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Micromechanical Properties of GaP⟨Dy⟩ Epilayers

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Abstract—The physicomechanical properties of GaP epilayers grown by liquid phase epitaxy from indium-based high-temperature solutions have been studied using microindentation. The results demonstrate that the growth of GaP epilayers from indium-based high-temperature solutions leads to a reduction in their microhardness, microbrittleness, and fracture toughness. The addition of a rare-earth dopant to a high-temperature solution has an ambiguous effect on the strength of the epilayers. Low rare-earth concentrations may both reduce and increase the microhardness of the epilayers, depending on epitaxy conditions. The random microhardness distribution of samples containing rare-earth inclusions has two peaks: one due to the rare-earth inclusions, and the other due to the region with a relatively low lanthanide concentration.

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INTRODUCTION

Interest in gallium phosphide epilayers stems from the fact that such layers can be used to fabricate optoelectronic devices for the visible range [1]. On the other hand, doping of III–V compounds with lanthanides has considerable potential from the viewpoint of application of such materials in the development of light sources for optical fiber communication systems [2–4].

Available data on the microhardness of III–V epilayers are contradictory. In particular, Arbenina and Kabanova [5] reported GaAs epilayers grown from an ytterbium-containing high-temperature solution to have an increased hardness (by up to 25%). At the same time, Kulish et al. [6] did not detect such microhardness changes upon lanthanide doping of GaAs epilayers. Moreover, lanthanides were found to differ markedly in behavior: Gd doping led to hardening of the epilayers, Tb had little effect, and Dy reduced the microhardness of the epilayers. Note that data on the micromechanical properties of rare-earth-doped GaP are not available in the literature.

EXPERIMENTAL

We used microindentation to investigate the physicomechanical characteristics (microhardness, microbrittleness, and fracture toughness) of GaP epilayers (6–9 μm in thickness) produced on GaP⟨S⟩ substrates ((111)B orientation) and doped with Dy during the growth from indium-based high-temperature solutions in the temperature range from 850 to 975°C. The cooling rate of the high-temperature solutions was ~1°C/min. The Dy concentration in the high-temperature solutions was varied in the range 0.05–1.5 wt %.

The parameters of the epilayers are listed in Table 1. In all of the epilayers, the percentage of indium, an isovalent background impurity, approached its solubility in GaP (~1 wt %).

Zn doping of the epilayers (Table 1, samples 3, 4) was performed through diffusion at 600°C for 4 h. For a number of samples, to remove volatile background impurities and obtain extrapure epilayers (Table 1, sample 4) the reactor was taken apart and then reassembled, and a supersaturated high-temperature solution was repeatedly (up to five times) held at a high