

Ferromagnetic Semiconductors

Ilmenite-Hematite solid solutions $(\text{FeTiO}_3)_{(1-x)} / (\text{Fe}_2\text{O}_3)_x$

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An NSF Materials Research Science and Engineering Center

Ferromagnetic Semiconductors

Mn in GaAs (Matsukura et al. 1977)

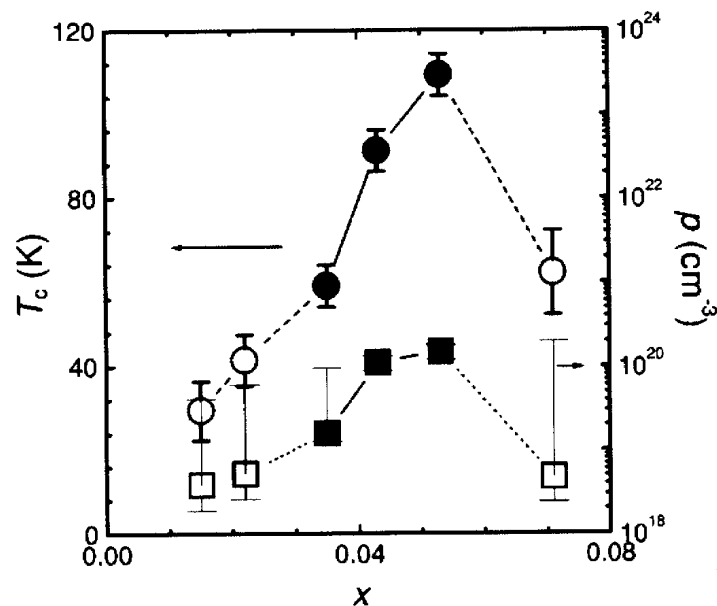


FIG. 2. Mn composition dependence of ferromagnetic transition temperature T_c and hole concentration p . Samples on the metal side of the metal insulator transition are shown by the closed symbols (see also Fig. 3).

Goal: Raise T_c

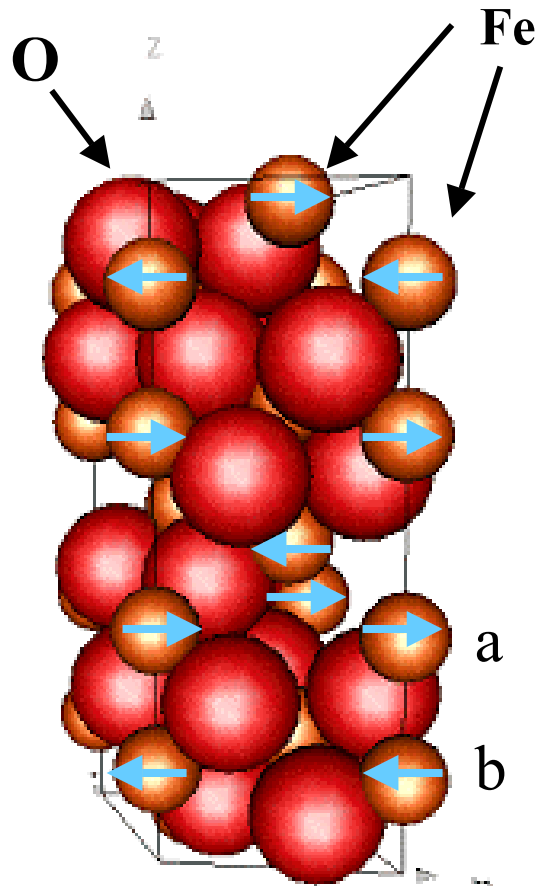
- More Magnetic Ions
- More Carriers
- High Fermi Energy DOS

Problems:

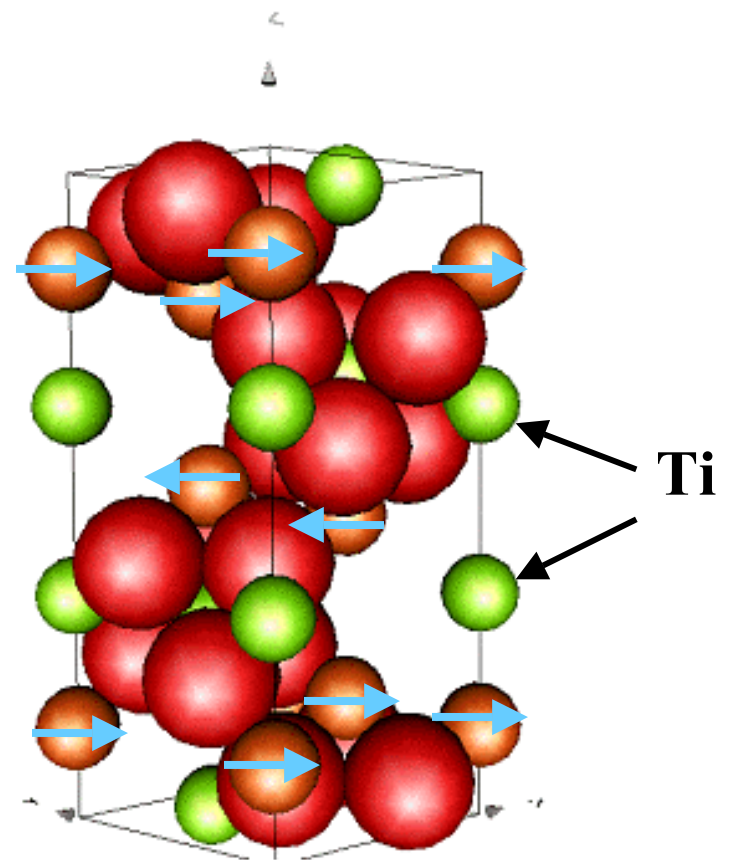
- More Disorder
- Self-compensation
- Only p-type conduction

