

Catalyst-free MBE growth of Mn doped GaAs nanowires on silicon substrates

J. Sadowski^{1,2}, P. Dłużewski¹, T. Wojciechowski¹, K. Gas¹, W. Zaleszczyk¹, W. Szuszkiewicz¹, J.F. Morhange³, T. Kasama⁴, R. E. Dunin-Borkowski⁴

¹ Institute of Physics, Polish Academy of Sciences, al. Lotników 32/46, 02-668 Warszawa, Poland

² MAX-Lab, Lund University, 221 00 Lund, Sweden

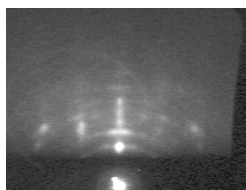
³ Université Pierre et Marie Curie, 4 Place Jussieu, 75252 Paris, France

⁴ Center for Electron Nanoscopy, Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark

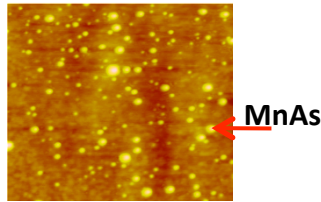
Possible methods of formation of as-grown GaMnAs nanowires

low temperature GaMnAs MBE growth on GaAs(100) with segregated MnAs dots as NW growth catalyst

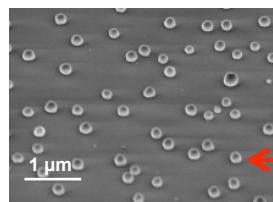
high temperature GaAs:Mn MBE growth on Si(100) with Ga droplets inducing the NW growth



RHEED

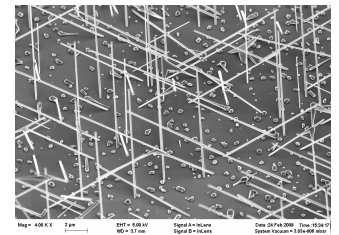


AFM



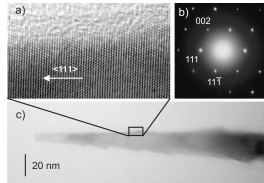
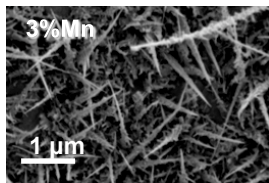
MBE growth of GaAs

Ga

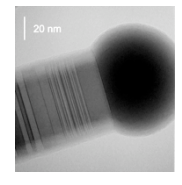
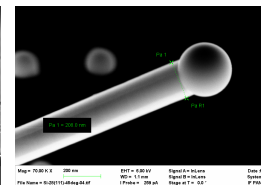


GaAs nanowires 45° tilt view

Continuing the MBE growth with segregated MnAs leads to formation of nanowires



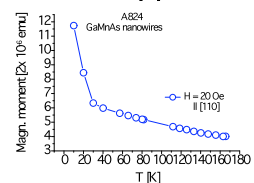
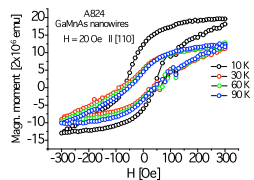
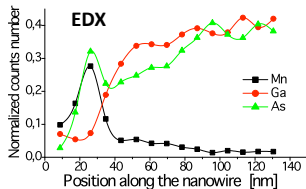
SEM - Si(100) substrate with Ga droplets deposited in the MBE growth chamber



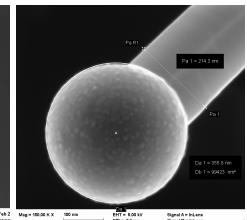
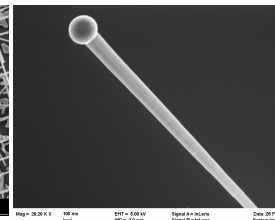
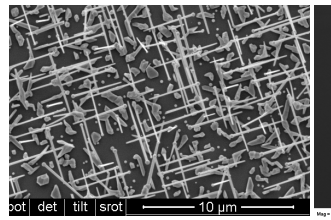
GaAs nanowires side view

NW tip: SEM

TEM



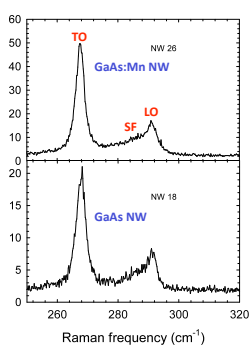
MBE growth with As₂, Ga and Mn fluxes at high substrate temperature (600 °C)



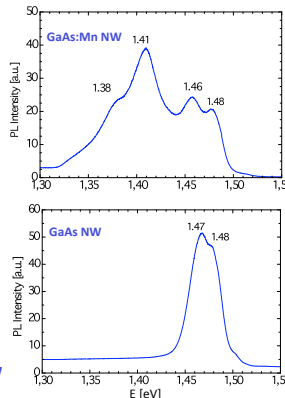
GaAs:Mn nanowires SEM pictures

GaMnAs NW samples grown with segregated MnAs are ferromagnetic but NWS are disordered, have needle-like shapes and branches

Optical measurements



Micro Raman - single NW
T = 295 K, λ = 514.5 nm



PL at 10 K,
Excitation energy 2.33 eV

GaAs:Mn nanowires: TEM, Mn composition mapping Mn accumulation in the Ga droplet

Mn in the main part of NW – below the detection limit of TEM

CONCLUSIONS:

Mn doped GaAs nanowires were grown by the two methods:
(1)- low temperature MBE growth of GaMnAs with MnAs segregation
(2)- high temperature MBE growth of GaAs:Mn on Si(100) with Ga nanodroplets
type (1) NWs - ferromagnetic (probably), very disordered, bad optical properties
type (2) NWs - much better structural properties, Mn in doping concentrations, better optical properties

Acknowledgements:

This work has been supported by the Swedish Research Council (VR) and by the Ministry of Science and Higher Education (Poland) through grant N N202 126035