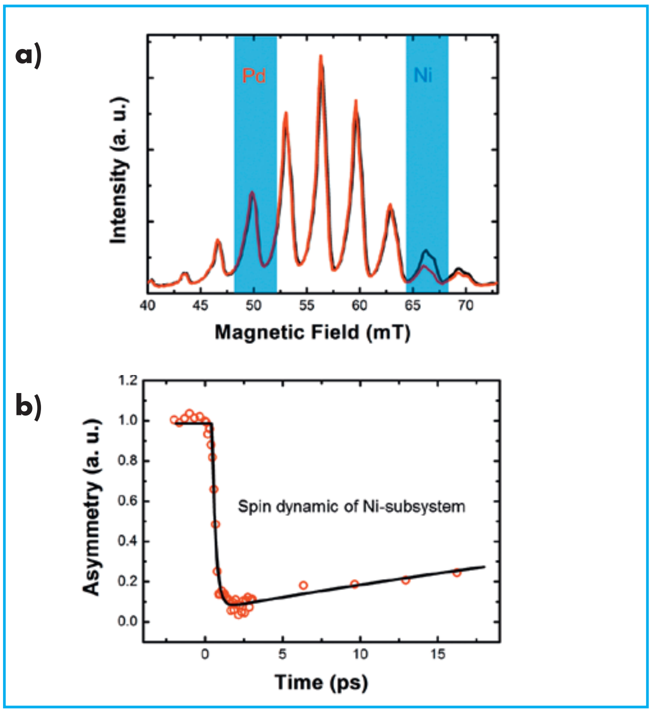

Fig.2. (a) Intensity spectrum of the reflected light from a Ni-Pd thin-film with magnetization pointing 'up' (red) and 'down' (black). A clear T-MOKE asymmetry is visible at the energy of the Ni and the Pd absorption edge.
2 (b) The temporal evolution of the magnetic signal at the Ni absorption edge after optical excitation shows an ultrafast quenching on the sub-picosecond time scale.

Summary
In our transverse magneto-optical Kerr effect experiment employing extreme ultraviolet light with energies ranging between 20 eV and 72 eV we can separate magnetic contributions from Ni and Pd elemental subsystems. Time-evolution of the spectra as a function of time after the system excitation delivers crucial insight into the physical mechanism of optically triggered spin-dynamic on femtosecond time scales.

References
[1] Rudolf, D., La-O-Vorakiat, C., Battiato, M., Adam, R., Shaw, J. M., Turgut, E., Maldonado, P., Mathias, S., Grychtol, P., Nembach, H. T., Silva, T. J., Aeschlimann, M., Kapteyn, H. C., Murnane, M. M., Schneider, C. M. and Oppeneer, P. M., Ultrafast magnetization enhancement in metallic multilayers driven by superdiffusive spin current Nature Commun. 2012, Vol. 3 1037.

[2] Mathias, S., La-O-Vorakiat, C., Grychtol, P., Granitzka, P., Turgut, E., Shaw, J.M., Adam, R., Nembach, H.T., Siemens, M., Eich, S., Schneider, C. M., Silva, T., Aeschlimann, M., Murnane, M.M. and Kapteyn, H. Probing the timescale of the exchange interaction in a ferromagnetic alloy PNAS, 2012, 1201371109v1-6.

[3] Hecker, M., Oppeneer, P.M., Valencia, S., Mertins, H.-Ch. & Schneider, C.M. Soft X-ray magnetic reflection spectroscopy at the 3p absorption edges of thin Fe films Journal of Electron Spectroscopy and Related Phenomena, 2005, Vol. 144–147(0), pp. 881 - 884

[4] Grychtol, P., Adam, R., Valencia, S., Cramm, S., Bürgler, D.E. & Schneider, C.M. Resonant magnetic reflectivity in the extreme ultraviolet spectral range: Interlayer-coupled Co/Si/Ni/Fe multilayer system, Phys. Rev. B, 2010, Vol. 82(5), p. 054433

[5] Wijn H. P. J., Magnetic properties of metals: d-elements, alloys, and compounds. Springer, (1991).

[6] Koopmans, B., Malinowski, G., Dalla Longa, F., Steiauf, D., Fähnle, M., Roth, T., Cinchetti, M. and Aeschlimann, M. Explaining the paradoxical diversity of ultrafast laser-induced demagnetization Nature Materials, 2010, Vol. 9, pp. 259-265.

[7] Kapteyn, H. C., Murnane, M.M. and Christov, I.P. Extreme Nonlinear Optics: Coherent X Rays from Lasers Physics Today, 2005, Vol. 58(3), pp. 39-46.

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