Ferromagnetic Semiconductors

Hematite

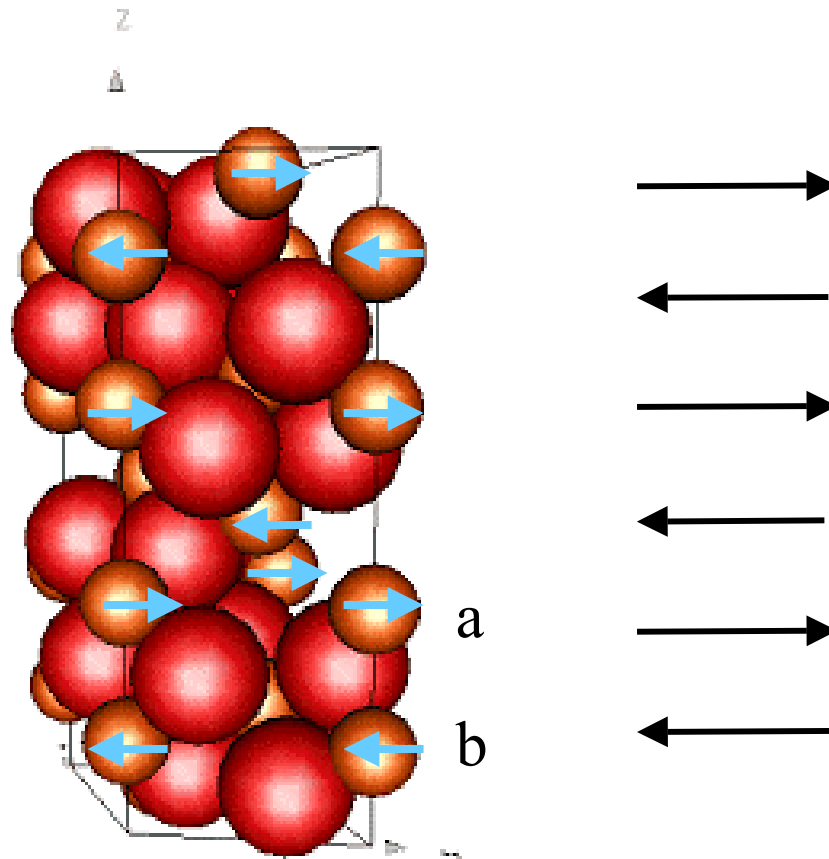


Ilmenite



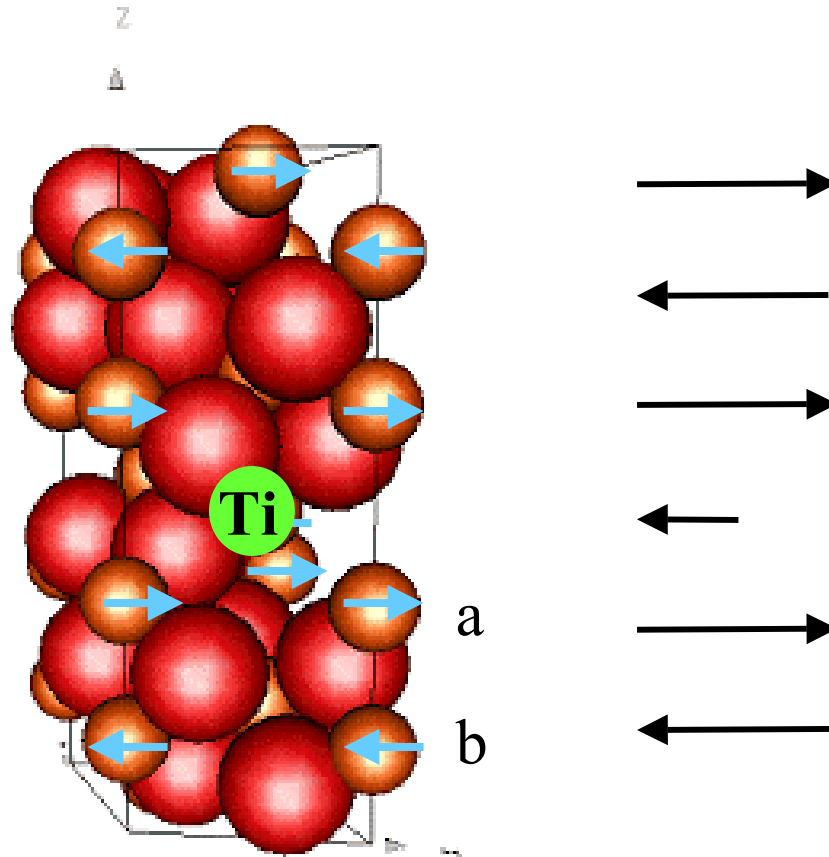
Ferromagnetic Semiconductors

Hematite / Ilmenite



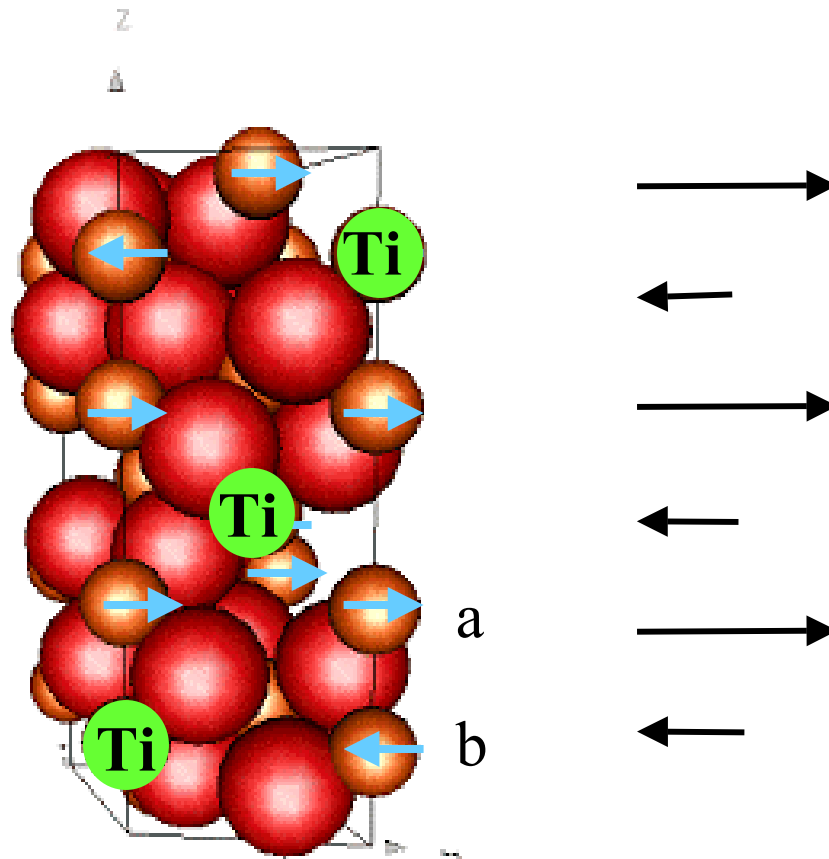
Ferromagnetic Semiconductors

Hematite / Ilmenite



Ferromagnetic Semiconductors

Hematite / Ilmenite



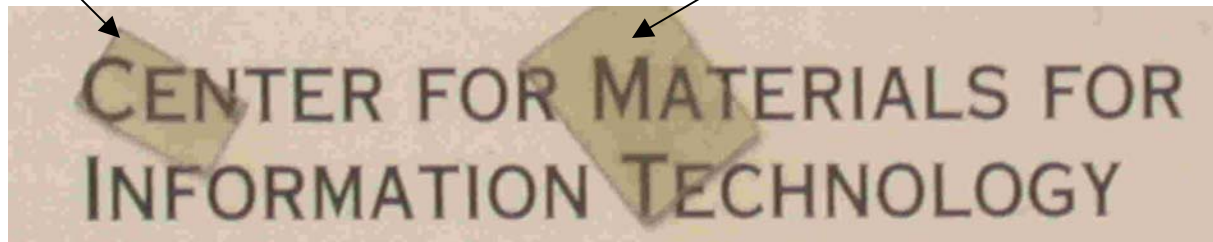
Ferromagnetic Semiconductors

Optical Properties: Ilmenite/hematite film on MgO

Transparent Ilmenite/hematite films on MgO
band gap!

