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Light-emitting diodes fabricated on an electrical conducting flexible substrate

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ABSTRACT

An array of InGaN-based flexible light-emitting diodes (FLEDs) was fabricated on a Ni-embedded electrical conducting flexible fabric with a full-scale 2-in. size. The FLED chip operation under current injection was realized using a single current probe as the negative electrode on the n-GaN surface; the conducting substrate was used as the positive electrode. The stability of the output power in the FLEDs was improved dramatically on the Ni-embedded conducting flexible fabric compared to that on the conventional polyimide flexible substrate. The former showed linear operation up to an input current 950 mA with no wavelength shift, whereas the latter exhibited rolling-over behavior after an input current of 200 mA.

1. Introduction

Light-emitting diodes (LEDs) with flexible device feasibility have attracted considerable attention for emerging applications in biomedical and displays. Although organic material-based LEDs are inherently congruous to flexible devices, inorganic material-based flexible LEDs (FLED) are also expected because of their basic advantage over organic LEDs, such as high brightness, high efficiency and high stability. A range of novel applications with InGaN-based FLEDs have been actively sought, including smart textile, deformable displays, and implantable biomedical electronics [1–5]. Although some advances have been being made in the field of InGaN-based FLEDs [6–13], there are still challenges that need to be addressed. One of them is the transfer of high-quality epitaxial layers onto flexible substrates in a wafer level, which was first successfully demonstrated on a 2 in. wafer level by Gossler et al. [13]. Although an individual InGaN-based chip or an array of chips have been transferred to flexible substrates, multiple transfer processes and/or the accompanying complex procedures might hinder the wafer scale production for cost-effective mass production. The other is the problems of the operating quality in the output power of FLED, which may be due to the poor electrical and thermal properties of the conventionally-used polymer-based flexible substrate.

Recently, we reported the fabrication of InGaN-based FLEDs at a full-scale 2-in. wafer level [14,15]. Using a simple direct-transfer process based on a laser lift-off (LLO) technique, an array of InGaN-based FLED chips were transferred to a full-scale 2-in. polyimide substrate and showed FLED operation under current injection. Although the possibility of the mass production of high-quality InGaN-based FLEDs with high-current operation was demonstrated, there is still room for improving the output power quality of FLEDs.

As one of the ways to improve the output power quality of FLEDs, it may reasonable to replace the conventional polymer-based flexible substrate with an electrically conducting flexible substrate. Through this, improved output quality from the better thermal conductivity as well as current injection operation only with single wiring from the conducting substrate as the other electrode are expected.

Based on this consideration, in this study, Ni-embedded electrical conducting flexible fabric was used as the flexible substrate of

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FLEDs. The simple direct-transfer process based on the LLO technique was applied to transfer an array of InGaN-based FLED chips on a full-scale 2-in. conducting flexible substrate. The operation properties were compared with those of FLEDs with a conventional polymer-based flexible substrate.

2. Experiment

Arrays of FLEDs were fabricated using a simple direct transfer process developed previously [14]. An InGaN/GaN epitaxial layer for LEDs was grown on 2 in. sapphire substrates. The patterning of SiO_2 open windows and p-Ohmic metal deposition inside the open window were performed on the epitaxial layer. Cu was electroplated onto the p-Ohmic layer for improving the thermal stability of the LEDs. The prepared sample was then bonded with a Ni-embedded electrical conducting flexible fabric. The electrical conducting flexible fabric we used in this research is a conducting tape from WINNOVA Co. Ltd. [16]. The tape actually consists of conductive fabric and conductive adhesive in addition to release paper as shown in Fig. 1(a) which is the schematic diagram for the cross section of it. The thickness of the conductive fabric plus the conductive adhesive is 0.12 mm and that of the release paper is 0.130 mm. From scanning electron microscopy (SEM) images

