TEM investigations of (Ga,Mn)As core/shell Nanowires

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(Ga,Mn)As is the prototypical ferromagnetic semiconductor, and has been extensively characterized over the past decade [1-5]. Nanowire (nw)-devices such as nw-FETs [6] and nw-LEDs [7] can become spintronic-devices when a ferromagnetic (Ga,Mn)As shell is brought onto a regular GaAs nanowire.

The technique used to produce nanowires is based on MBE and utilizes the gold catalyst growth technique [8]. This work is devoted to the optimization of the growth parameters by TEM investigations performed immediately after the growth of specimens produced under various growth conditions.

GaAs nanowires can grow in Zincblende or Wurtzite structure depending on the growth parameters. As a consequence of a not yet optimized growth, stacking defects are also present along the nanowire (figure 1a). Furthermore, cross section TEM images shows that the nanowire’s cross section is either a hexagon or a dodecahedron (figure 1b), and is related to the diameter of the wires and consequently to the diameter of the gold particle that acts as catalyst.

Preliminary SQUID measurements reveal that the GaMnAs-coated nanowires actually show magnetic behaviour (figure 2a). The measured magnetic signal is an integral over the sample. The investigation of inhomogeneities and thickness variations along the nanowires is crucial for understanding their individual magnetic behaviour.

Nanowires with an inhomogeneous GaMnAs shell were also observed. The molecular beam hits the rotating sample during the growth at an angle of 45 degree. This causes a “shadow effect” that produces nanowires with a thicker head and a thinner tail (figure 2b). This is because the molecular beam will reach the lower part of a dense array of vertical nanowires at 45° with less probability, compared to the upper part wich is directly exposed to the beam. Figure 2c shows an irregular morphology of the GaMnAs shell. One possible explanation of this effect lies in the increase of the temperature along the nanowires due to the different exposition to the molecular beam because of the shadow effect. This may induce the formation of Mn-Mn and Mn-As dimers, wich act as further nucleations sites. The second possible explanation is the presence of small catalyst particles along the nanowires that gives rise to lateral growth.

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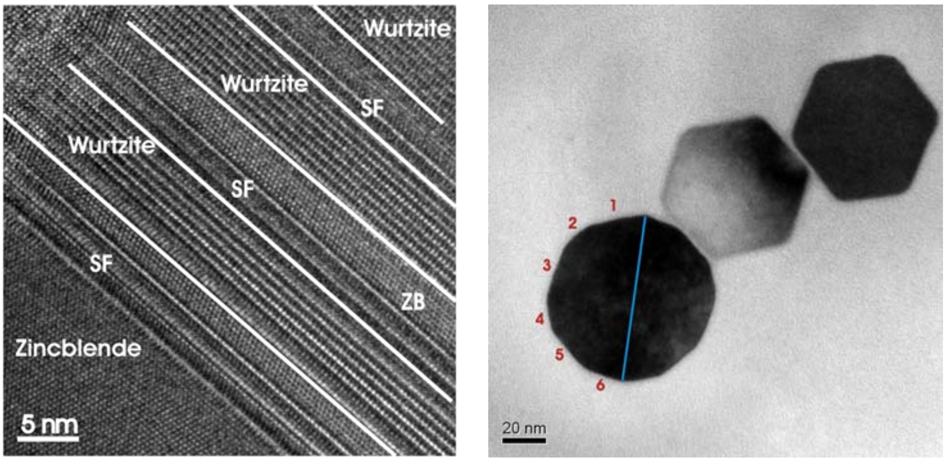
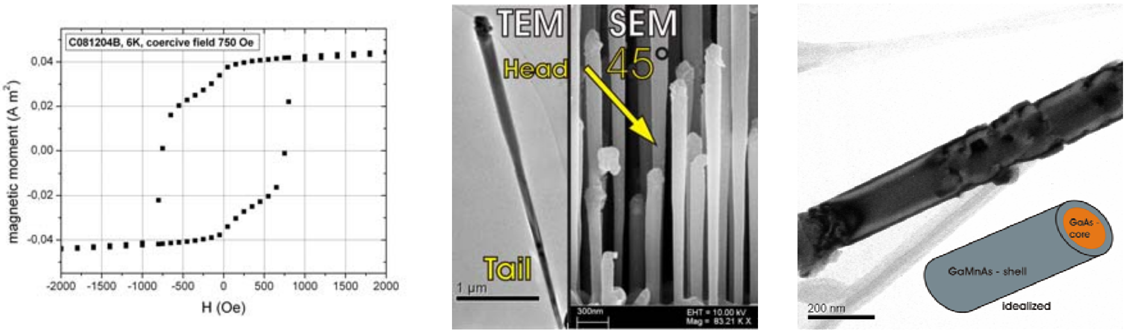


a) b)

Figure 1.
a) HRTEM micrograph of a GaAs NW in the Zincblende <110> direction. The crytal structure switchs between Zincblende and Wurtzite. Stacking faults are embedded in between.
b) BF micrograph of a cross section sample. Hexagons and dodecahedrons are visible.



a) b) c)

Figure 2.
a) Hysteresis curve, measured at 6K perpendicular to the growth direction.
b) TEM BF Picture. The shadow-effect produces core/shell nanowires with a thicker head and a thinner tail. SEM side-view picture. Due to the 45° angle between growth direction and molecular beam and the densely arranged nanowires the GaMnAs shell thickness is not constant along the nanowires.
c) Inhomogeneities in the GaMnAs shell due to the temperature gradient along the nanowires.