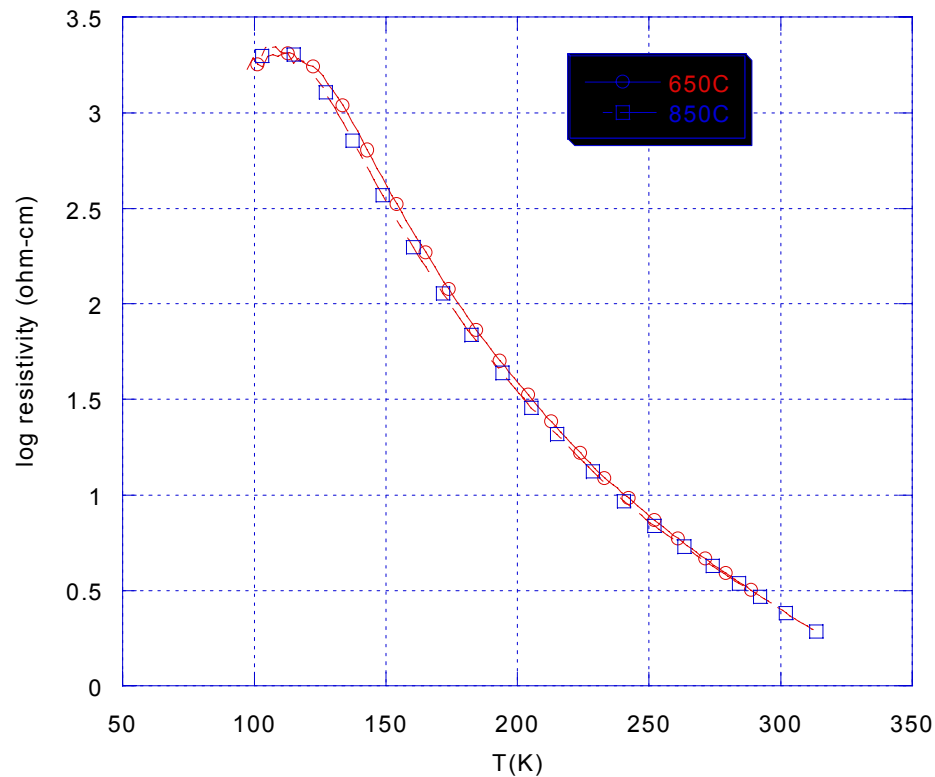
19nm $(\text{FeTiO}_3)_{0.67} (\text{Fe}_2\text{O}_3)_{0.33}$

33nm $(\text{FeTiO}_3)_{0.80} (\text{Fe}_2\text{O}_3)_{0.20}$



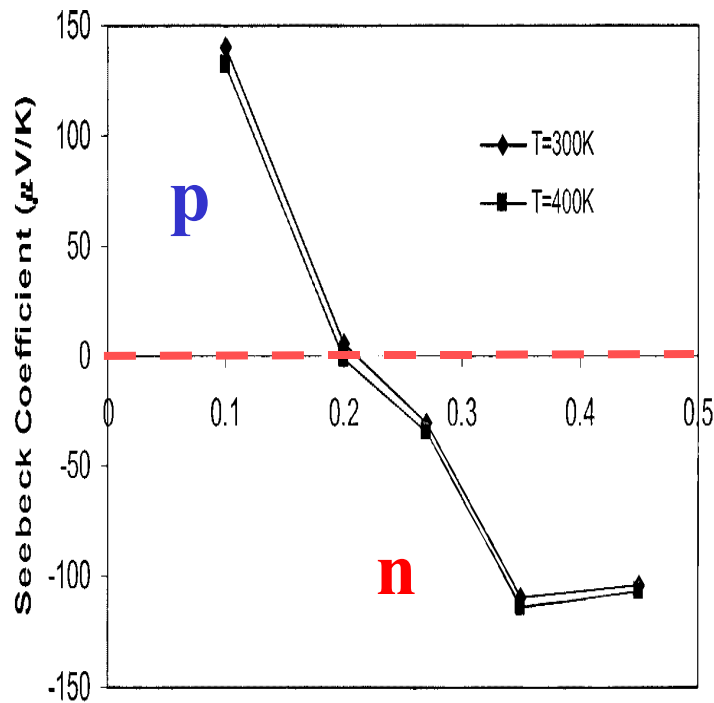
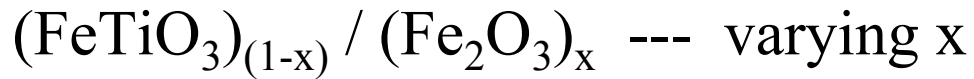
Ferromagnetic Semiconductors ilmenite-hematite // electrical properties

