Magnetic structure of Fe-rich nanocrystals in a GaN plane

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Phase separated materials, like those formed when transition metals are introduced into a semiconductor matrix above their solubility limits, offer new possibilities for material science and technology. In a set of papers of the some of the present authors [1] it has been shown that GaN doped with Fe is one of these systems. In particular, it has been demonstrated that either by co-doping with donors or acceptors or by varying the growth conditions (temperature, growth rate, doping method) a control over the aggregation of a variety of Fe_xN ferromagnetic (FM) and antiferromagnetic (AF) nanocrystals (NCs) has been obtained in MOVPE grown GaN:Fe. Recently, the localization of these Fe-rich NCs into 2D planar arrays embedded in a GaN matrix with tunable phase and composition was demonstrated [2].

In this work we present the results of a dedicated SQUID magnetometry study on these phase separated GaN:Fe samples which confirm the existence of both FM and AF responses appearing at different proportions. The most dominating one is persisting up-to-above room temperature FM component. However, the observed non-Brilloiun-like temperature dependence of the saturated moment at the experimental temperature range (2 – 400 K) points to the presence of a variety of Fe-rich compounds with a broad spectrum of Curie temperatures (T_C). Most interestingly, the ensemble of these NCs does not behave as a blocked superparamagnetic system. On the contrary, the strict 2D arrangement of these NCs and the sizable strength of their magnetic moments allows for inter-NCs *ferromagnetic* coupling through dipolar interaction which may be effective even at temperatures up to the internal T_C of these NCs. This superferromagnetism is responsible for the nearly *T*-independent fast saturation observed at weak fields. Some of the layers exhibit a linear in the magnetic field component, which we interpret as the presence of antiferromagnetically coupled NCs. This finding indicates that such planar arrays of Fe-rich NCs can be made suitable for both FM- and AF-spintronic functionalities.

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