行政院國家科學委員會專題研究計畫成果報告

用有機化學氣相沉積系統和氣態源分子束磊晶系統成長氮化鎵基板材料與同質磊晶的研究

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一、中文摘要

用一個特殊設計的有機化學氣相沉積系統，獲致了氮化銦高速率的磊晶。成長速率是因為成長源氨氣被預先解離而提昇。一層 500 埃厚的氮化鎵緩衝層是用來改進薄膜晶體的品質。

關鍵詞：氮化銦、高速率磊晶、氮化鎵

Abstract—*High-growth-rate epitaxy of InN film was achieved by a novel-designed metalorganic chemical vapor deposition (MOCVD). The growth rate is greatly enhanced by the pre-cracking of the precursor NH_3. A thin GaN buffer layer with the thickness of 500 Å was also adopted to improve the film quality.*

Keywords：InN, high-growth-rate epitaxy, GaN

二、緣由與目的

Indium nitride (InN), which is a III-V compound semiconductor with a stable wurtzite crystal structure and a direct band gap of ~ 1.9 eV[1], is promising for visible optoelectronics and high efficiency solar cells. InN epitaxial layer has been grown by different systems including molecular beam epitaxy (MBE), metalorganic chemical vapor deposition (MOCVD), and chloride-transport vapor phase epitaxy (VPE). However, high quality InN hasn't been achieved yet mainly due to the lack of a lattice matching substrate, and restricted growth conditions which are limited by the low dissociation temperature of InN and required high equilibrium vapor pressure of N_2[2]. Usually the growth temperature of InN should be kept relatively low (~500℃) to prevent the dissociation of InN, however the cracking efficiency of NH_3 at such low temperature is poor, resulting in a low growth rate of ~0.3μm/hr[3]. In this paper, we report that a high growth rate of 1.4μm/hr epitaxy of InN was achieved by a novel-designed MOCVD system with a NH_3 precracking device. A low-temperature GaN buffer layer on a sapphire substrate was adopted to improve the InN quality.

三、研究方法

A schematic diagram of the MOCVD apparatus for the InN growth is shown in Fig.1. Trimethylindium (TMIn: $(CH_3)_3In$) kept at 20℃

and high-purity NH_3 were used as the precursors. TMIn vapor was carried by 20~30 sccm H_2 gas and then another 200sccm N_2 gas was added to increase the gas velocity of group-III line. NH_3 flow rate varied from 800 to 1600 sccm, which corresponds to a V/III ratio about 10000. To prevent pre-reaction between TMIn and NH_3, they were fed into chamber separately through quartz tube. The tube delivering NH_3 passed over a high temperature graphite(temperature range 800~1000 ℃) for NH_3 cracking. The precracked NH_3 gas was mixed with TMIn and carrier gas just above the substrate and jeted vertically onto a sapphire substrate. The growth temperature at substrate varied at the temperature range of 400~600℃.

四、結果與討論

The typical horizontal temperature profile of the reactor was shown in the lower part of Fig.1. To overcome the large lattice mismatching(25.7%) between InN and sapphire substrate, a 500Å GaN buffer layer that has 11.1% lattice mismatching to InN was grown at 520℃ on a sapphire substrate first and recrystallize it at 900℃. Then low down the substrate temperature to 400~600℃ to grow InN.

Films with specular surface were achieved when GaN buffer layer was used, while with rough surface when grown on bare sapphire. Fig.2 (a) shows the crossections of InN film with GaN buffer layer. The surface is smooth while the crossection appears with columnar structures. The thickness is 0.7μm corresponding to a growth rate of 1.4μm/hr, which is much larger than the previously reported data[3]. The greatly increased growth rate obtained indicates that NH_3 cracking efficiency is effectively enhanced by pre-heating NH_3 gas. Fig.2 (b) shows the crossection of InN film grown on bare sapphire. The surface is rough and dominated by island structure. The improved morphology on the InN film using a GaN buffer layer compared to that on the bare sapphire substrate is attributed to the smaller lattice mismatch between InN and GaN. The θ-2θ mode X-ray diffraction pattern of InN/GaN/sapphire layer is shown in Fig.3. The diffraction peaks of 34.5° and 31.7° were from the (0002)GaN and (0002)InN respectively, indicating (0001)-oriented hexagonal InN was epitaxially grown on the (0001) sapphire substrate. The corresponding c-axes lattice constant of the InN film is 5.65Å.

五、參考文獻

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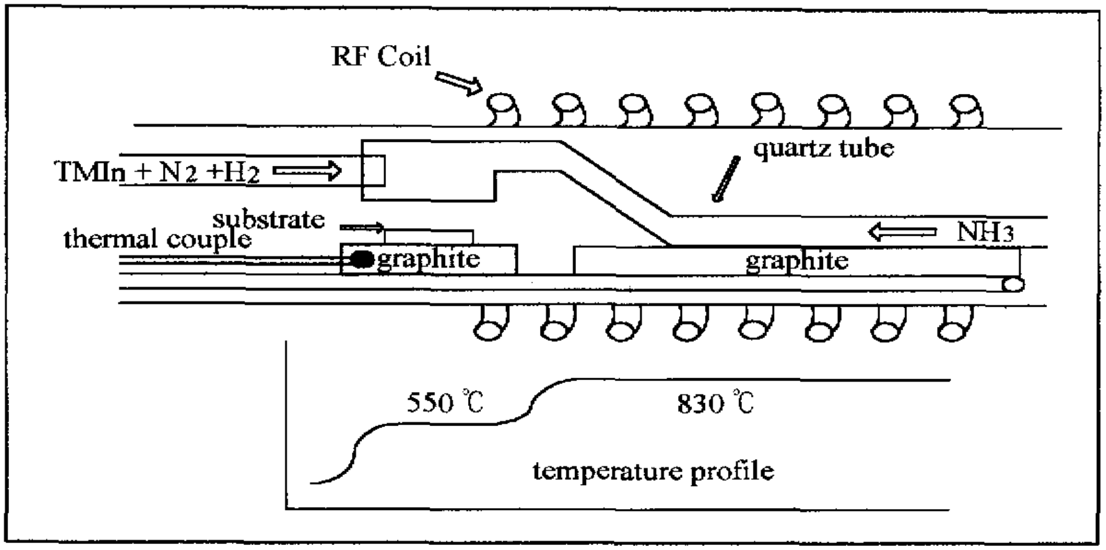

Fig.1 Schematic diagram of the apparatus and temperature profile used in this work.

Fig.2 SEM photographs of InN film grown on sapphire (a) with GaN buffer layer. (b) without GaN buffer layer.

Fig.3 X-ray diffraction profiles of InN film grown on sapphire at 550℃.