Ferromagnetic Semiconductors

Ilmenite-Hematite solid solutions $(FeTiO_3)_{(1-x)}$ / $(Fe_2O_3)_x$

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R.K.Pandey, G. Mankey, W. Butler, R. Schad

NSF MRSEC

Ferromagnetic Semiconductors

Mn in GaAs (Matsukura et al. 1977)

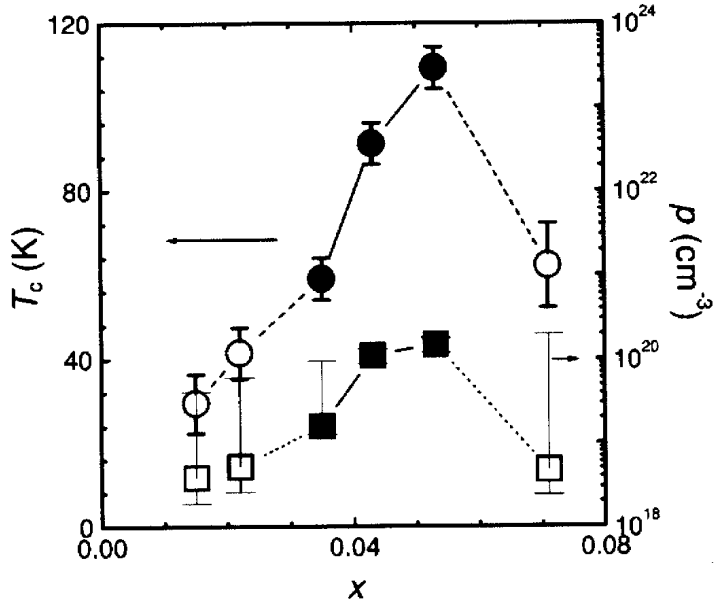


FIG. 2. Mn composition dependence of ferromagnetic transition temperature T_c and hole concentration p. Samples on the metal side of the metal insulator transition are shown by the closed symbols (see also Fig. 3).

Goal: Raise Tc

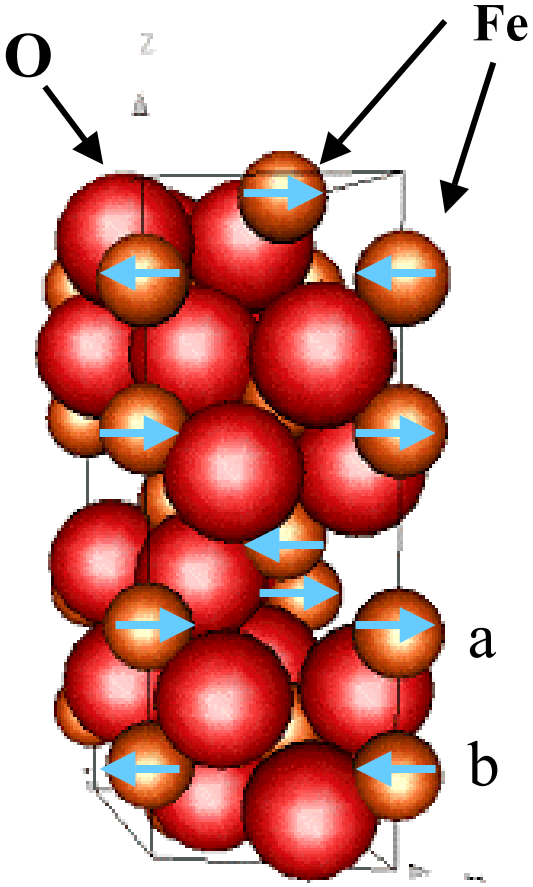
- More Magnetic Ions
- More Carriers
- High Fermi Energy DOS

Problems:

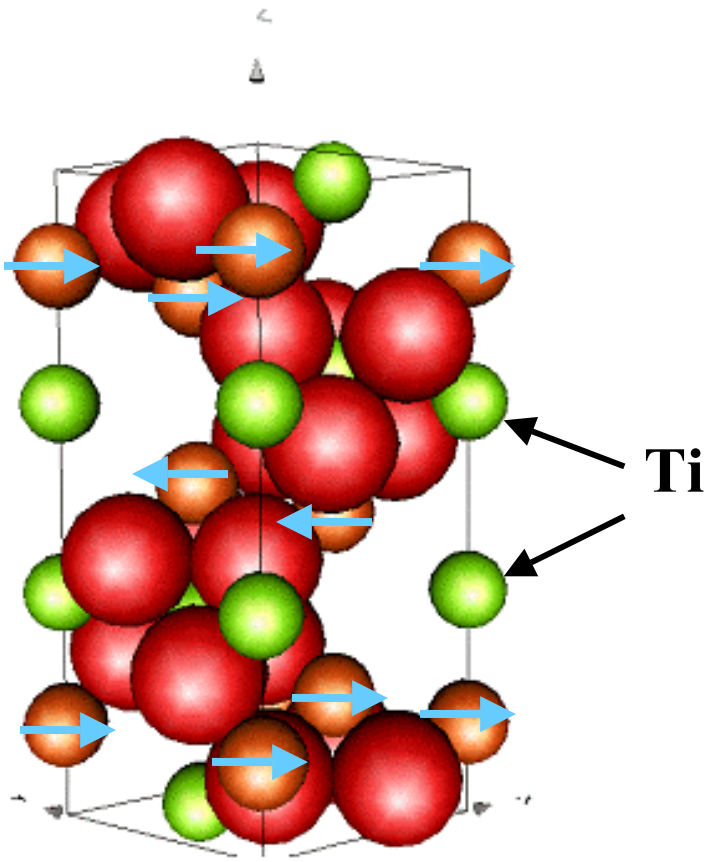
- More Disorder
- Self-compensation
- Only p-type conduction

