Properties of Epitaxial Ilmenite Hematite Magnetic Semiconductor Films

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Objective

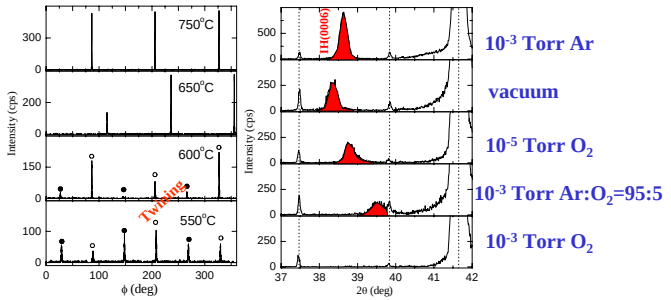
- Grow epitaxial Ilmenite-Hematite (IH) films.
- Characterize and understand magnetic, electrical and optical properties
- Study spin transport properties
- Fabricate and evaluate p-n and tunnel junction devices

	Ilmenite-Hematite(IH) $(1-x)FeTiO_3$-xFe_2O_3	(Ga,Mn)As	doped ZnO
Curie Temperature	>500 K (dependent on composition) ~1000 K	<110K	300K ~400K
Magnetic Moment	$4\mu_B$/Fe 147 emu/g (>7000 Gauss)	4.46μ_B/Mn (5K) 400 Gauss (5K)	2μ_B/Co (6K) 20.8 emu/g
Semiconductor type	n or p (dependent on composition)	p	P
E_g	~3.5 eV	<1.5 eV	~3.35 eV
Transparent	Yes	No	Yes[a]
Mobility/ carrier concentration	<1 $cm^2V^{-1}s^{-1}$/	High/3*10^{20} cm^{-3} (@1.5K)	17.9 $cm^2V^{-1}s^{-1}$ /2.9*$10^{20}cm^{-3}$ 3.5*$10^{20}cm^{-3}$

PLD Parameters for IH Film Growth

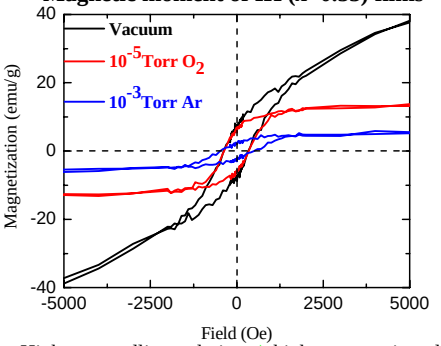
Excimer Laser:
KrF (248 nm, 20ns, 2 Hz, 1.7J/cm_2, ~5000 Pulses)
Chamber base pressure: 10^{-7} Torr
Substrate: Al_2O_3 (lattice mismatch ~7%) c-cut
Target to substrate distance: 5 cm
In-situ annealing: 1 hour
Substrate Temperature: 550-750°C
Ambient gas: vacuum
Ar (10^{-3}Torr)
O_2(10^{-5}Torr, 10^{-3}Torr)
mixed Ar & O_2(in 95:5 ratio, 10^{-3}Torr)

X-ray diffraction of IH (x=0.33) films



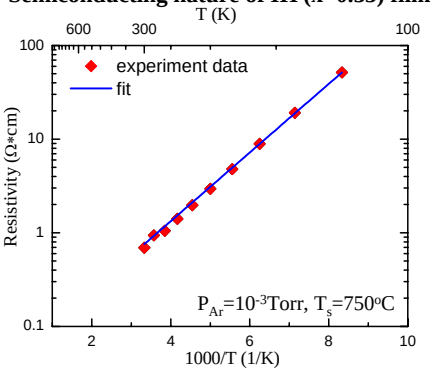
- Enough thermal energy needed for ions to migrate to the most epitaxially ordered lattice position
- Higher oxygen pressure leads to smaller lattice constant
- Films grown in high oxygen pressure lose crystallinity

Magnetic moment of IH (x=0.33) films



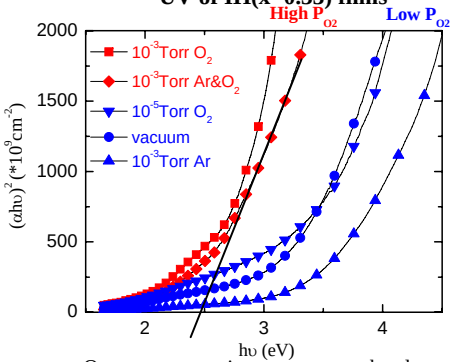
- Higher crystalline ordering ⇨ higher magnetic ordering
- Oxygen vacancy effect on magnetic moment ---??

Semiconducting nature of IH (x=0.33) film



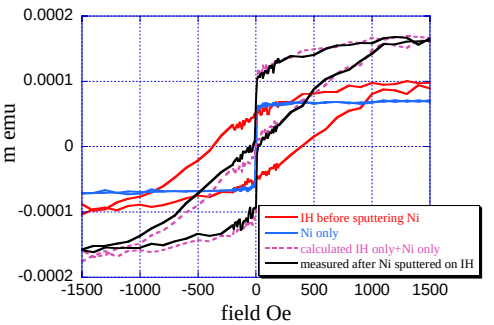
- Transport activation energy E_a=0.15eV by using Wilson's formula $\rho = \rho_0 \exp(E_a/2kT)$

UV of IH(x=0.33) films



- Oxygen vacancy increases energy band gap

Magnetic interaction between IH and other ferromagnetic layers



- Moment of IH and Ni layers switch individualy

Conclusion

- Epitaxial IH film quality highly depends on the oxygen pressure and substrate temperature ----Best deposition condition: 750°C, 10^{-5} Torr O_2
- IH film (x=0.33) has ferromagnetic and semiconducting nature
- Oxygen vacancy increases the energy band gap

Future Work

- Investigate magnetic behavior & improve magnetic ordering
- First-principle calculation of IH Band structure, understand electronic, magnetic and optical properties changing with oxygen vacancy
- Investigate magnetic exchange of IH layers in contact with other ferromagnetic layers