Resistivity plot for $x=0.45$ thin film
prepared at different temperatures



IH shows **semiconducting**
electrical properties

Ferromagnetic Semiconductors
ilmenite-hematite // doping

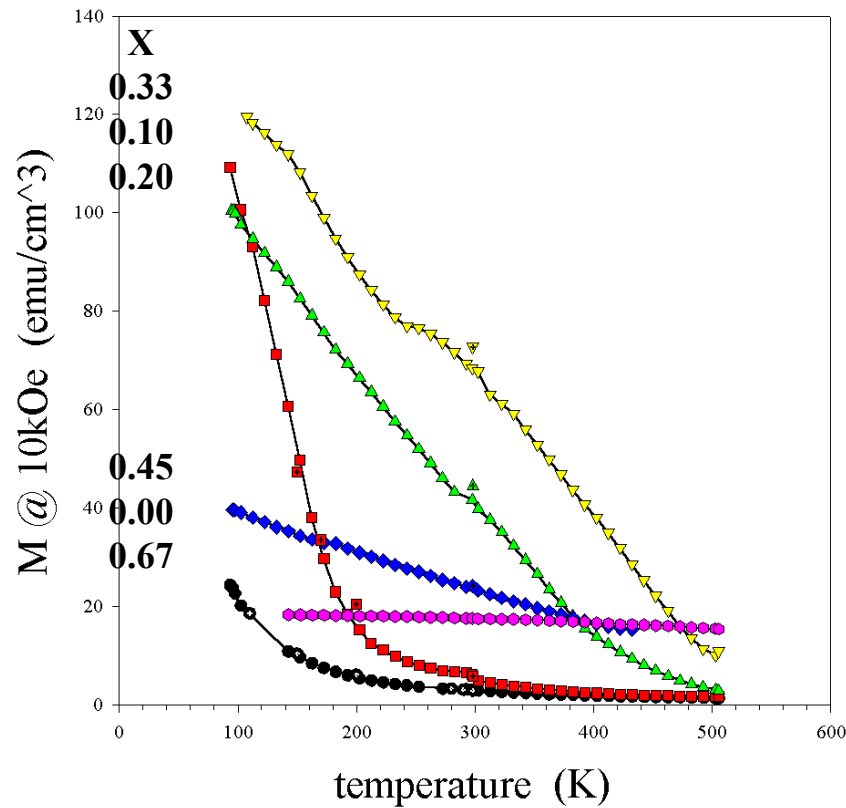


p- or n- semiconducting

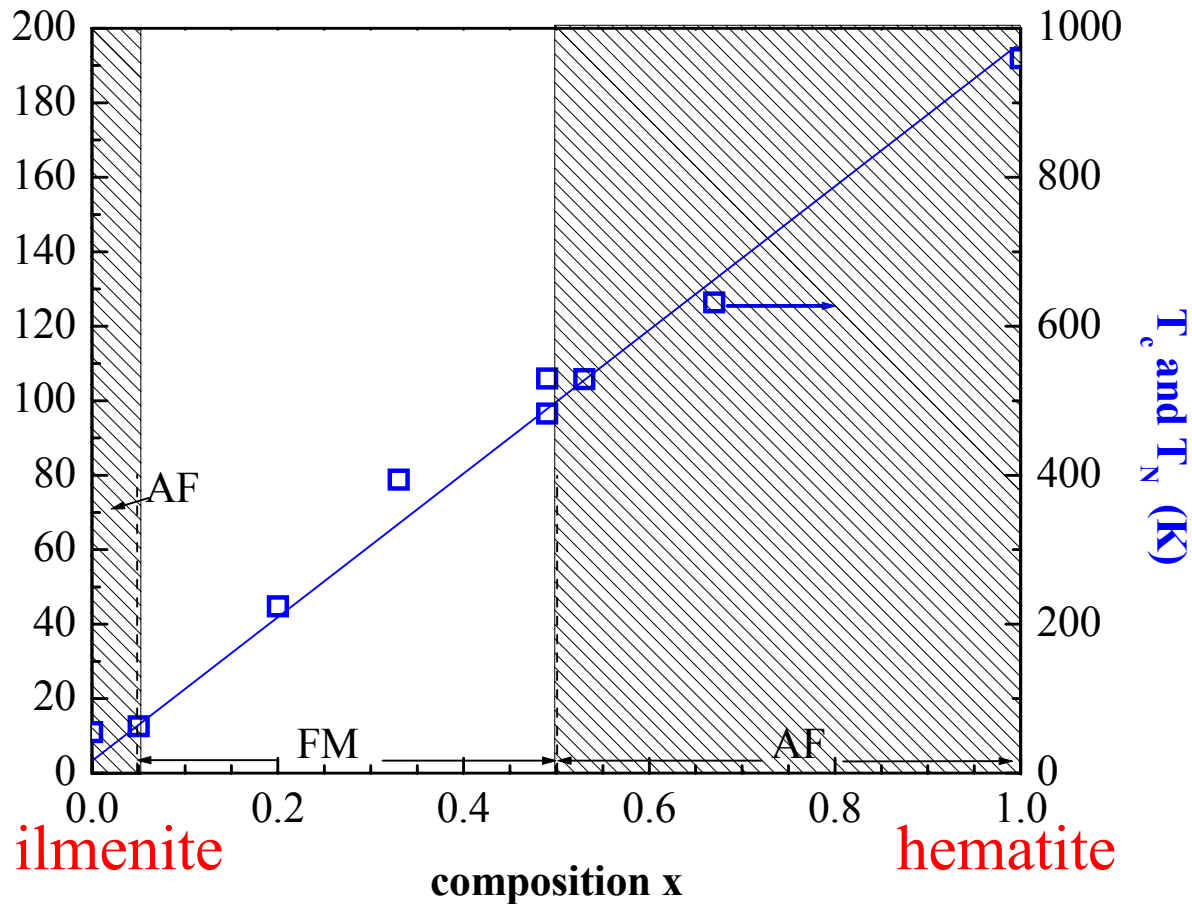
ilmenite Composition x => hematite

Ferromagnetic Semiconductors ilmenite-hematite // magnetic properties (bulk)