Ferromagnetic Semiconductors

Hematite

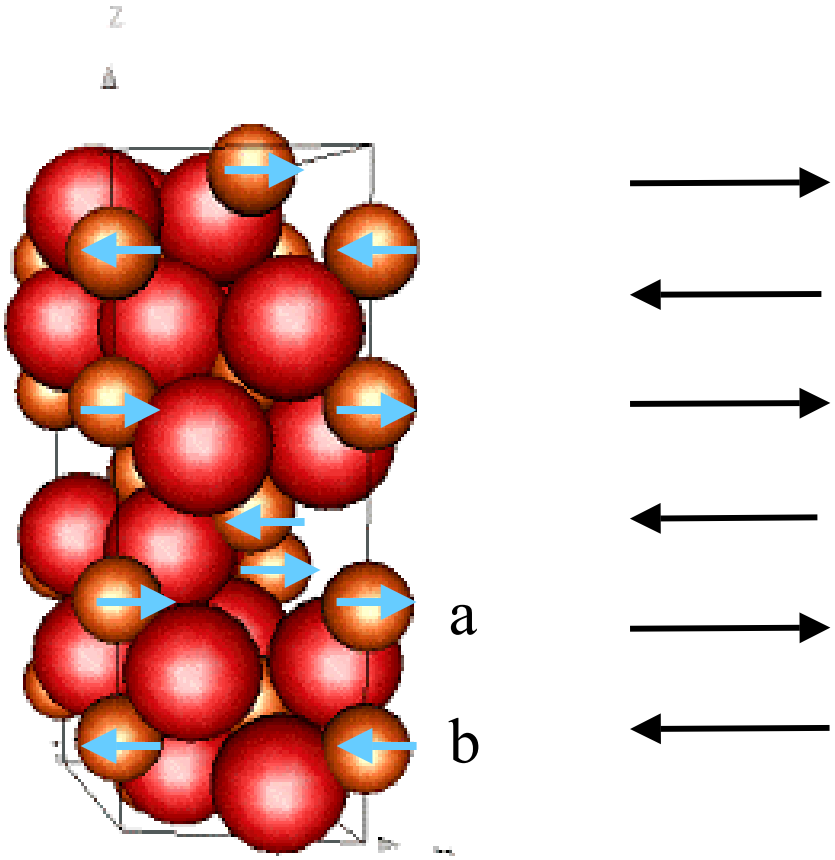


Ilmenite



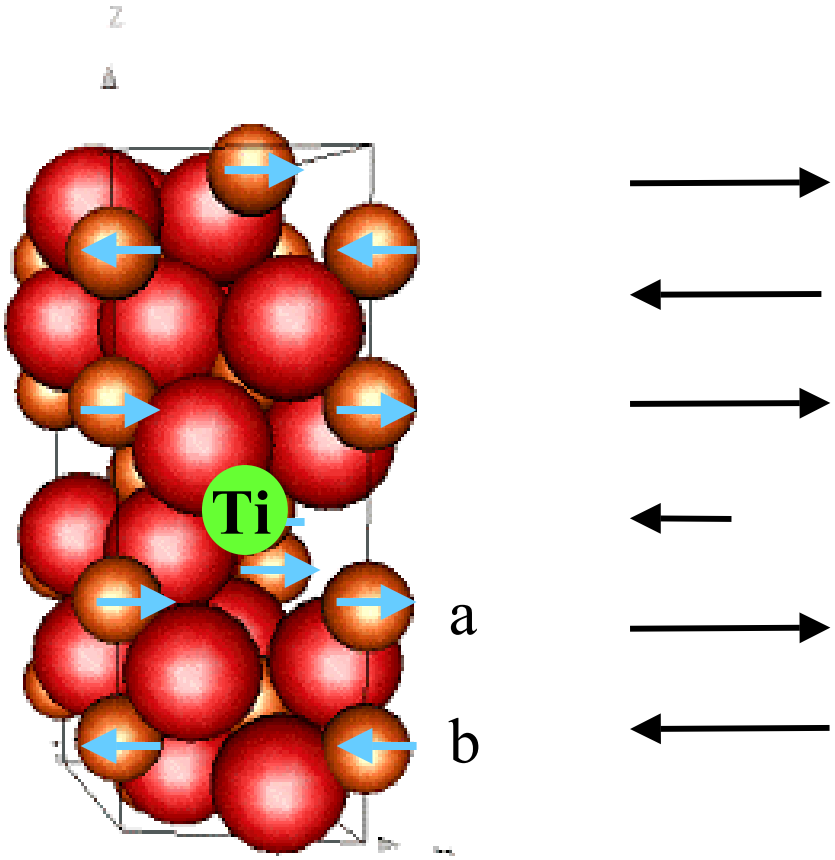
Ferromagnetic Semiconductors

Hematite / Ilmenite



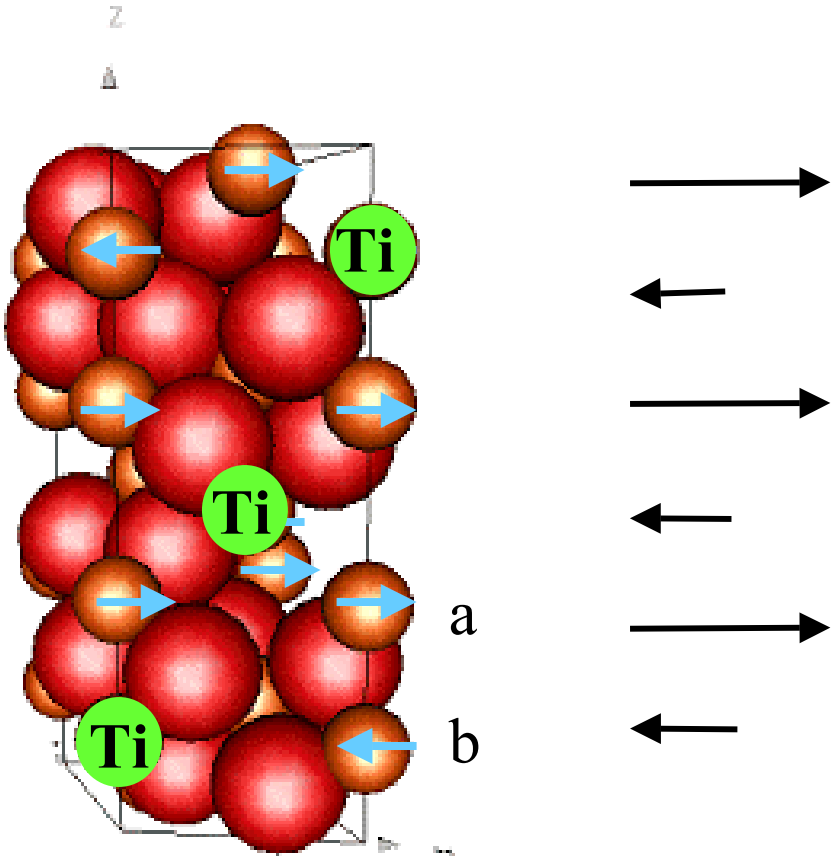
Ferromagnetic Semiconductors

Hematite / Ilmenite



Ferromagnetic Semiconductors

Hematite / Ilmenite



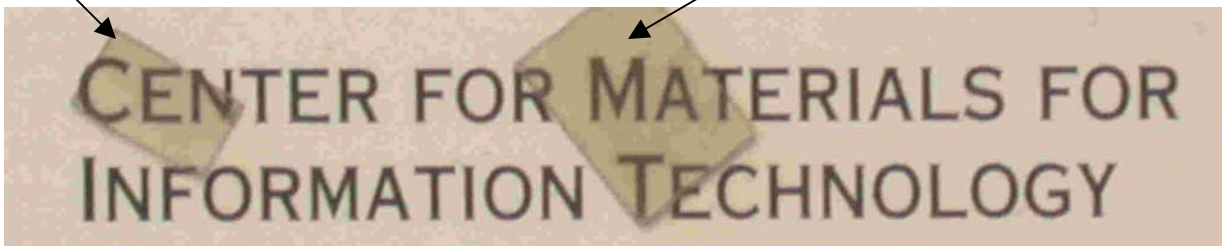
Ferromagnetic Semiconductors

Optical Properties: Ilmenite/hematite film on MgO

Transparent Ilmentite/hematite films on MgO
band gap!

