A novel Graphene/Heusler Alloy Heterostructure for Advanced Spintronics

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The graphene-based spintronic devices are receiving an intensive interest due to the great potential for next-generation ultrafast and lower-power-consumption memory and logic technology. [1, 2] Nevertheless, the performance in the developed graphene-based spintronic device up to dates are found too poor to satisfy the requirement for real device application. The low spin polarization of the ferromagnets involved in the reported graphene-based spintronic devices is thought to be one of the main reasons corresponds to the poor performance. Thus, the adoption of ferromagnets with high spin polarization into graphene-based spintronic devices are crucial to improve the performance. This report presents our recent efforts on the successfully fabrication of a novel heterostructure consisting of CVD-grown single-layer graphene on half-metallic full Heusler alloy $Co_2Fe(Ge_{0.5}Ga_{0.5})$ (CFGG, hereafter) ferromagnet with high spin polarization.[3] The quality and interfacial electronic and magnetic properties were investigated in order to evaluate the feasibility by using this new heterostructure for advanced spintronic device applications.

The quality of the graphene grown on CFGG was characterized by Raman spectroscopy as shown in Fig.1(a). The small intensity of the defect-induced D band compared to the G band suggests a high crystal quality of graphene formed on CFGG. Fig.1(b) shows the x-ray absorption spectroscopy XAS spectra at the C *K*-edge obtained in the partial-electron-yield (PEY) mode at the x-ray incident angle α of 30° and 90° with respect to the sample surface, respectively. We observed a sharp peak (285 eV) due to the π* resonance of graphene, as well as the peak (290~300 eV) due to the σ* resonance. The sharpness of the π* resonance peak

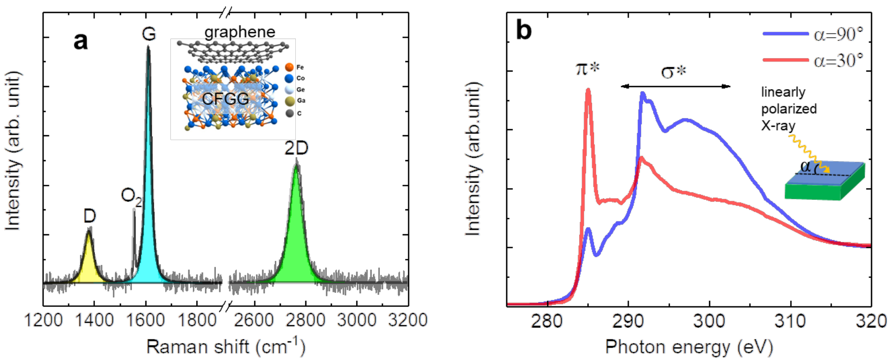

Figure 1. a) Raman spectrum of graphene/CFGG heterostructure. b) C *K*-edge XAS spectra. The sharp peak at 1557 cm^{-1} of (a) is attributed to O_2 in ambient air. Inset of (a) is a sketch of the graphene/CFGG heterostructure.

in the graphene/CFGG heterostructure is markedly different from that in the heterostructures of graphene and other ferromagnets, where a significant splitting and broadening of the π* resonance peak was reported in association with the orbital hybridization between graphene and ferromagnets. This result indicates CFGG does not cause a severe degradation in the electronic properties of graphene.

The magnetic properties at the interface region of the CFGG thin film in the graphene/CFGG heterostructure were explored by depth-resolved (DR) x-ray magnetic circular dichroism (XMCD) spectroscopy. Figs 2(a) and (b) compare the XAS and XMCD spectra at the Co and Fe $L_{2,3}$-edges obtained in the bulk-sensitive total-electron-yield (TEY) mode and the DR-PEY mode under the surface-sensitive condition with mean probing depth $\lambda_p \sim 4$ Å, which corresponds to the outermost surface located at the graphene/CFGG interface. The spectroscopic features of the TEY and DR-PEY XAS spectrum are compatible with each other, which indicates a carbide free graphene/CFGG interface. The evaluated total magnetic moments (m_{total}) per atom and their spin and orbital components (m_{spin} and m_{orb}, respectively) evaluated from the TEY XMCD spectrum and the series of the DR-PEY XMCD spectra obtained at different emission angles are summarized in Figs. 2(c) and (d). It is found that, only a slight decrease of magnetic moment was found at the interface comparing to that of the bulk region. The preservation of the large magnetic moment throughout the interface region is in sharply contrast to the significant reduction as reported for other heterostructure such as graphene/Fe.[4]

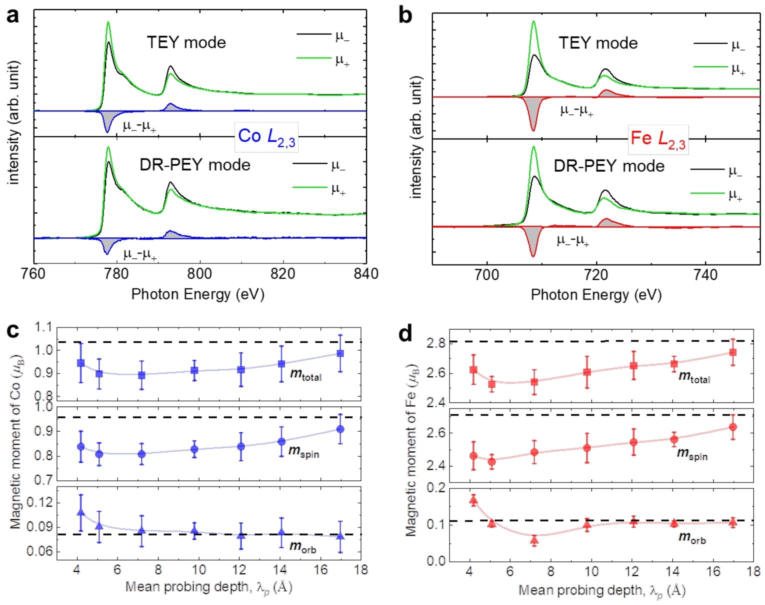

Figure 2. (a, b) Comparison of XAS and XMCD spectra of SLG/CFGG heterostructure at Co and Fe $L_{2,3}$-edges obtained in TEY and DR-PEY modes. (c, d) Plots for orbital, spin and total magnetic moment of Co, and Fe *vs.* mean probing depth (λ_p). The DR-PEY spectra in (a) and (b) are at $\lambda_p \sim 4$ Å. The dashed lines in (c) and (d) indicate the magnetic moments evaluated from the TEY XMCD spectra.

The unusual preservation of the inherent electronic and magnetic properties at the graphene/CFGG interface indicates a dramatic improvement in the efficiency of spin injection and transport in graphene comparing to other graphene/ferromagnet heterostructures. Our results suggest the newly developed graphene/CFGG heterostructure can be a very potential building block for high-performance graphene spintronic device application.

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