$(\text{FeTiO}_3)_{(1-x)} / (\text{Fe}_2\text{O}_3)_x$ --- varying x



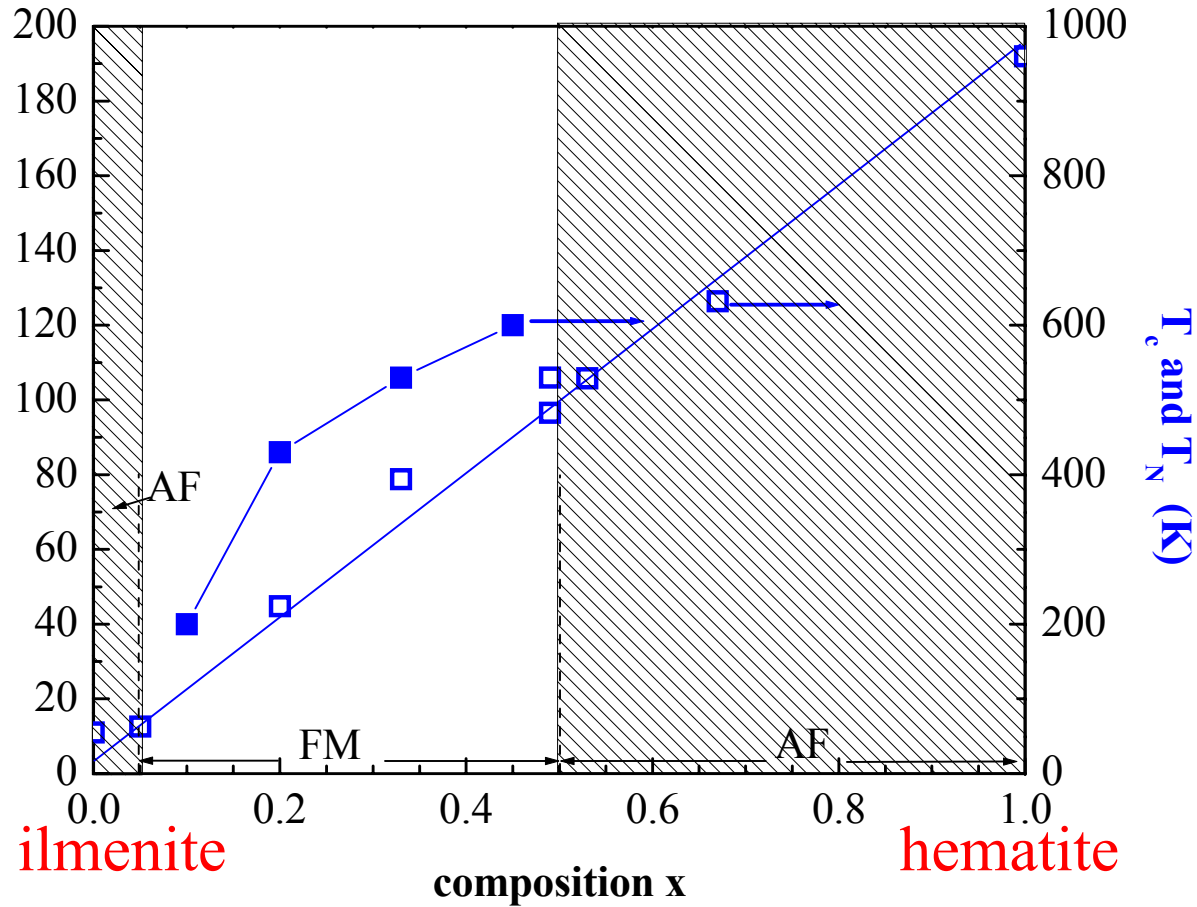
Ferromagnetic Semiconductors ilmenite-hematite // magnetic properties (bulk)



