# Unveiling Origins of the Ferromagnetism in Fe-based Ferromagnetic Semiconductors

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Spintronics is a research field to manipulate and utilize both the charge and spin degrees of freedom of carriers to sustain the development of information technologies. Ferromagnetic semiconductors (FMSs) have attracted much attention as promising materials for semiconductor spintronic device applications because one can control their magnetic properties by changing the carrier concentration [1,2]. This is so-called *carrier-induced ferromagnetism*. This ferromagnetic property in FMS enables us to manipulate both the charge and spin degrees of freedom.

In contrast to the traditional Mn-doped FMSs that exhibit only p-type conduction, novel Fe-doped III-V FMSs have recently attracted much attention because Fe-based FMSs can accommodate both n- and p-type carriers and ferromagnetism having Curie temperature ($T_C$) above room temperature [2-5]. Since devices with spin-related functionalities have already been achieved using the p-type and/or n-type FMSs [1,2], Fe-based FMSs open a novel way for the development of future spintronic devices.

To understand the mechanism of the ferromagnetism in FMSs and to develop designing of spintronics devices using FMSs, it is indispensable to reveal the electronic structures of FMSs. The band structure of FMS consists of valence or conduction band and impurity band originating from the 3*d* state of the doped magnetic impurity. We have studied III-V FMSs so far using the soft x-ray spectroscopy to unveil the mechanism of the carrier-induced ferromagnetism from the electronic structure point of view [6,7]. In this talk, I would share with you our SX-ARPES and SX-RIXS studies on Fe-based III-V FMSs *n*-type (In,Fe)As [8] and *p*-type (Ga,Fe)Sb [9].

[1] I. Zutic, Rev. Mod. Phys. **76**, 323 (2004).
[2] M. Tanaka, S. Ohya, and P. N. Hai, Appl. Phys. Rev. **1**, 011102 (2014).
[3] N. T. Tu *et al*., Appl. Phys. Lett. **108**, 192401 (2016).
[4] A. V. Kudrin *et al*., J. Appl. Phys. **122**, 183901 (2017).
[5] N. T. Tu *et al*., Appl. Phys. Express **11**, 063005 (2018).
[6] M. Kobayashi *et al*., Phys. Rev. B **89**, 205204 (2014).
[7] M. Kobayashi *et al*., Phys. Rev. Lett. **112**, 107203 (2014).
[8] M. Kobayashi *et al*., to be submitted.
[9] T. Takeda *et al*., arXiv:2001.02895.