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Etching Characteristics of Low-k Polymer for Wide Modulation Bandwidth VCSELs

Akihiro Matsutani, Naoki Jogan, Fumio Koyama and Kohroh Kobayashi
Tokyo Institute of Technology, Precision and Intelligence Laboratory,
R2-21 4259 Nagatsuta, Midori-ku, Yokohama 226-8503, Japan
Email: matsutani.a.aa@m.titech.ac.jp

Abstract

We investigated etching characteristics of low-k polymer for wide modulation bandwidth VCSELs. We used an O_2-plasma etching process for patterning a low-k polymer passivation film. The parasitic capacitance of VCSELs could be reduced by using the low-k polymer.

1. Introduction

Vertical-cavity surface-emitting lasers (VCSELs) are expected to be a key device for high-speed local area networks, which enables low power consumption and small packaging. A small signal modulation bandwidth of 21.5GHz [1] and direct pulse modulation at 20Gb/s [2] and 25Gb/s [3] were reported so far. To reduce the parasitic capacitance is an important issue for improving the modulation bandwidth. Polyimide has been often used as a passivation film. However, the dielectric constant k of the polyimide is as large as 3.2-3.5 at 1 MHz. Therefore, it is important to reduce the dielectric constant of the passivation film for decreasing the parasitic bonding pad capacitance.

In this paper, we report O_2-plasma etching characteristics of the low-k polymer for wide modulation bandwidth VCSELs.

2. Experiment and Result

We used the AL-polymer (ASAHI GLASS Co., Ltd) as low-k materials for a passivation film. The dielectric constant k of the AL-polymer is 2.4-2.5, which is 30% lower than that of the polyimide. The AL-polymer is not photosensitive. Therefore, a patterning process using resist mask and dry etching is needed for fabrication of devices. We prepared approximately 2 μ m thick AL-polymer as samples. These samples were cured in N_2 atmosphere after spin coating. The AZ photoresist was used as a mask material. We used a RIE etching system (converted Samco RIE-1N) with a RF frequency of 13.56 MHz. A sample table is cooled by water. We used pure O_2 as an etching gas.

Figure 1 shows the etching rate of the AL-polymer as a function of RF power. The AL-polymer was etched at a gas pressure of 2 Pa and an O_2 gas flow rate of 50 sccm. The etching rate of the AL-polymer increases with increasing of the RF power. Etching rate ratio between the AL-polymer and the AZ photoresist was maximized at 100W.

Figure 2 shows the etching rate of the AL-polymer as a function of the process pressure. The AL-polymer was etched at an RF power of 100W and an O_2 gas flow rate of 50 sccm. The etching rate of the AL-polymer increases with increasing of the process pressure. The etching rate ratio reached at a maximum value of 1.2 at 2Pa.

Figure 3 shows the etching rate of the AL-polymer as a function of the O_2 gas flow rate. The AL-polymer was etched at 100 W and 2 Pa.

We fabricated VCSELs for wide modulation bandwidth using the AL-polymer as shown in Fig. 4. The parasitic capacitance of the p-electrode could be reduced to 0.1pF [4]. The capacitance using the AL-polymer was as small as a half of that using polyimide for the same device structure. The reduction of the parasitic capacitance is primarily due to the smaller dielectric constant of the AL-polymer. In addition, a

3dB-modulation bandwidth of 17GHz was obtained in the VCSEL with a small mesa structure [4].

3. Summary

In summary, we investigated etching characteristics of low-k polymer for wide modulation bandwidth VCSELs. We reported O_2 plasma etching characteristics of the AL-polymer as a low-k material. The maximum etching rate ratio between the AL-polymer and the AZ photoresist was approximately 1.2. The AL-polymer is useful for insulating high-speed optical devices including wide modulation bandwidth VCSELs.

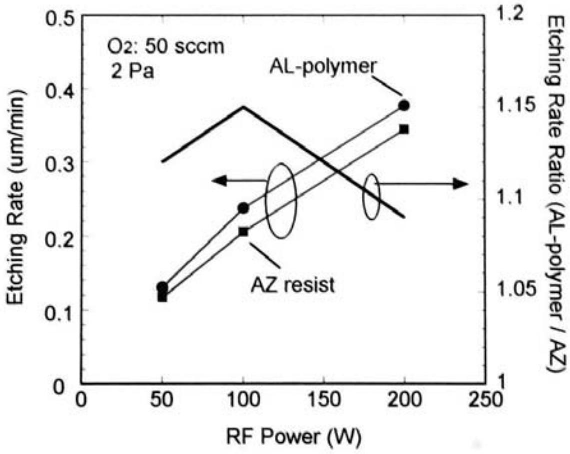

Fig.1 Etching rate of the AL-polymer as a function of RF power.

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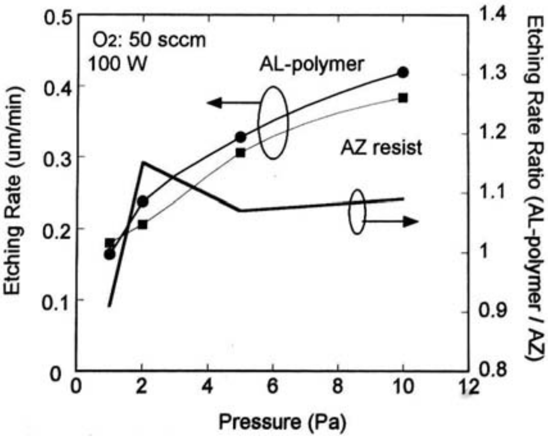

Fig. 2 Etching rate of the AL-polymer as a function of the process pressure.

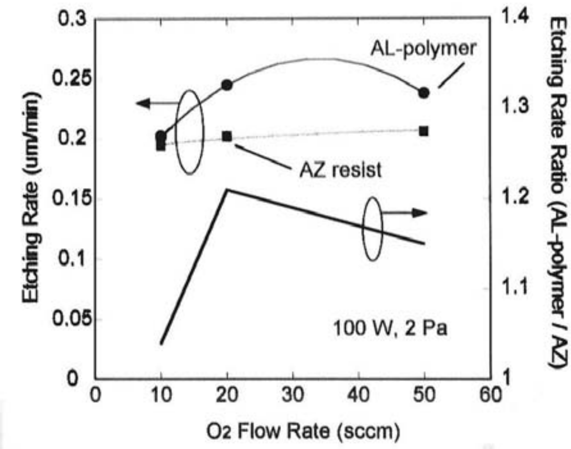

Fig. 3 Etching rate of the AL-polymer as a function of the O_2 gas flow rate.

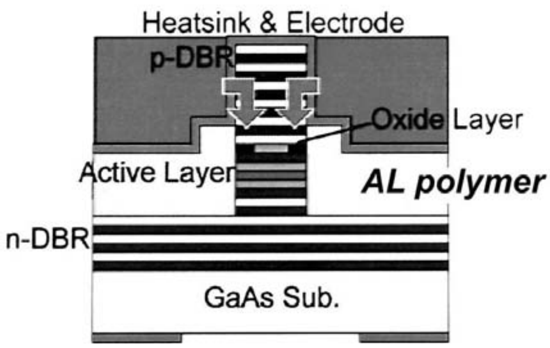

Fig. 4 Schematic diagram of VCSEL using AL-polymer.