UV活性化によるシリコン/砒化ガリウムの高強度融着と シリコン上量子ドットレーザ形成への応用

Strong Bonding of Silicon and Gallium Arsenide Using UV Activation and Application to Fabrication of Quantum Dot Lasers on Silicon

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Wafer bonding technology has been applied to integrate III-V semiconductor lasers on Si as light sources for silicon photonics for the past few years. In our group, we have demonstrated InAs/GaAs quantum dot (QD) lasers, with several properties superior to other semiconductor lasers [1], on Si substrate by direct bonding [2] and metal bonding [3]. The bonded lasers have comparable pulsed-pumped performances as that for the as-grown lasers. However, in order to meet requirements of good compactness and simpler fabrication for a communication system, the lasers on Si with stronger bonding strength enabling stable device fabrication for continuous-wave (CW) operation and high-speed direct modulation are needed. Therefore, here we present an ultraviolet (UV)-activated wafer bonding technology [4], where the activated surfaces show strong hydrophilicity offering a bonding strength of 0.2 MPa to bonded Si/GaAs pairs, stronger than the hydrophobically-bonded pairs usually with a bonding strength of 0.02 MPa. We further apply this bonding scheme to integrate QD lasers on Si, and demonstrate its CW-pumped performances in this study.

Compared to the well-known plasma activation, UV-based activation can also effectively modify surface properties, but with less damages to the surfaces. In this report, we bond GaAs on Si with UV and UV-ozone surface pretreatment. All substrates were chemically cleaned in an ultrasonic bath, and then the native oxides were removed by hydrofluoric acid. We then modified the substrate surfaces by UV and UV-ozone with different treating time. Figure 1 shows surface wettabilities are significantly improved by the UV-based activation. Figure 2 shows 3-D atomic force microscope images of GaAs and Si substrates before and after the activation. Surface roughnesses are eased by both of the UV and UV-ozone activation, in which the UV-ozone treatment shows smoother surfaces by its stronger cleaning ability compared to the pure UV activation. Furthermore, the experimental results also indicate the surface roughnesses increase with longer activation time, which may result from the over-activated surfaces that adsorb unintentional particles/contaminants. Tensile stress measurement for evaluating the bonding strength indicates the average bonding strength of the UV-based-activated GaAs/Si bonded pairs is around 0.2 MPa, significantly stronger than that by the hydrophobic bonding, whose strength is usually less than 0.02 MPa. This UV-based-activation bonding method was then applied to integrate QD lasers on Si. The bonded laser was formed by as-cleaved facets with a cavity length of 600 µm, and the CW-pumped lasing performances are shown in Fig. 3.

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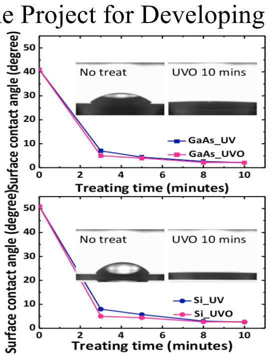

Fig. 1 GaAs and Si surface contact angles with UV and UV-ozone activation.

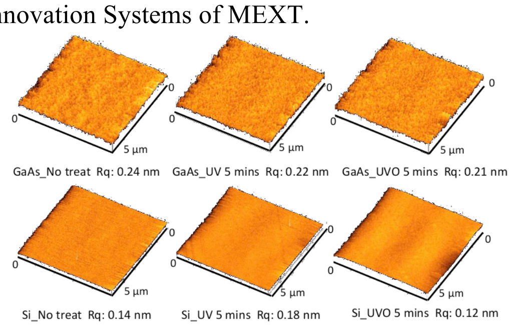

Fig. 2 AFM images of GaAs and Si surface roughness Rq before and after activation.

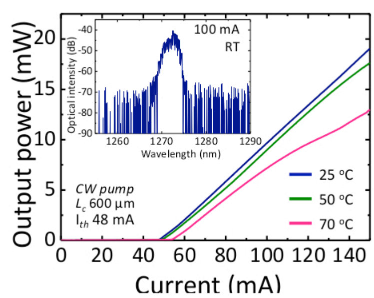

Fig. 3 Light-current curves at varied temperatures and (inset) electroluminescent spectrum of the InAs/GaAs QD lasers on Si substrate by UV-activated bonding.

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