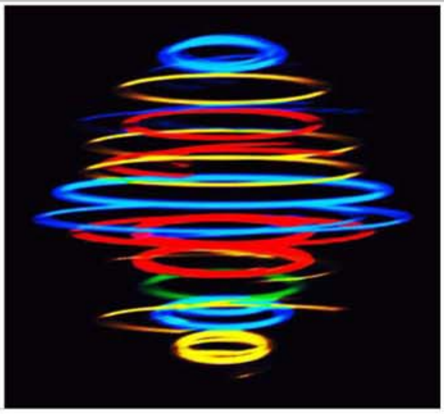
Spintronic device properties strongly depend on a nanometer scale structure

Structure of Magnetic Semiconductors



Spintronics

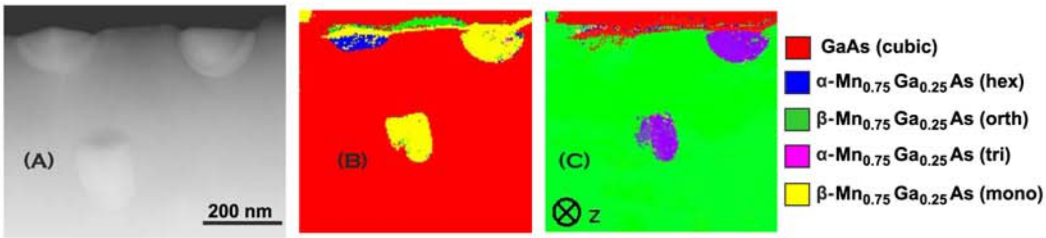
Magnetic semiconductor materials have attracted widespread attention in recent years due to their potential applications for the transport of information by exploiting both the intrinsic spin of the electron and its associated magnetic moment, in addition to its fundamental electronic charge. The new technology which emerged from discoveries in the 1980s concerning spin-dependent electron transport phenomena in solid-state devices was called Spintronics ('Spin Transport Electronics') also known as magnetoelectronics.

The material system (Mn,Ga)As on GaAs is of great interest for the development of such spintronic devices because the unstrained-bulk-MnAs is ferromagnetic at room temperature (α-MnAs, $P6_3/mmc$). It undergoes a phase transition to paramagnetic phases at 40°C (β-MnAs, Pnma) and above 125°C (γ-MnAs, $P6_3/mmc$)). "Surface contactable quasi-embedded" MnAs crystallite precipitates are formed in a [001] – oriented GaAs matrix during the cooling down stage of a MnAs layer that was deposited by metal-organic chemical vapor deposition (MOCVD) above 600 °C.

In order to obtain a thorough understanding of the (Mn,Ga)As crystallite formation process, the crystallographic phase and orientation of the precipitates with respect to the matrix have to be determined. The chemical composition of the precipitates was determined by quantitative EDXS analysis , their chemical composition was defined as $Mn_{0.75}Ga_{0.25}As$.

The challenge:	Identify unknown phase of MnGaAs precipitates among 4 different crystal phases & establish orientation relation between GaAs matrix and precipitates
Solution:	ASTAR technique coupled with precession electron diffraction

A careful inspection of the PED diagrams on the precipitates showed that there existed super structure reflections not consistent with MnAs bulk structure. ASTAR template matching analysis with all possible templates of 4 possible phases compatible with $Mn_{0.75}Ga_{0.25}As$ (total 38561 templates) shows a coexistence of precipitates with the monoclinic β-phase (space group $P2_1/m$) and of precipitates with the hexagonal α-phase ($P6_3/mmc$) at room tempereture. An example of ASTAR phase and orientation analysis of the embedded (Mn, Ga)As-crystallite precipitates in GaAs is illustrated below.



Experimental Data

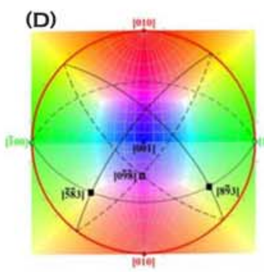
TEM type: Jeol 2200 FS
Map resolution: 1 nm
Scanned area: 2 x 2 µm

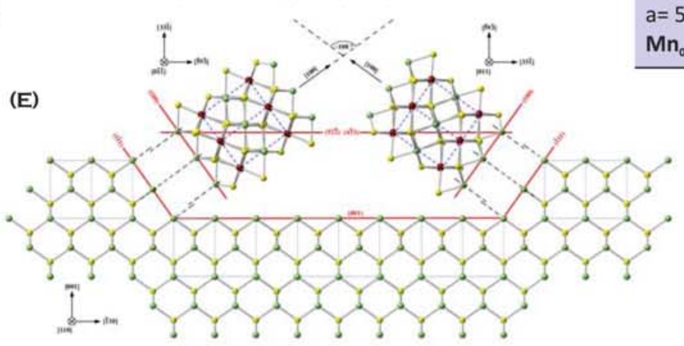
(a) HAADF image of GaAs matrix and precipitates (b) corresponding ASTAR phase map
(c) ASTAR orientation matrix along z (d) stereographic projection of monoclinic phase
(e) orientation relation between GaAs matrix and the completely embedded (Mn,Ga)As crystallite &
(f) stereographic projection of cubic GaAs

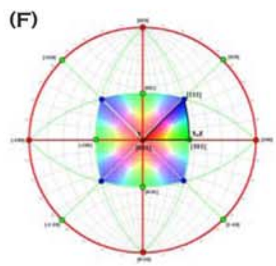
figure 1

Crystal Structure

GaAs: Cubic, $F\bar{4}3m$
a= 5.65 Å
$Mn_{0.75}Ga_{0.25}As$: hexagonal, $P6_3/mmc$







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