第 24 卷第 11 期
2003 年 11 月
半 导 体 学 报
CHINESE JOURNAL OF SEMICONDUCTORS
Vol. 24, No. 11
Nov., 2003

Fabrication of Windowed Very-Small-Aperture Laser Diodes*

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Abstract: A windowed very-small-aperture laser (VSAL) source for use in high-resolution near field optical data storage is fabricated. The windowed regions are introduced to avoid shorting the pn junction with metal coating and suppress the COD effect. It facilitates producing VSAL by simplified technology and improves the laser performance. A VSAL with 400nm small aperture is demonstrated by focused ion beam (FIB) and the output power is 0.3mW at 31mA.

Key words: very-small-aperture laser; optical near field; ridge waveguide; focused ion beam

PACC: 4255P; 4260D; 4280T

CLC number: TN248.4 **Document code**: A **Article ID**: 0253-4177(2003)11-1145-04

1 Introduction

In recent years, an ultra-high density optical memory using optical near field is attracting much interest for future Tera byte optical data storage[1]. Optical near-field aperture storage technique uses a beam of light exiting a sub-wavelength size aperture in an opaque screen to record on a media within its close proximity. With this technique, solid immersion lens (SIL) microscopy[2], scanning interferometric apertureless microscope (SIAM)[3], and near-field scanning optical microscopy (NSOM)[4] have extended the spatial resolution of optical microscopy beyond the diffraction limit. Data densities of about 45Gb/in^2 are reported[1]. However, a shortcoming of these prior art methods of near-field imaging is the relatively low attained read-out rate for the insufficiently strong light to interact with the sample. Up to now, the amount of light available from aperture near-field sources has been very small (≈50nW for 100nm to 200nm aperture) leading to the recording and readback rate of about 10kHz[5], limited primarily by shot noise.

As an active near field source, very-small-aperture laser diodes (VSAL) that have 10^4 times greater output power and 24Mb/s data rate than any previous apertured near-field sources[6]. The VSAL consists of an edge-emitting laser diode with a metal-coated facet where a small aperture is created. The technology of fabricating a submicron aperture through a metallic coating to form a VSAL is very complex. Especially on the antireflection layers additional dielectric layers should be deposited to prevent the pn junction short, because the sputtered metal layer will pervade to the facet of the electrodes. So it is difficult to fabricate this laser in mass production favorably. In this article an optimized 650nm VSAL with a window in the vicinity of emitting face is fabricated. The introducing of the window structure solved the problem of

* Project supported by National High Technology Research and Development Program of China (No. 2002AA313060)

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Received 4 May 2003, revised manuscript received 17 June 2003

short and made the following technology successfully performed. The modified antireflection films and high reflection coating are made to maximize the output power as well as the readback sensitivity.

2 Device structure

The concept of the VSAL can be applied to the laser diodes with any wavelength and design[7]. Since output transmission through a small aperture and the density of storage are highly dependent on the wavelength of light, we use lasers at $\lambda = 650$nm which are the shortest wavelength in our laboratory. To fabricate the VSAL, the conventional edge-emitting ridge waveguide lasers are used. Schematic structure of the windowed very small aperture laser with 50μm window width for 450μm cavity length is shown in Fig. 1.

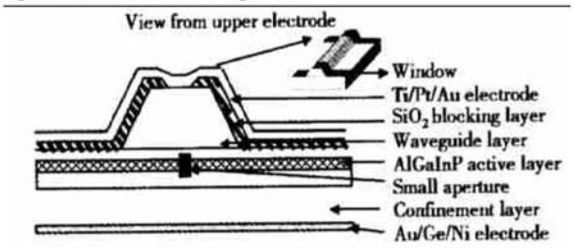

Fig. 1 Schematic diagram of the windowed very-samll-aperture laser diodes

According to the theory of optical thin film[8], it is possible to select a multilayer coating that provides a low transmittance and reflectance at radiation wavelength λ, and provides the high transmittance after a portion of the coating removed to form aperture. So the light radiation will emit from the aperture. The layer thickness of SiO_2 and Au are 212nm and 60nm, respectively. Figure 2 shows the computed transmittance and reflectance curves for SiO_2/Au multiplayer coating. Curve 1 gives the transmittance through the SiO_2 layer from the semiconductor into air. Curve 2 gives the reflectance of coating back into the semiconductor, and curve 3 gives transmittance through the SiO_2/Au coating from the semiconductor into air. For metal layer, Au, Ti, and Al all with high absorption at λ can be chosen.

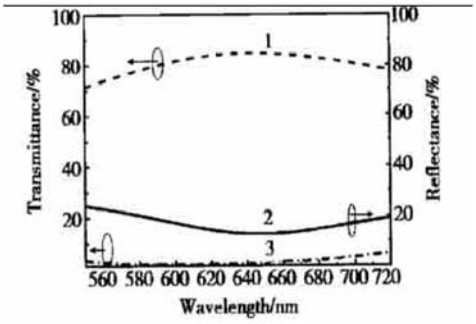

Fig. 2 Depentence of the transmittance and reflectance on wavelength

3 Device fabrication and properties

The window structure is made by lift-off the Ti/Pt/Au p-type contacts. And then is sputtered SiO_2 in the windowed region. Formation of the dielectric multilayer coating (SiO_2) on the endface of the edge-emitting semiconductor laser is accomplished by electron cyclotron resonance (ECR) chemical vapor deposition. The metal layer (Au) is deposited by magnetron sputtering.