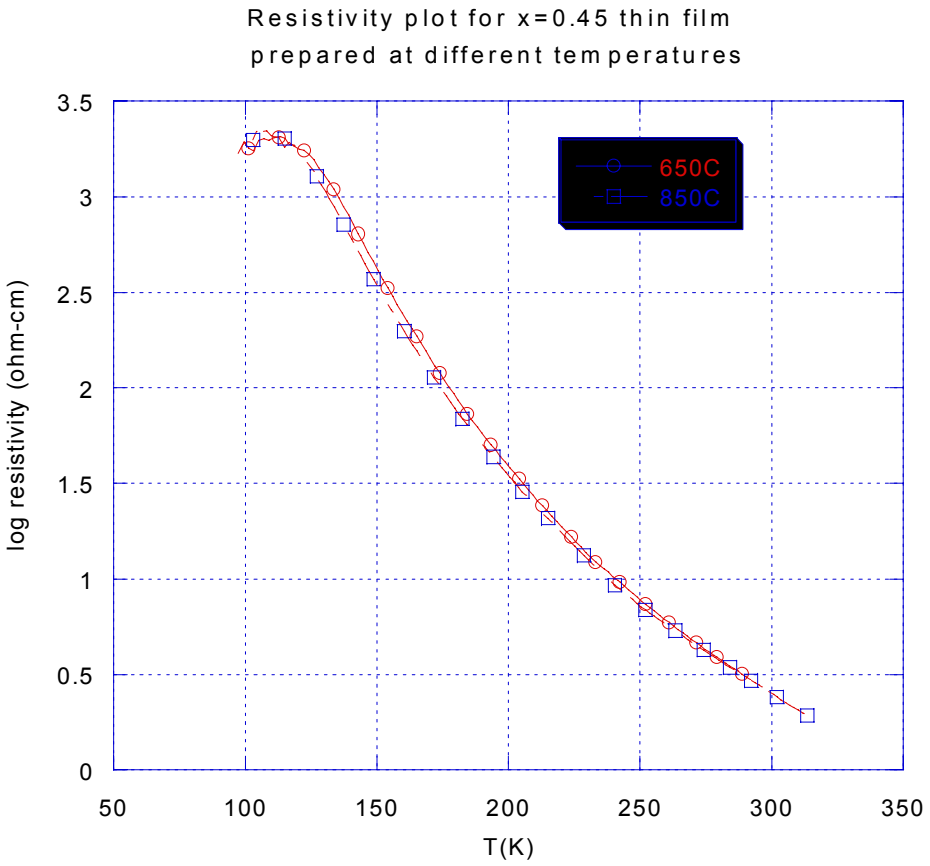
19nm $(FeTiO_3)_{0.67}$ $(Fe_2O_3)_{0.33}$