T_c - literature

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

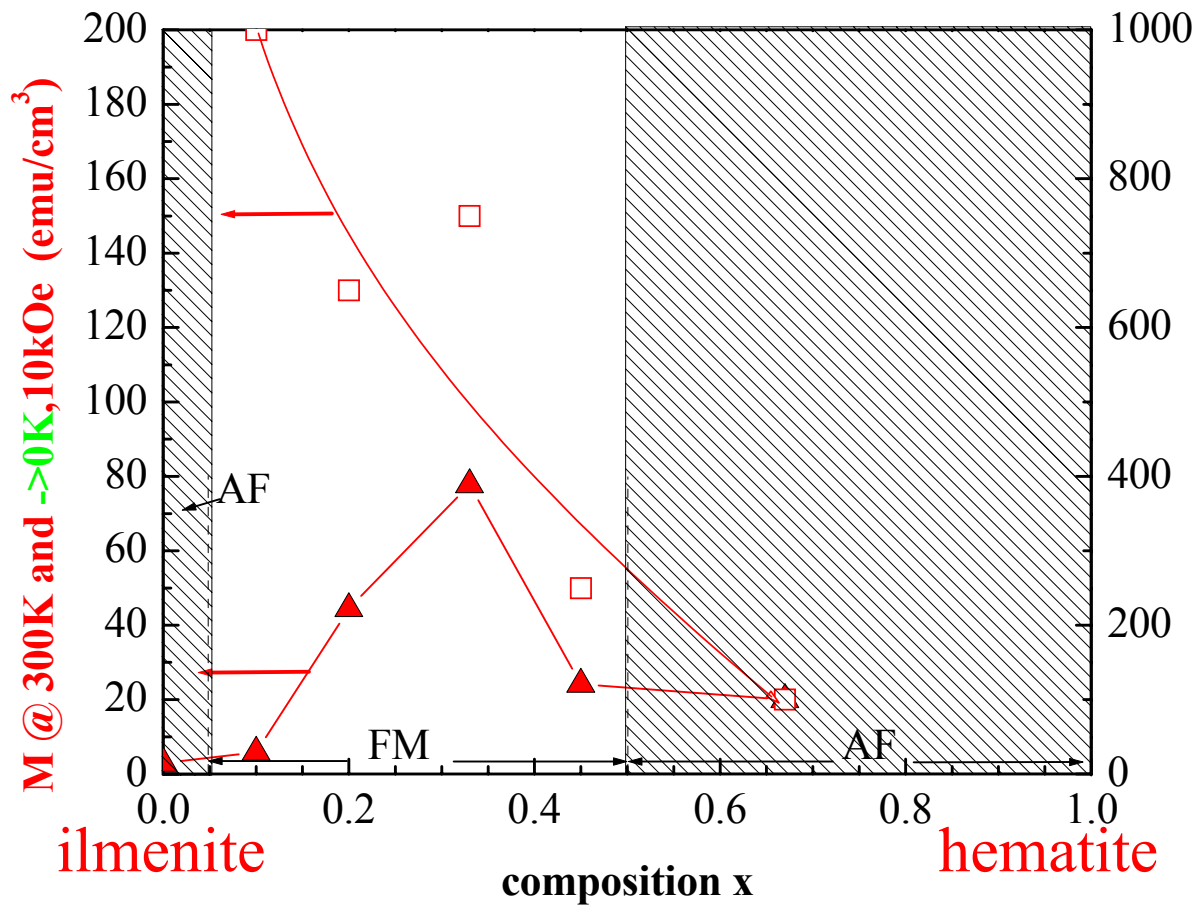
Ferromagnetic Semiconductors ilmenite-hematite // magnetic properties (bulk)



