Arbitrary helicity control of circular polarization state from lateral-type spin-LED at room temperature

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Along with pure circularly polarized light (CPL) emission [1], arbitrary-helicity controllability on spin-polarized light emitting diodes (Spin-LEDs) is another strong point among any other CPL source, which was demonstrated at 10 K on the basis of the fact that the helicity of CPL depends on the spin direction of injected electrons [2]. Reported in this paper is arbitrary-helicity control of CPL emitted at room temperature (RT) from the cleaved side facet of a lateral-type spin-LED with two ferromagnetic electrodes in an antiparallel magnetization configuration [3].

The structure of the tested spin-LED devices consists of a GaAs-based double heterostructure, 1-nm-thick crystalline AlO_x layer, and a pair of Fe electrodes with different thickness of 100 and 30 nm. The manipulation of the external magnetic field results in an antiparallel magnetization configuration in remnant states. The EL spectra of σ+/σ− components were detected with a photomultiplier tube through a linear polarizer and a quarter wave plate. The time traces of σ+/σ− EL intensities were measured with a digital oscilloscope. Electrical polarization switching was implemented by sending square current waves that were different from each other by a half period. Figure 1 shows the experimental results for frequency f = (a) 10 and (b) 100 kHz. Distinct switching of σ+/σ− components (red/blue) and periodic inversion of circular polarization (black) are observed, while the periodic changes in the total EL intensities (green) are small. With increasing frequency, the rounding of intensity squareness and slight increase in the fluctuation of total EL intensities are observed. These effects may be associated with the coexistence of two opposite spins in the active region at the switching period. Further, we demonstrate arbitrary modulation of the polarization at RT. The experimental results are shown in Fig. 2. The horizontal axis represents the emission intensity ratio I_{100} / (I_{100}+I_{30}). Here, I_{100} and I_{30} are EL intensities with subscripts of 100 and 30 denoting the respective electrodes. The resultant polarization values can be controlled continuously from negative through zero to positive values by tuning the current sent to each electrode.

[1] N. Nishizawa *et al.*, PNAS **114**, 1783 (2017). [2] N. Nishizawa *et al.*, APL **104**, 111102 (2014).
[3] N. Nishizawa *et al.*, APEX **11**, 053003 (2018).

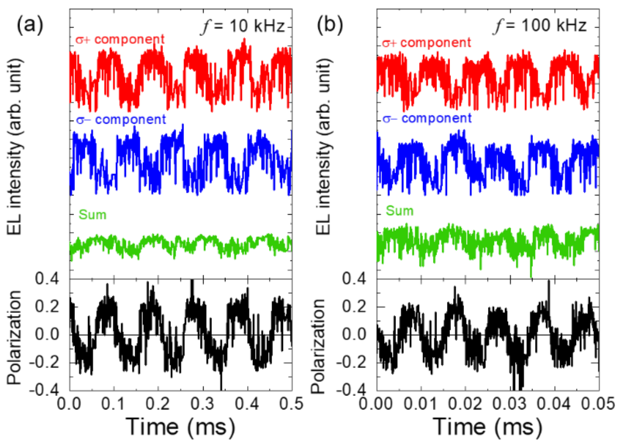

Fig.1: Experimental data for electrical polarization switching by sending square current waves into two electrodes with f = (a) 10 and (b) 100 kHz at RT. Red and blue lines in the top two rows represent the σ+/σ− components, respectively. Green lines in the third row represent the total EL intensities. Black lines show the time traces of circular polarization.

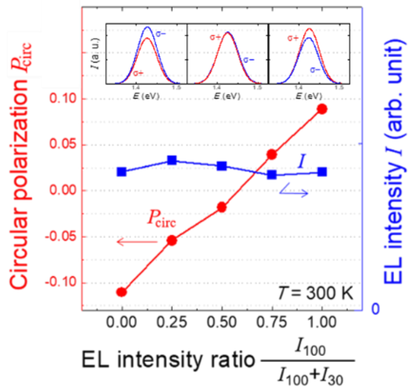

Fig. 2: Experimental data for arbitrary modulation of polarization at RT. The horizontal axis shows the EL intensity ratio I_{100} / (I_{100}+I_{30}). Red symbols and the line show the P values on the left, and the blue color corresponds to the total EL intensity on the right axis. The plots in the upper inset show helicity-dependent EL spectra at specific intensity ratios of 0, 0.5 and 1.0 from left, respectively.