33nm $(FeTiO_3)_{0.80}$ $(Fe_2O_3)_{0.20}$



Ferromagnetic Semiconductors

ilmenite-hematite // electrical properties

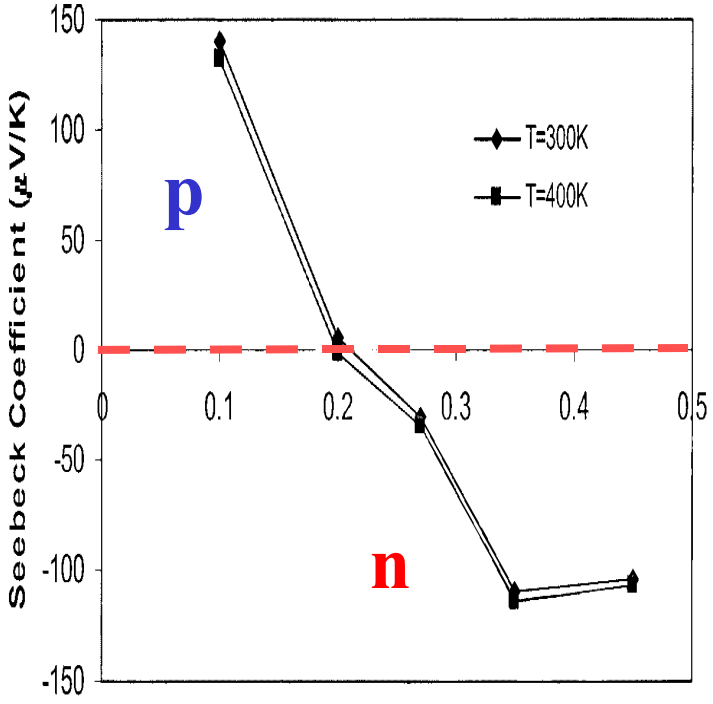


IH shows semiconducting electrical properties

Ferromagnetic Semiconductors

ilmenite-hematite // doping

$(FeTiO_3)_{(1-x)} / (Fe_2O_3)_x$ --- varying x



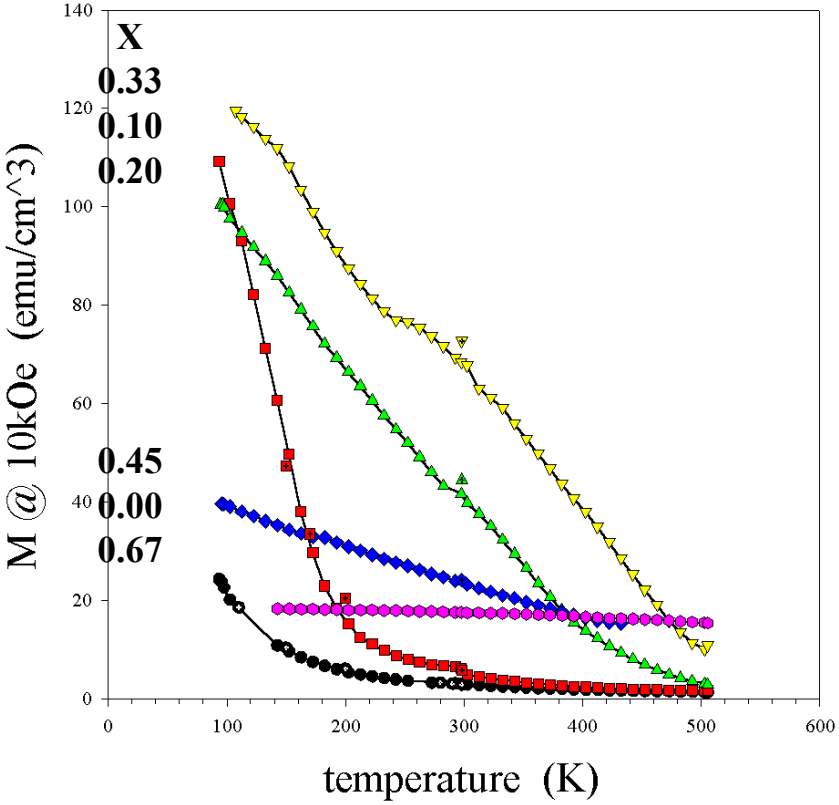
p- or n- semiconducting

ilmenite => hematite

Ferromagnetic Semiconductors

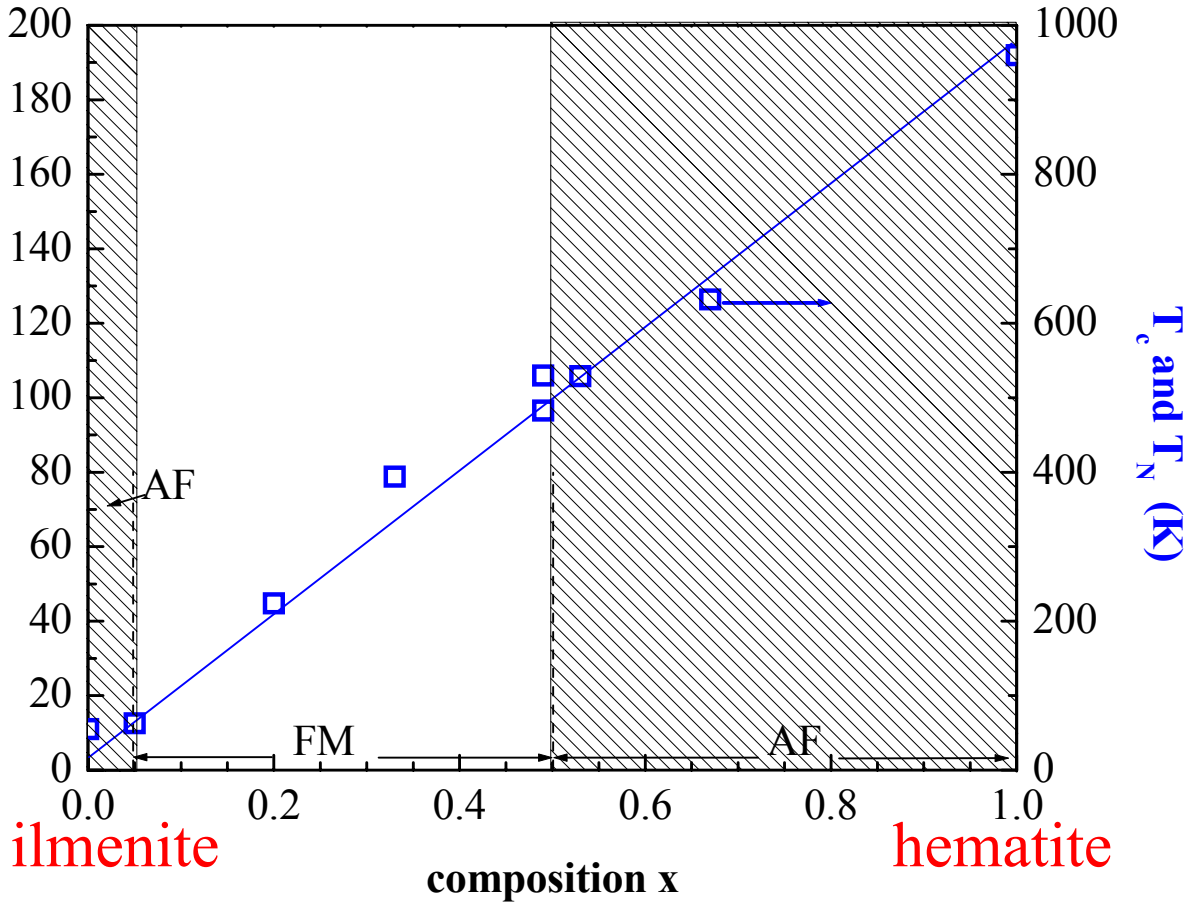
ilmenite-hematite // magnetic properties (bulk)

$(FeTiO_3)_{(1-x)} / (Fe_2O_3)_x$ --- varying x



Ferromagnetic Semiconductors

ilmenite-hematite // magnetic properties (bulk)

