Influence of local substrate temperature on magnetic properties of (Ga,Mn)N grown by PAMBE

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In this report we summarize the results of studies quantifying the role of the growth temperature T_g on the magnetic properties of (Ga,Mn)N. To this end a range of high quality $Ga_{1-x}Mn_xN$ layers have been grown by plasma assisted molecular beam epitaxy with manganese concentration $0.2 \le x \le 10\%$, having the x value tuned by changing T_g between 700 and 590 °C, respectively. Our studies are augmented by a systematic structural and microstructure characterization by atomic force microscopy, secondary ion mass spectrometry, transmission electron microscopy, powder-like and high resolution X-ray diffraction, which do not reveal any crystallographic phase separation, clusters or nanocrystals, even at the lowest T_g. Our synchrotron based X-ray absorption near-edge spectroscopy supported by density functional theory modeling and SQUID magnetometry results point to the predominantly +3 configuration of Mn in GaN and thus the ferromagnetic phase has been observed in layers with $x > 5\%$ at $3 < T \delta 10$ K. The main detrimental effect of T_g reduced to 590 °C is a formation of flat hillocks, which increase the surface root-mean-square roughness, but only to mere 3.3 nm. Fine substrates' surface temperature mapping has shown that the magnitudes of both x and Curie temperature T_C correlate with local T_g. It has been found that a typical 10 °C variation of T_g across 1 inch substrate can lead to 40% dispersion of T_C. The established here strong sensitivity of T_C on T_g (Fig. 1) turns magnetic measurements into a very efficient tool providing additional information on local T_g, an indispensable piece of information for growth mastering of ternary compounds in which metal species differ in almost every aspect of their growth related parameters determining the kinetics of the growth. We also show that the precise determination of T_C by two different methods, each sensitive to different moments of T_C distribution, may serve as a tool for quantification of spin homogeneity within the material.

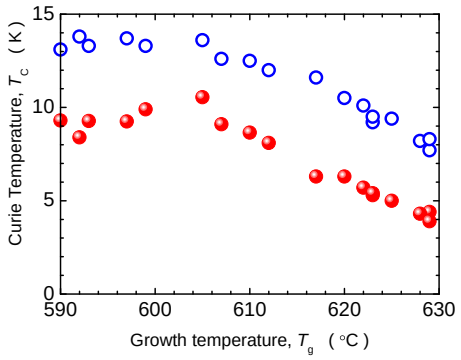

Fig.1 T_C as the function of local T_g. The magnitudes of T_C are determined from the extrapolation of thermoremanence to zero (open symbols) and from the position of the inflection point of the temperature dependent magnetization (solid symbols).

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