Selective thermal oxidation of gallium arsenide——A new technology for GaAs-GaAlAs strips DH lasers and semiconductor integrated optics

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The III-V compound GaAs is one of the most important substrate materials for semiconductor lasers and integrated optics, and the new techniques for processing GaAs are very interesting.

The thermal oxidation process of GaAs was carried out in the usual diffusion furnace in an atmosphere of air at about 495 °C. We found that the relation between oxide thickness and oxidation time is linear for long oxidation periods at 495 °C. The estimated growth rate is about 340 Å/hr. We measured the x-ray diffraction spectra and infrared absorption spectra of the native thermal oxide film on GaAs. These experimental results show that the oxide film has γ-Ga_2O_3 structure which seems to be consistent with Murarka's inference.

Besides, we also carried out the experiment on GaAs-GaAlAs epitaxial wafers, we found that under the same conditions, the thermal oxidation rate on GaAlAs is much slower than that on GaAs. This is contrary to Tsang's observation.

The Cr-Au metal film was evaporated in a vacuum chamber at about 1×10^{-5} mmHg. The thickness of Cr and Au layers were about 1000 Å and 5000 Å, respectively. The Cr-Au film was then etched to form a stripe pattern by the convenient photolithography and was used as a mask for the oxidation. The width of a metal stripes was 20 μm or 8 μm. Those areas of GaAs surface which were exposed to the air are oxidized at high temperature, but, in the main, the stripe-regions covered by metal films were not. Under the metal mask, we found that some lateral oxidation occured at both edges of each stripe-region. The width of the lateral oxidation was almost the same as the thickness of the oxide film. The actual width of stripe-region was thus narrower than that of the metal mask, for example, we can obtain a stripe width of either 4 μm or 2μm from a metal mask of width 8 μm by controlling different oxidation times.

We also measured the specific contact resistance of Cr-Au layer on p-type GaAs after thermal oxidation. It was of the order of 5×10^{-5}—$8 \times 15^{-5} \Omega \cdot cm^2$. This fact means that the evaporated Cr-Au film acts not only as a mask of thermal oxidation but also as an ohmic contact on *p*-type GaAs. This is very useful for the fabrication of semiconductor lasers and other active devices in integrated optics.

We have made stripe geometry GaAs-GaAlAs DH lasers by selective thermal oxidation technique. The stripe widths are 20μm, 12μm, 4μm and 2μm, respectively. The lateral optical confinement of the stripe lasers was verified by the observation of the near-field pattern. We also obtained the optical waveguides on GaAs-GaAlAs-GaAs heterostructure by selective thermal oxidation technique. Rectangular GaAs waveguides were formed under the metal mask when the front of oxide film reached the interface between GaAs and GaAlAs epi-layers, and two end-faces of the guides were formed by the cleavage process. The guiding was inspected by a He-Ne laser lasing at 1.15 μm. The optical confinement of optical waveguide was also verified by the observation of the near-field pattern of the guide. The characteristics of this type of DH lasers and the performance of optical waveguides are being further investigated experimentally and theoretically.

GaAs 选择性热氧化——一种用于 GaAs—GaAlAs 条形激光器与半导体集成光学的新工艺

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Ⅲ—Ⅴ族化合物 GaAs 是半导体激光器与集成光学的重要衬底材料，已研制成激光器、调制器、探测器、光波导等，并已报导了用 GaAs 材料制成的单片集成光路。为了进一步发展半导体激光器和集成光学，也需要研究新的工艺技术，如近年报导的择优腐蚀技术和选择性分子束外延生长技术等。

GaAs 的热氧化是在普通的扩散炉内在空气中进行的。氧化温度为 495°C左右，氧化时间从 2 小时至 72 小时不等。氧化后的薄膜厚度用金相显微镜观察样品剖面和干涉光谱的测量测定，结果表明在 495°C下 P型、N型以及半绝缘 GaAs 的热氧化速率无明显差别，〔100〕晶向与〔110〕晶向的氧化速率也无显著差异，495°C长时间热氧化的生长速率符合线性规律，与 Murarka 的观察相一致，估算的生长速率约 340 Å/hr。利用X光衍射仪测量了热氧化膜的X光衍射谱，并用红外分光光度计测量了热氧化膜的红外吸收光谱，两个测量结果都表明热氧化膜的主要成份是氧化镓，并具有 γ-Ga_2O_3 结构，与 Murarka 的推测相一致。一般情况下高掺杂P型 GaAs (掺 Zn)的热氧化层的击穿电压大于 100 V。用反射极值法测量了热氧化膜的折射率，再由干涉光谱求得氧化膜厚度与剖面观测结果相比较。

除了对 GaAs 进行热氧化实验外，还对 GaAs–GaAlAs 外延片进行热氧化。实验发现，同样条件下，GaAlAs 外延层的热氧化速率比 GaAs 慢得多，这同 Tsang 等观测结果相反，进一步的实验尚在进行之中。

我们采用蒸发的 Cr–Au 金属膜作选择性热氧化的掩膜。Cr–Au 膜是在1×10^{-5}mmHg 下真空蒸发的。先蒸发厚约 1000 Å的 Cr 随即再蒸发厚约 5000 Å的 Au，再经普通的光刻步骤将金属膜刻蚀成宽为 20μm 或8μm 的细条，然后进行了热氧化。经热氧化以后，在金属膜以外的 GaAs 表面上形成了氧化层，同时金属膜条底部的 GaAs 两侧也发生了侧向氧化，其侧向氧化的尺寸接近于未掩蔽部位的氧化层厚度，而在金属条中央底部 GaAs 表面则并不被氧化，故实际的 GaAs 的条形宽度小于金属掩膜的宽度。测得热氧化以后 Cr–Au 金属膜与P型 GaAs的接触电阻约在 $5\times10^{-5}-8\times10^{-5}\Omega\cdot cm^2$ 的数量级范围，这证明蒸发 Cr–Au 金属膜既能起到热氧化的掩蔽膜作用，又能与P型 GaAs 形成欧姆接触，这对于制作半导体激光器及集成光学有源器件是很有用的。

将以上的选择性热氧化技术应用于 GaAs–GaAlAs DH 外延片子，在顶层P型 GaAs上用选择性热氧化形成条形，条宽约 20μ、12μ、4μ、2μ，再在外延片的N面形成 Sn–Ag 欧姆接触，而后将片子解理得到腔长约 300μm的管芯，做成具有选择性热氧化结构的条形GaAs–GaAlAs DH 激光器，从近场辐射图样看到激光器的侧向限制作用良好，进一步的分析研究正在进行之中。

在 GaAs 衬底上外延生长 GaAlAs 和 GaAs 层，然后进行选择性热氧化，使热氧化的深度达到顶层 GaAs 与下一层 AlGaAs 层的交界面处，则在金属条掩蔽的部位就形成一个矩形光波导，解理截取约 520μm 长的样品，将 $\lambda=1.15\mu m$ 的 He-Ne 光束从光波导一端镜面射入，则从另一镜面的近场图样可观察到光被限制在条形波导中。进一步的实验还在进行之中。