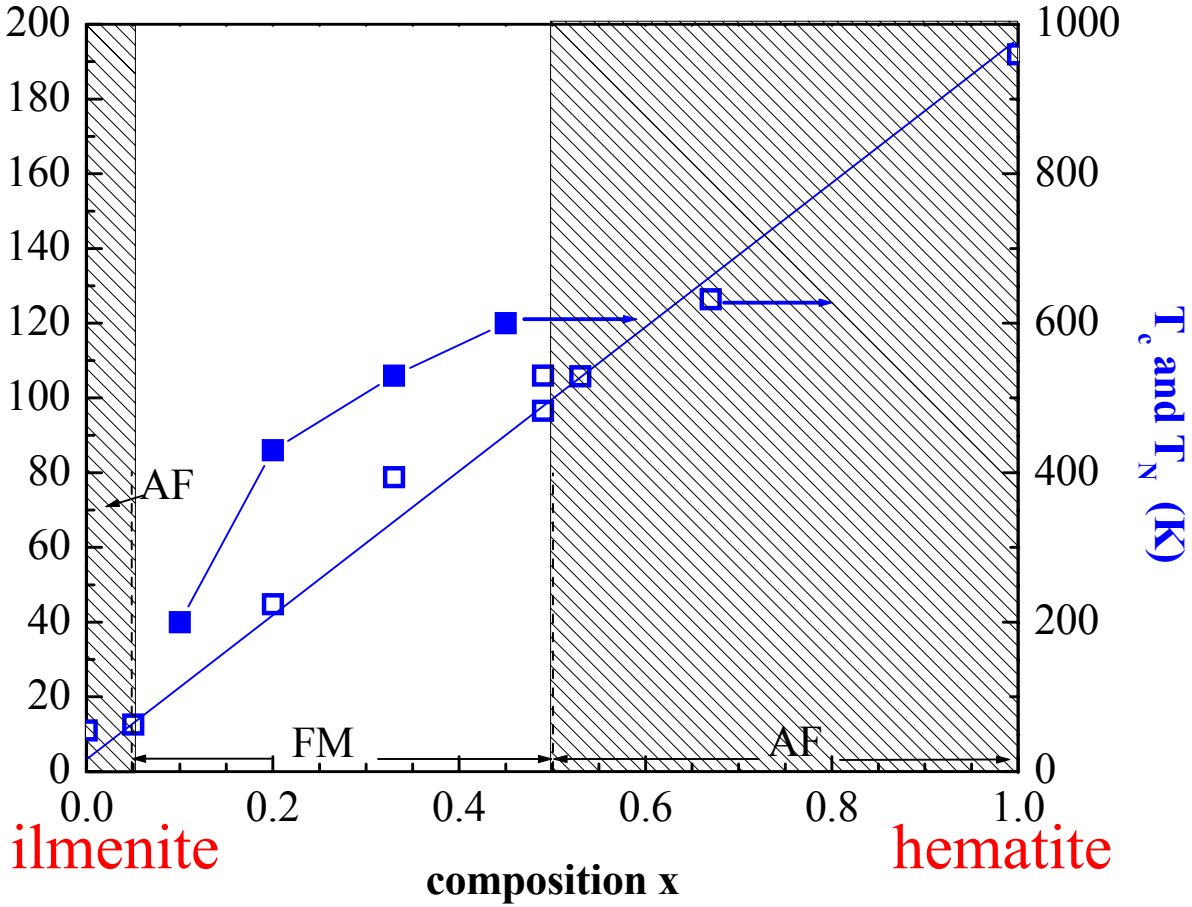


T_c - literature

open symbols: Ishikawa, Akimoto J.Phys.Soc.Jap.12, 1083 (1957)

Ferromagnetic Semiconductors

ilmenite-hematite // magnetic properties (bulk)

