The Nucleation of MnSb on the GaAs Surface

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Summary

Semiconductors are desired for optical electronics, while ferromagnetic materials are ideal for laser isolators. The difficulty to combine the two is due to their different crystal forms. We attempt to grow ferromagnetic MnSb onto semiconductor GaAs using Molecular Beam Epitaxy (MBE) and study the nucleation process of MnSb during the growth process.

Terms

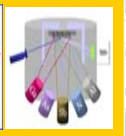
MBE (Molecular Beam Epitaxy)

•Main Chamber

•Transfer Chamber

•Entry Chamber

MBE Machine



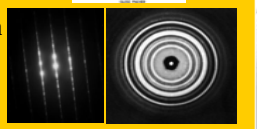
Growth Chamber

GaAs and MnSb Crystal structures

•GaAs: Face-centered cubic

•MnSb: Hexagonal

Electron Diffraction



Electron Diffraction Newton's Ring

•Newton's Ring

•Bragg's Law:

n*lambda = 2d sin (theta)

•Single-crystal:

- •Very smooth: one bright spot
- •Little rough: clear streaks plus spots
- •Very rough: ring patterns

•Poly-crystal: unclear patterns

Reciprocal Lattice

•Definition: *Each family of lattice planes (hkl) is associated with a point g, also identified by (hkl), whose distance from the origin of the coordinate system equals 1/d and which is located on the normal to the lattice planes (hkl).*

•G (hkl) = 1/d(hkl)

Procedure

Temperature

Growth Chamber: -196 Degree Celsius (N2 is used for cooling)

Pressure

•Growth Chamber: 10^(-10) Torr (760 Torr = 1 atm)

•Mn: 2.2x10^(-8) Torr

•Sb: 7~8x10^(-8) Torr

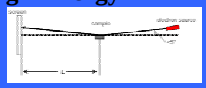
Growth Rate

Growth rate = 1 monolayer/second

Tests

RHEED (Reflection High-Energy Electron Diffraction)

•RHEED Gun + Screen

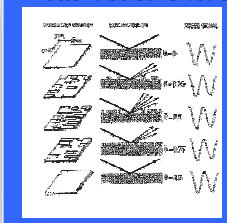


RHEED Gun Illustration

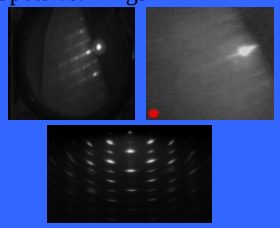
•Electron Beam angle =2 Degrees

•Reflection of Crystal Growth Condition

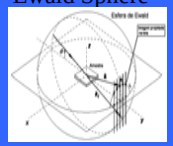
•Patten: Streaks vs. Spots vs. Rings



Growth Condition vs. RHEED Signal



•Ewald Sphere



3D Illustration of electron diffraction

•X-ray Diffraction

•Indication of growth orientation

•Three Variants: alpha, beta, thai

Scanning Electron Microscopy

•Up to 50 nanometers

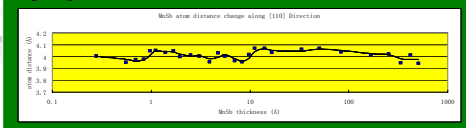
Results

Plane Orientation of Crystal Growth

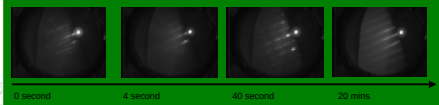
•<10-11>MnSb normal to a GaAs (001) surface

MnSb atom distance change during Growth

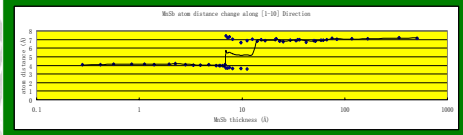
1. [110] Direction



2. [110] Direction RHEED Illustrations

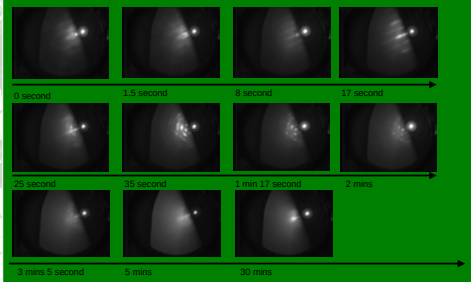


3. [1-10] Direction



1 second => 1 Monolayer => 0.28 Å

4. [1-10] Direction RHEED Illustrations



Conclusion

Our experiments shows that the orientation of MnSb crystal growth on GaAs is <10-11>MnSb normal to a GaAs (001) surface. RHEED patterns along the [110] GaAs direction indicates a relatively stable atom distance of MnSb, while the ones along the [1-10] GaAs direction shows a dynamic change of the MnSb atom distance along with the MnSb thickness. Moreover, unclear patterns between 30s and 1min 30s along the [1-10] GaAs direction is suspected to indicate poly-crystal structures.

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