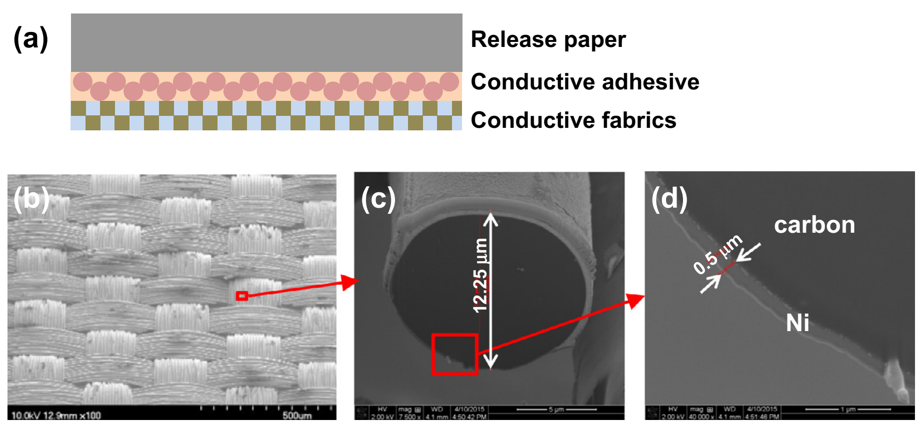

Fig. 1. (a) Schematic diagram for the cross section of the conducting tape, and SEM images of (b) the conductive fabric in global view, (c) and (d) the constituent single string of the fabric.

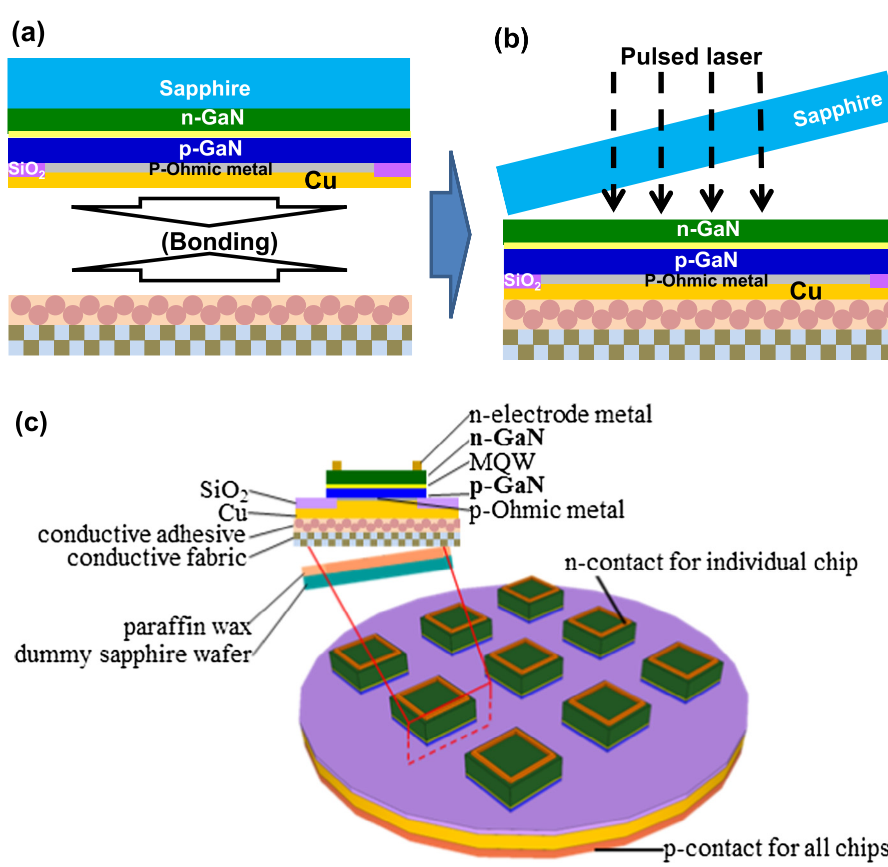

Fig. 2. Schematic diagram for the FLED fabrication process (a) bonding process, (b) LLO process and (c) the final FLED chip on a full-scale 2-in. size.