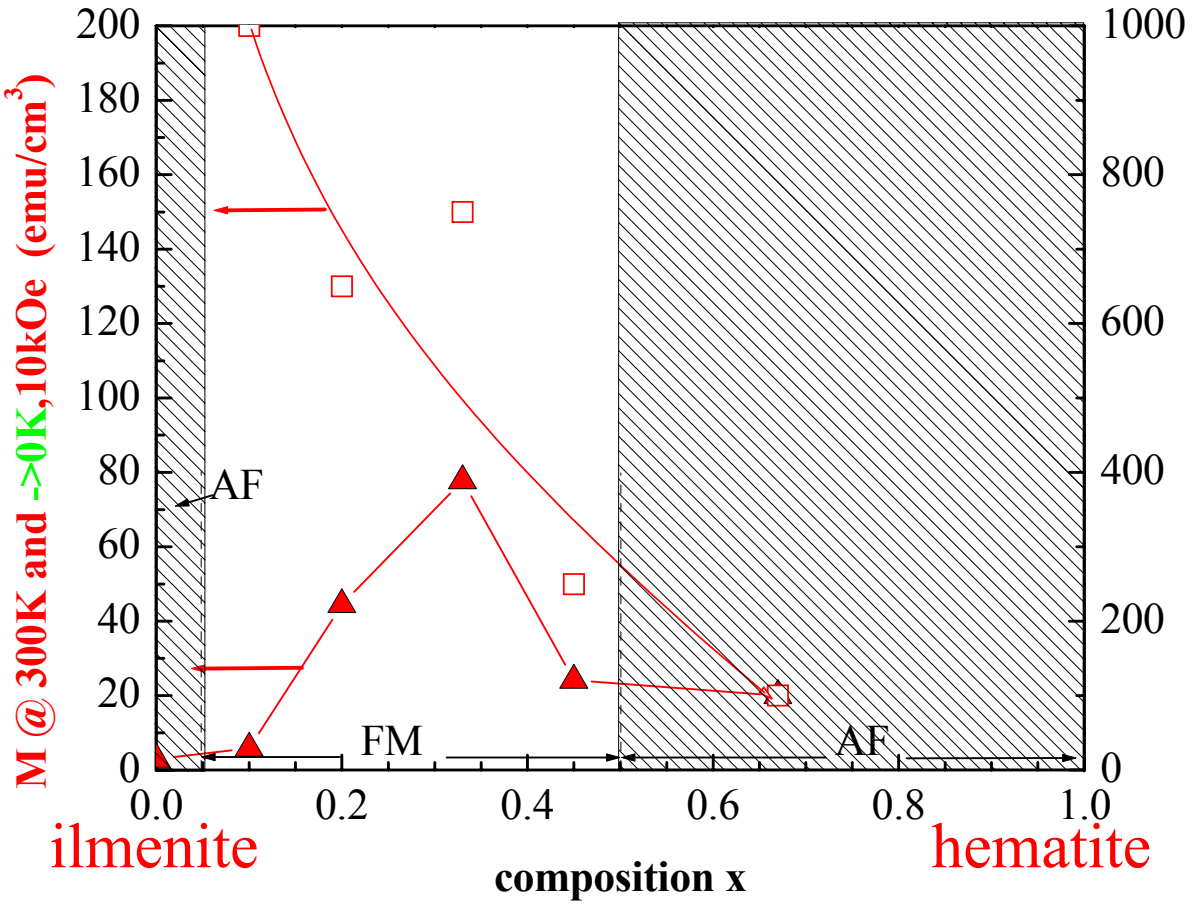


enhanced T_c

open symbols: Ishikawa, Akimoto J.Phys.Soc.Jap.12, 1083 (1957)

