INVESTIGATION OF PROBLEMS ABOUT THE LIGHT POWER OUTPUT OF GaAs-GaAlAs DH SURFACE LEDs

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Abstract

A modified conventional RF sputtering equipment is used in preparing the Al₂O₃ antireflection (AR) coating. An increase in the light output by 30--60% at a driving current of 200 mA for the GaAs-GaAlAs DH LEDs coated on the front faces with a AR coating thickness of about λ/4 has been obtained. Under the same AR coating conditions a light output increase of less than 30% for the degraded LEDs of the same type has been determined. It may probably be attributed to the defects formed in the bulk of the Ga₁₋ₓAlₓAs crystals caused by degradation of diodes which restricts light output increase.

I. Introduction

The internal quantum efficiencies of GaAs–GaAlAs DH diodes fabricated for optical communication application have been estimated to be as high as 80% or more. But due to the high refractivity of GaAs-air interface coupled with multiple internal reflection and absorption of diodes, the loss of light is inevitable. Therefore, the external quantum efficiency for most of the diodes is less than 3%. LEDs for application in long-haul optical communication systems are characterized by their high effective radiance and long-term reliability. Although the diodes having hemispheric lens on the emitting surfaces exhibit higher external efficiencies[1-3], such devices are expensive to make for application purpose. Some works[4-5] also reported on investigation of LEDs degradation. Their results showed that the degradation or the light output decrease of LEDs was caused by the generation of the defects or dislocations in the interior of GaAlAs crystals. Obviously, to increase the light output of LEDs and prevent their degradation are a very important problem. In the present work, the effect of the front faces on the light output of the surface LED is investigated. In the same case, the light output increase for degraded LEDs coated with Al₂O₃ is also observed.

II. Experiment and Results

A conventional RF sputtering equipment with a source power of 3kW at 13.5MHz was used in depositing Al₂O₃ antireflection (AR) coatings (refractive index: 1.7) on the front surfaces of LEDs. A high purity Al₂O₃ target was employed as described in [6], in which the calculated values of the reflectivities of some conventional AR coatings (Al₂O₃, SiO₂ or TiO₂) were taken as a function of optical thickness when they were respectively deposited on a GaAs substrate. Comparison among these calculated values showed that the reflectivity of the Al₂O₃
AR coating is smaller, and its coefficient of thermal expansion ($\alpha = 6.8 \times 10^{-6}\,\text{C}^{-1}$) is almost the same as that of GaAs ($\alpha = 6.4 \times 10^{-6}\,\text{C}^{-1}$) at 20–260°C. In order to eliminate possible damage by secondary electron bombardment on devices during depositing AR coatings by sputtering on front faces of LEDs. It is necessary to modify the sputtering equipment so that a "region without damage" on the surface of the substrate table can be provided. Fig. 1 is a photo showing that when $\text{Al}_2\text{O}_3$ film is sputtered on the substrate placed on the surface of the substrate table, the central part is a "region without damage".

The surface LEDs are fabricated from standard four-layer material (Fig. 2). The first layer is $n$-type GaAlAs grown on a $n$-GaAs substrate, the second (active) layer is $p$-type GaAlAs, the third and the last layer are $p$–GaAlAs and $p$-GaAs, respectively. For preventing the heavy absorption of emitted radiation, a well must be etched through the GaAs substrate to bring the surface of $n$-GaAlAs layer into contact with air. The LEDs of two kinds used in this work are the normal LED and the degraded LED. $\text{Al}_2\text{O}_3$ coatings are deposited by sputtering on the front faces of LEDs under the same conditions.

The light output increase of a LED as a function of the front surface reflectivity is known. When the AR coating thickness is near $\lambda/4$, the front surface reflectivity is relatively higher. The optimum AR coating thickness is $\lambda/4$ (about 1250Å thickness of $\text{Al}_2\text{O}_3$ coating) corresponding to the maximum output increase of the LED. Therefore, the $\lambda/4$ or about $\lambda/4$ coating thickness of $\text{Al}_2\text{O}_3$ is chosen for coating the front surfaces. The light output of LEDs is measured before and after depositing AR coating.