Pulsed laser epitaxy of ferromagnetic GdN thin films

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Rare earth nitrides have attracted much interest due to the complex interactions between their f-electrons, which give rise to a wide range of electrical properties, including magnetism and insulating states[1]. GdN is a ferromagnetic insulator and as such may be useful in the development of spin filter devices[2]. There is also a renewed interest in GdN due to their proposed topological states[3]. One problem is that it has been difficult to produce high quality thin films of GdN to study interesting electronic behaviors. Although a thorough understanding of the physical mechanisms behind the properties of GdN is paramount, there has been little progress in the growth of epitaxial GdN films. For example, attempts to synthesize epitaxial GdN films by pulsed laser deposition[4] or even molecular beam epitaxy[5, 6] have not yielded the desired results from an epitaxial growth perspective.

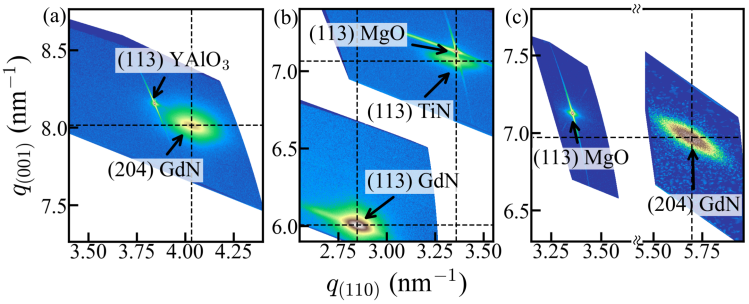

Fig. 1. HRRSMs of epitaxially grown GdN thin films. (a) Epitaxial relation between (204) GdN and (113) $YAlO_3$ diffraction peaks (sample A). (b) Epitaxial relation between (113) GdN, (113) TiN, and (113) MgO (sample B). TiN films grew coherently on the (001) MgO substrates. (c) Epitaxial relation between (204) GdN and (113) MgO (sample C). GdN films grew along the [111] axis.

Here we grew GdN thin films on pseudocubic (001) $YAlO_3$ substrates (sample A), TiN buffered (001) MgO (sample B), and (001) MgO (sample C) by pulsed laser deposition (PLD)[7]. Those films were characterized by using high-resolution x-ray diffraction, high-resolution scanning transmission electron microscopy and high-resolution reciprocal space mapping (HRRSM). Moreover, we performed magnetization measurements as a function of temperature using a superconducting quantum interference device magnetometer. The synthesis of high-quality rare-earth nitride thin films by PLD requires the ablation target to be of comparable density to the deposited film. An excimer laser with a wavelength of 248 nm was used. The laser fluence was set to 1.2 J/cm^2 and the repetition rate to 5 Hz. We optimized growth parameter of substrate temperature and nitrogen pressure to obtain single phase of GdN. GdN films were synthesized at 900 °C under 50 mTorr N_2 pressure. To avoid oxidation of GdN, all GdN films were covered with a 50 nm TiN capping layer. We found (100) GdN films were synthesized in sample (A, B) from HRRSM [Fig. 1(a) and (b)]. The growth direction of GdN films is controllable between (001) and (111) w./w.o. TiN buffer layer on (001) MgO [Fig. 1 (b) and (c)]. Sample (A) is promissing in the search for Chern insulator, as (001) GdN can be obtained without a buffer layer. From magnetization measurements, the easy magnetization axis is always in-plane in all samples. This indicates that the hard magnetization axis can be altered by changing the epitaxial growth direction.

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