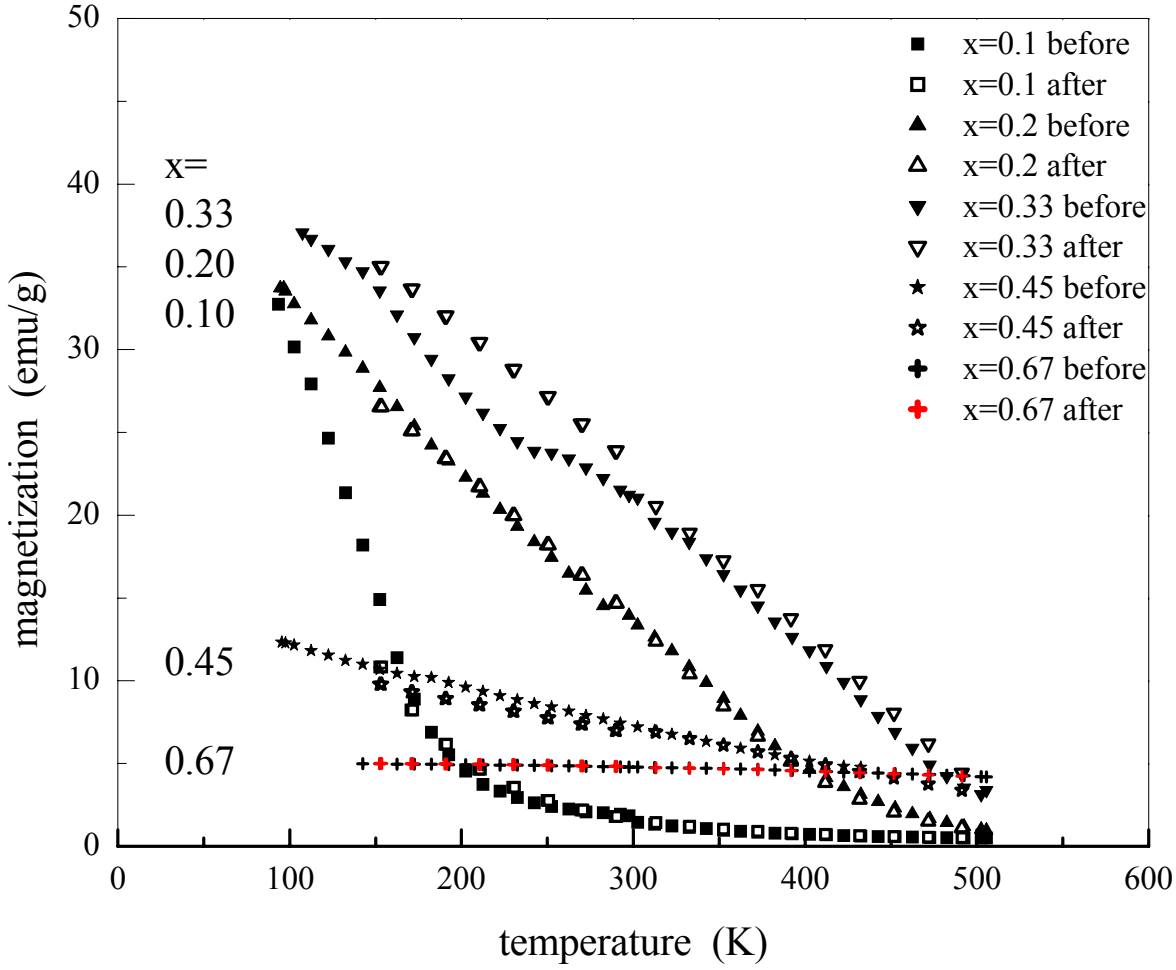
Ferromagnetic Semiconductors

ilmenite-hematite // magnetic properties (bulk)



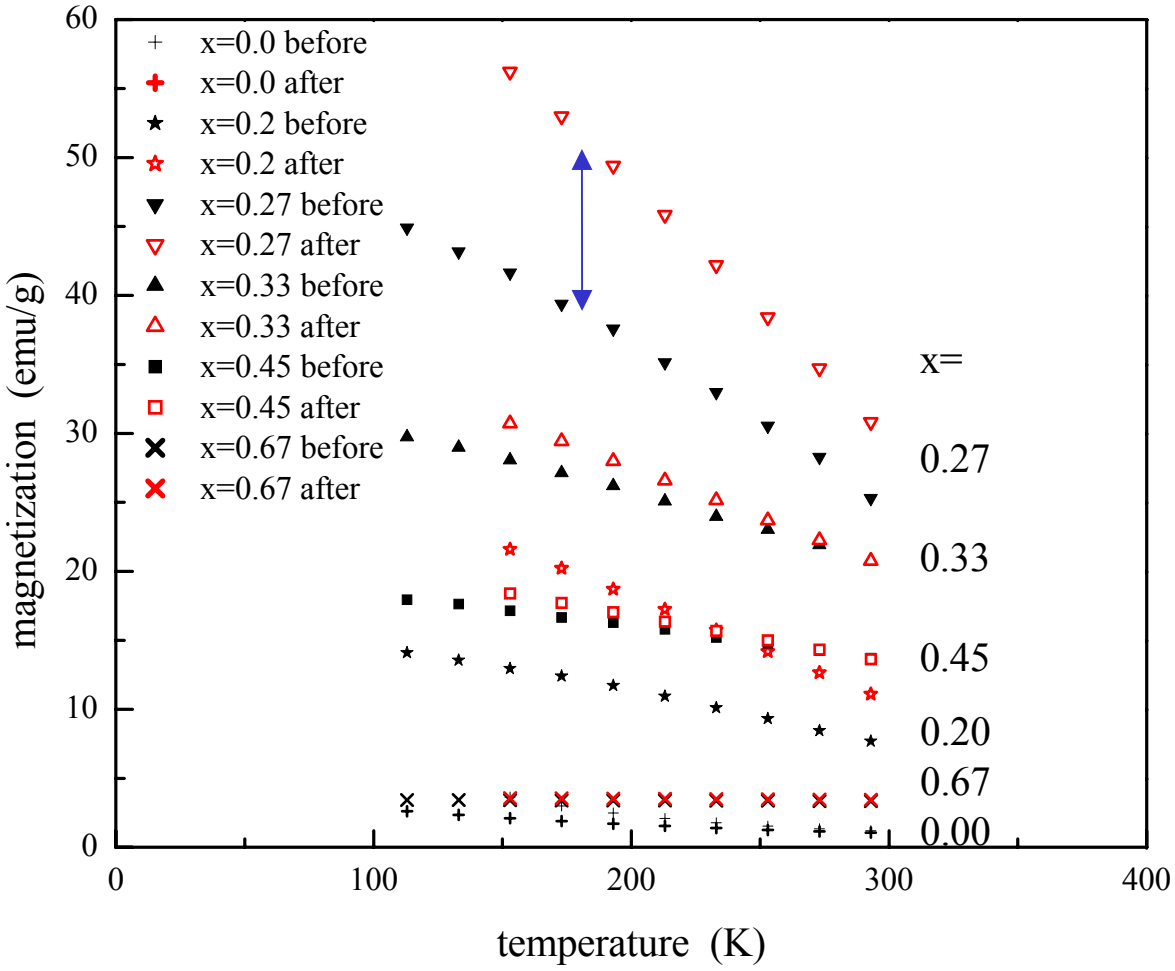
Ferromagnetic Semiconductors

Magnetic Moments are radiation hard against neutron irradiation



Ferromagnetic Semiconductors

Magnetic Moments are enhanced by proton irradiation



Ferromagnetic Semiconductors

Future Work

- epitaxial layers on various substrates using PLD and ALD
- enforced chemical ordering through combined TiO_2/Fe_2O_3 ALD
- understanding electric transport mechanism theory/experiment
- use of other dopants
- pn-junctions, bipolar spin transistor