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High Curie temperature ferromagnetism in self-organized GeMn nanocolumns.

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We have recently evidenced high Curie temperature (T_C >400 K) Mn-rich nano-columns self-assembled in a diluted $Ge_{0.94}Mn_{0.06}$ film. Their composition is close to Ge_2Mn as given by nanoscale chemical analysis (Electron Energy Loss Spectroscopy). Their average diameter, height and spacing are 3 nm, 80 nm and 10 nm respectively. Their volume fraction in the GeMn film is almost 16 %. From Transmission Electron Microscopy (TEM) cross sections we could clearly evidence that nano-columns are crossing the whole GeMn film. SQUID measurements reveal a very high Curie temperature (> 400 K) and Zero Field Cooled-Field Cooled (ZFC-FC) data rule out the presence of superparamagnetic nanoparticles. Growth is performed by simultaneously evaporating Ge and Mn atoms from standard effusion cells on Ge(001) single crystal substrates. The growth temperature is varied from 80 to 200 °C. In the whole temperature range, Mn-rich nano-columns are clearly observed by TEM. However magnetic properties depend on the growth temperature and high $T_C$columns are only obtain in a very narrow temperature range around 130 °C. Magnetotransport measurements have been performed with magnetic fields applied perpendicular to the film plane. A large positive magnetoresistance (up to 7000 % at 30 K) in contradiction with the negative MR in granular systems or other ferromagnetic semiconductors is measured. Taking MR effects into account we have evidenced a large Anomalous Hall Effect (AHE) up to room temperature despite of the low volume fraction of nano-columns in GeMn films. The presence of AHE proves that holes are spin-polarized by crossing nano-columns. In this presentation, we will discuss the kinetic mechanisms leading to the columns formation, the composition and crystal structure of the columns as well as their magnetic properties as a function of the growth temperature and Mn concentration.