After coating formation, the metal layer is removed from a portion of the emission face to form the aperture by focused ion beam (FIB) etching. Typically the removal is carried out such that all metal material is removed and at least some dielectric material remains in the emission face. One of the functions of the remaining dielectric is the protection of the underlying semiconductor. So the best material removal is terminated soon after completion of metal removal. The FIB machines can provide a Ga^+ beam focused to a spot size of 15nm, and can position the aperture in the center of the active region of the laser exactly. Figure 3 show the SEM image of the metallized endface of the ridge emitting lasers with aperture about 400nm × 700nm.

We have measured the light output power and the operation voltage versus drive current for the lasers. Figure 4 (a) shows the output characteristic of a normal 650nm laser diodes. The threshold current is about 24mA. The power reaches 6.1mW at

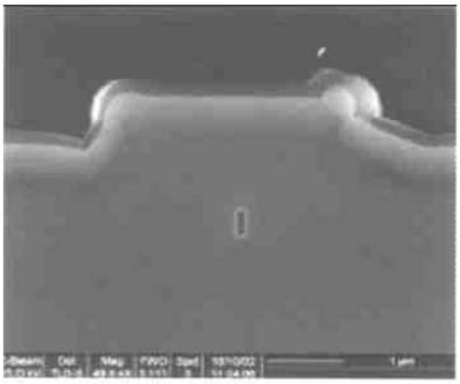

Fig. 3 SEM image of in the metallized emission face of the VSAL

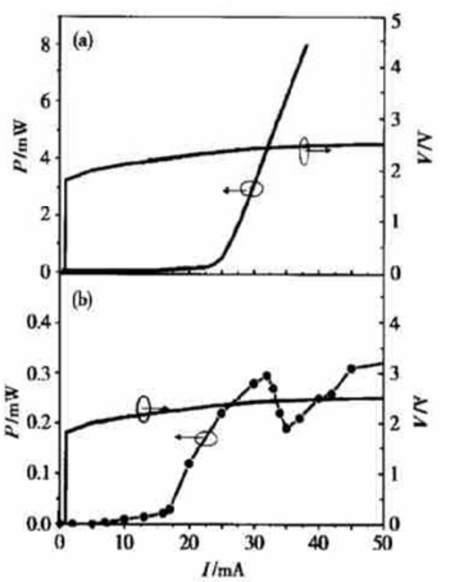

Fig. 4 Output power and operation voltage versus injection current of the laser (a) Output characteristic of the normal edge-emitting laser; (b) Output power from the VSAL

about 30mA. Figure 4 (b) shows the output characteristic after the formation of the aperture. The threshold current is lowered to about 16mA. This result is due to the optimized layer coating for a change of reflectivity of the facet. The maximum output power is about 0.3mW at 31mA. The throughput efficiency is about 5%. It is the result that much of the energy oscillates back and forth through the aperture facet in the form of electric and magnetic fields, but it do not propagate away from the aperture. The power is measured in the far field, which represents only a small fraction of the near-field power available. The size and shape of the small aperture should be optimized to improve the throughput further. There is a dip in the *P-I* curves, which we think due to the thermal effect. After that, the output begin to saturate.

4 Discussion and conclusion

The windowed very small aperture laser is successfully fabricated. The windowed region prevents the metal coating from shorting the pn junction and simultaneously provides a region without current injection in the endface, which suppress the COD effect. This window structure simplifies the technology and improves the device characteristic. For the VSAL with 400nm × 700nm slit aperture made by FIB, experiment results show the clear laser behavior and about 0.3mW output power at 31mA for the first time. Further experiment about the smaller aperture ($< \lambda/2$) and higher output power are under working in our group.

Acknowledgement We thank Doctor Xu Jun of the State Special Laboratory of Electron Optics-Electron Microscope in Peking University for supporting the FIB machines.

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窗口型极小孔激光器的研制*

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摘要: 报道了一种窗口型的用于高分辨率近场光学存储领域的极小孔激光器. 这种窗口结构的引入解决了出射端面处由于金属膜的存在而导致的 pn 结短路问题, 同时一定程度上抑制了激光器腔面处的 COD 效应. 简化了极小孔激光器的工艺, 降低了制备难度, 提高了激光器的输出特性. 通过 FIB 设备制备出了小孔大小为 400nm, 工作电流在 31mA 时的出光功率约 0.3mW 的极小孔激光器.

关键词: 极小孔激光器; 近场光学; 脊形波导; 聚焦离子束

PACC: 4255P; 4260D; 4280T

中图分类号: TN248.4 **文献标识码**: A **文章编号**: 0253-4177(2003)11-1145-04

* 国家高技术研究发展计划资助项目(No. 2002AA313060)

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2003-03-04 收到, 2003-06-17 定稿