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

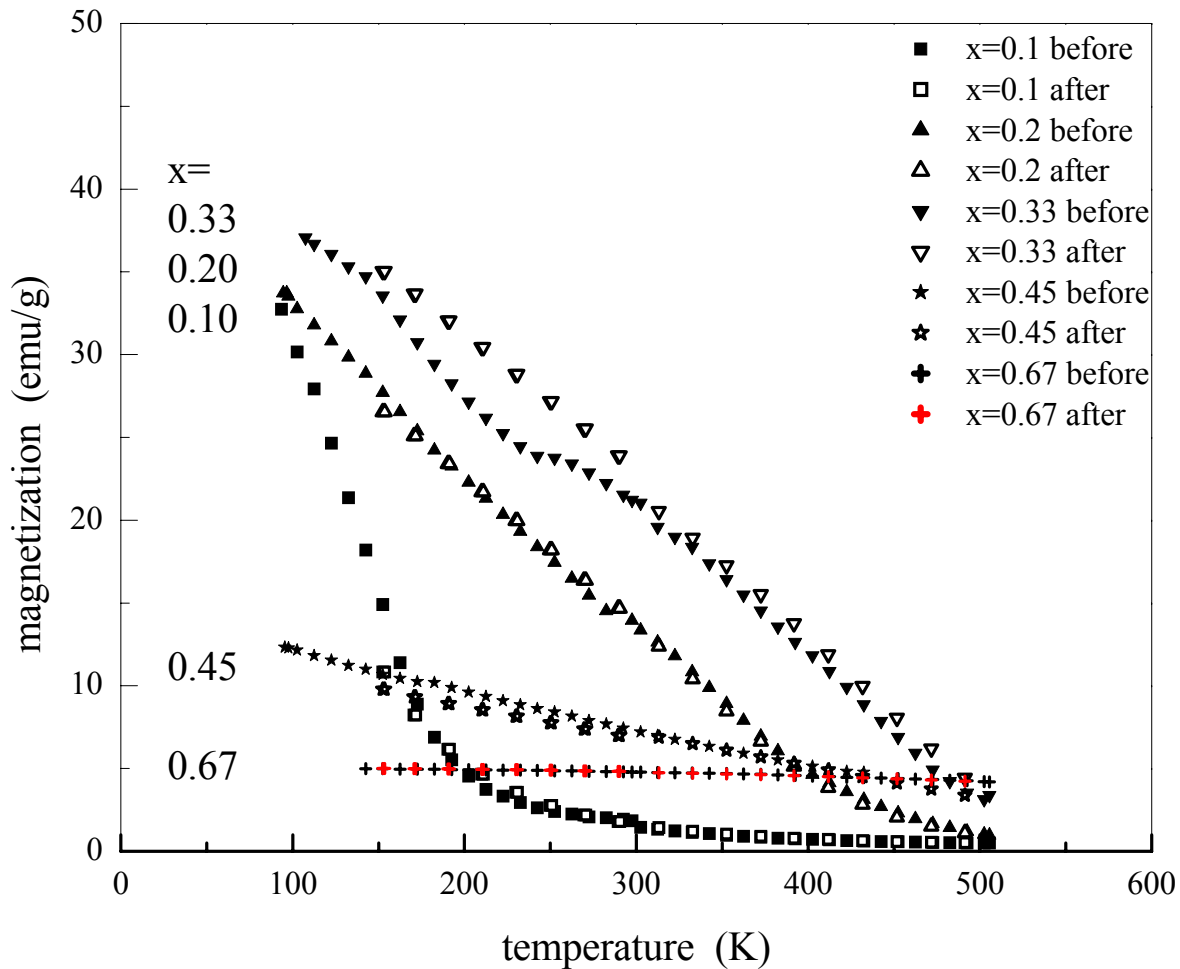
Ferromagnetic Semiconductors

ilmenite-hematite // magnetic properties (bulk)



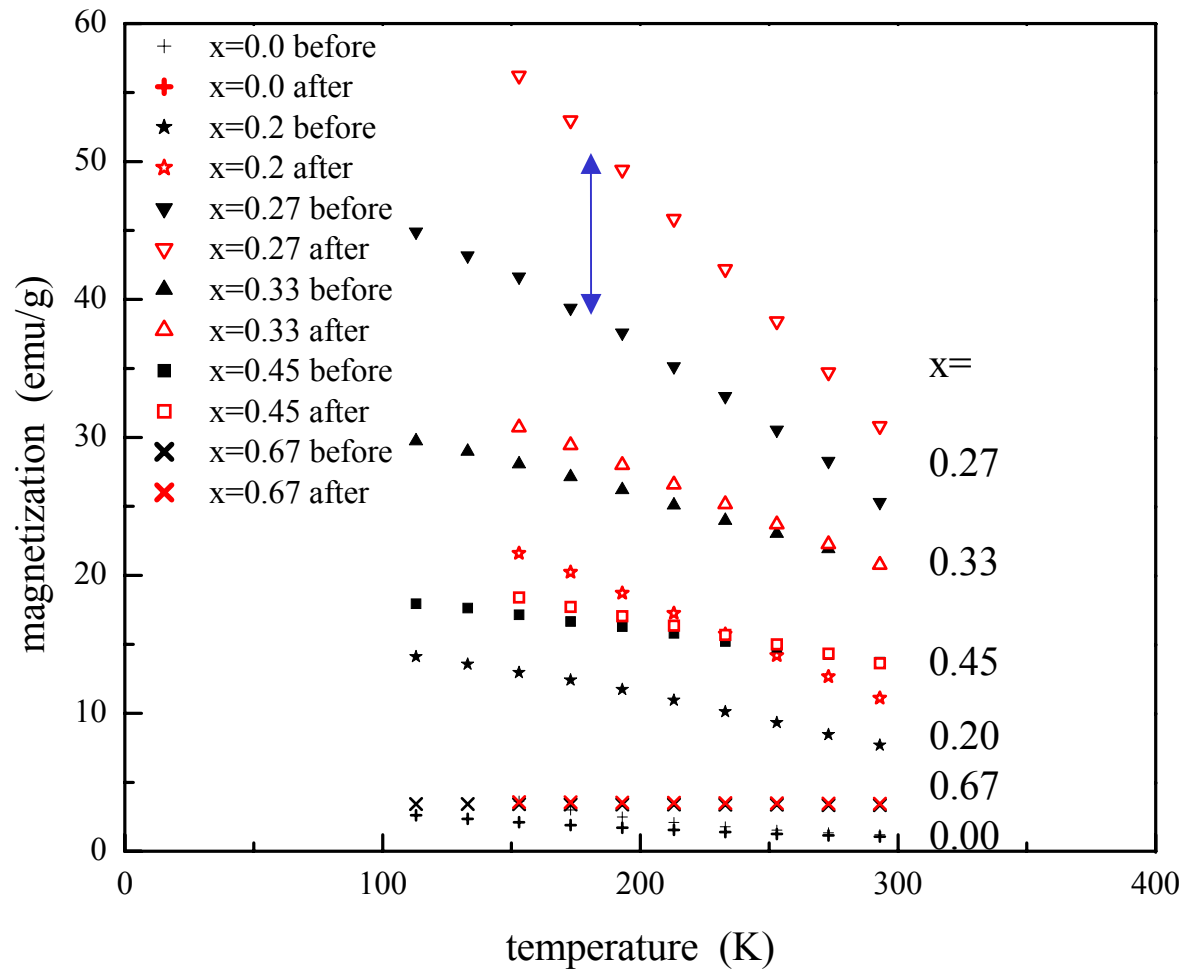
Ferromagnetic Semiconductors

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 $\text{TiO}_2/\text{Fe}_2\text{O}_3$ ALD
- understanding electric transport mechanism theory/experiment
- use of other dopants
- pn-junctions, bipolar spin transistor