YNU 横浜国立大学
YOKOHAMA National University

物理工学談話会　11月20日（月）午後 15:00〜16:00
会場：総合研究棟W701　世話人：レービガー　ハンネス
何方でも気楽にご参加ください

Strain-mediated high TC of GaAs:MnAs granular system – microscopic studies of Mn clustering in WZ-(Ga,Mn)As by in-situ transmission electron microscopy

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Wurtzite (WZ) (Ga,Mn)As, possessing similar symmetry to hexagonal α-MnAs, can be obtained when (Ga,Mn)As is grown as the shells of WZ-GaAs nanowire (NW) cores [1]. Experimental evidence has demonstrated that annealing WZ-(Ga,Mn)As leads to the formation of strained α-MnAs nanocrystals (NCs) embedded semi-coherently within the WZ-GaAs matrix, exhibiting ferromagnetism above 127 °C [2], unlike the bulk α-MnAs with a Curie temperature (TC) of approximately 40 °C.

The formation of α-MnAs NCs can be observed by employing in-situ transmission electron microscopy (TEM) with a Protochips system (Fig. 1 left) and suitable conditions to enhance the contrast of Mn clusters during scanning TEM (STEM). Sequential imaging during the annealing process allows for the visualization of MnAs precipitation in WZ-(Ga,Mn)As (forming the NW shell), as revealed in the initial in-situ STEM results presented in Fig. 1 (right).

To accurately track Mn segregation, an algorithm based on the advanced image processing procedures was developed for automatic and reliable analysis of NWs images. It made it possible to identify, and measure the size and the distribution of the detected particles. Through this analysis, the various stages of MnAs precipitation were determined:

- nucleation of the coherent WZ nano-clusters (NCLs) with Mn atoms in a substitutional positions MnGa, significantly stressed in the WZ-GaAs matrix (starting at ~300 °C)
- NCLs phase transition from WZ-MnAs to α-MnAs (~350 °C)
- growth of semi-coherent α-MnAs NCs, partially strained in the WZ matrix (~400 °C)

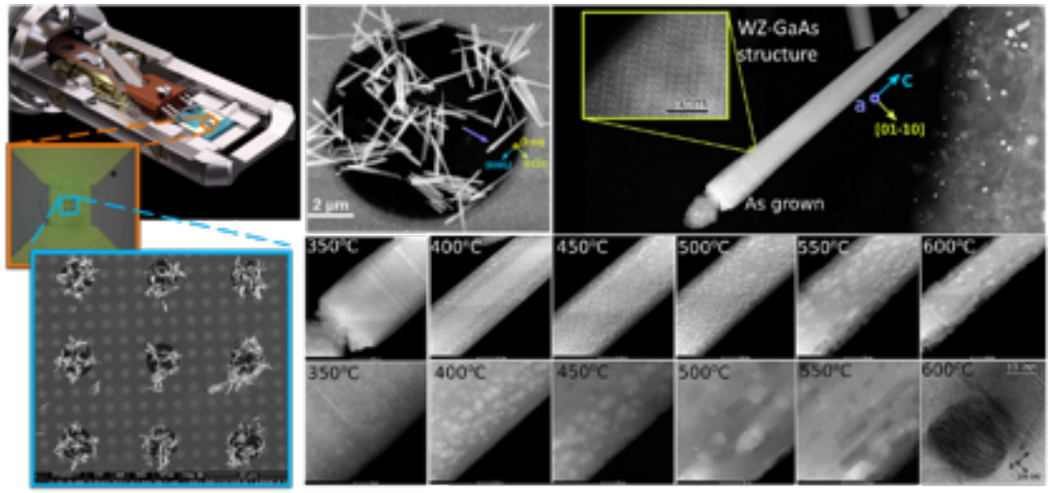

Fig. 1 *(left)* Protochips system for heating TEM experiment with NWs transfer onto nine holes dedicated for TEM measurement. *(right)* Subsequent stages of in-situ annealing for chosen temperatures showing structural evolution in one NW – (S)TEM images with lower and higher magnifications.

During my presentation, I will provide insights into the potential thermal control of the granular WZ-GaAs:MnAs system to achieve the desired size and distribution of MnAs NCs within core-shell NWs. In this context, I will also highlight the role of the (Ga,Al)As inner shell and the importance of the WZ-GaAs crystal structure's anisotropy in the process of Mn diffusion.

References

[1] J. Sadowski et al., Nanoscale 9, 2129 (2017).
[2] A. Kaleta et al,. Nano Lett. 19, 7324 (2019).