GRATING FORMATION BY WET CHEMICAL ETCHING FOR THE FABRICATION OF ULTRA-LOW THRESHOLD LASER STRUCTURES

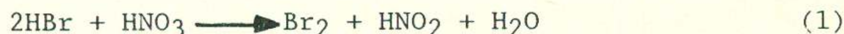
S.Pellegrino *, L.Boschis **, P.Dastè ***

Abstract

$HBr/HNO_3/H_2O$ etching solutions have been extensively investigated regarding their properties for submicrometer patterning of III-V compound semiconductors.
The chemical behaviour of the solution itself was clarified and the etching properties and mechanism were investigated.
High quality gratings for Dynamic Single Mode (DSM) Laser were fabricated and extremely pure emission spectra have been recorded.

Experimental

DSM lasers [Y.Suematsu et al., J. Lightwave Technology, Vol.LT-1 (1983) 161] based on the InGaAsP/InP system are very important devices for optical fiber communication.
A key technological step in their fabrication, lies in the formation of very fine structures on the surface of the InGaAsP layer.
Few etching solutions are available to perform such surface corrugation; we have investigated an unexplored one, the $HBr/HNO_3/H_2O$ system.
In an earlier part of this work we have derived the kinetic equation of Br_2 formation according to:



$$2HBr + HNO_3 \longrightarrow Br_2 + HNO_2 + H_2O \qquad (1)$$

The overall reaction (1) has been decomposed in several partial reaction steps and an additional oxygen effect was predicted and experimented as an important technological parameter.
In a second time etching experiments were carried out on largely spaced grid patterns for the determination of the etching rate and crystallographic dependence on InP, InGaAsP ($\lambda g = 1.3 \mu m$) epilayers and on GaAs, (100) oriented.

* **Teletttra SpA** - Via Trento, 30, 20059 Vimercate (MI), Italy
** **CSELT** - Via G.Reiss Romoli, 274, 10148 Torino, Italy
*** **LEP** - Avenue Descartes, 3 - BP15-94451 Limeil-Brevannes Cedex, France

A tight relation was found between rate and reaction products-derivates (Br_2, Br^-, Br_3^-) showing that the etching mechanism is considerably more complex than those previously proposed in litterature.
The etchant is easly controlled to obtain very low etching rates (min. 20Å min^{-1}) and also shows strong unselectivity, suitable for multi-structure etching.
First (2000 Å pitch, 800 Å deep) and second (4000 Å pitch, 1500 Å deep) order gratings were realized.
Fig.1 and 2 also show a broad capability of tailoring the shape, and this turns to be a very powerful way to control the grating's coupling coefficient.
A new DSM Laser structure, grown by LPE and named "Distributed Reflector" has been realized with a minimum threshold current of 25 mA (Fig.3).
Quantum Wires (Fig.4) (2000 Å pitch, 400 Å wide Wires) were fabricated on MOCVD grown Quantum Well structures.
Laser operation in Wire Laser devices is reported at 77 K.
Finally a Quantum Box pattern (Fig.5) was realized with high uniformity using double holographic exposure.
In conclusion, low threshold DSM Laser structures have been realized and furthermore it was proved how the etching system under study is suitable for the fabrication of a new class of high performance devices [M.Asada et al., IEEE J.Quantum Electron, QE-22 (1986) 1915] (low threshold, high bandwidth, narrow linewidth) exploiting completely the Quantum effects (3-D or Quantum Box lasers).

Aknowledgements

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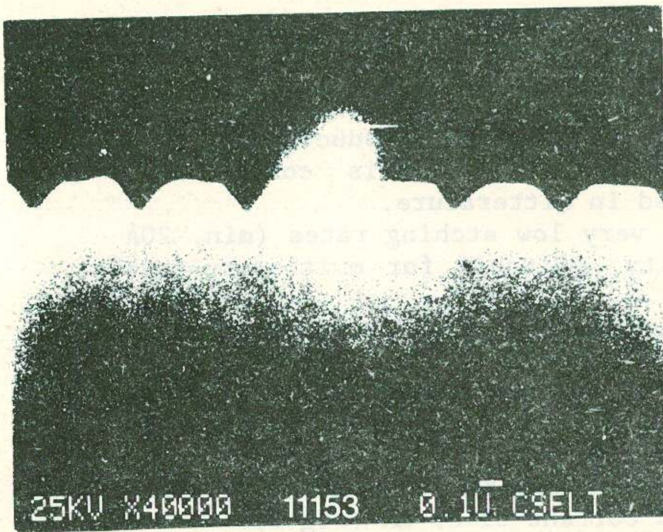


Fig.1

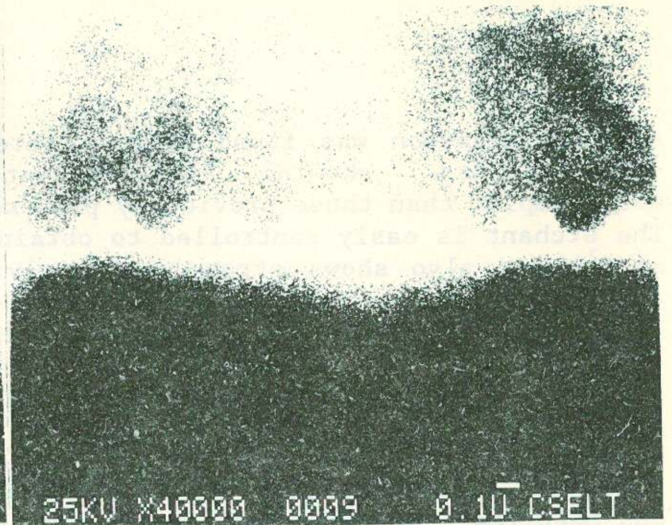


Fig.2

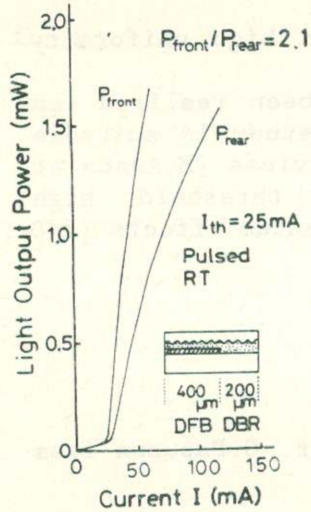
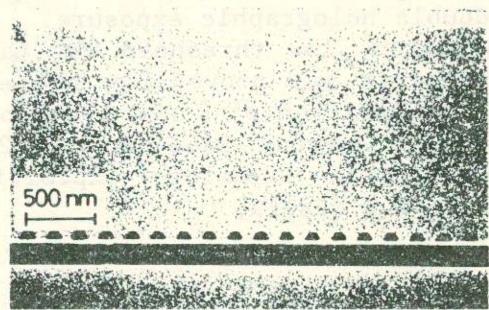


Fig.3



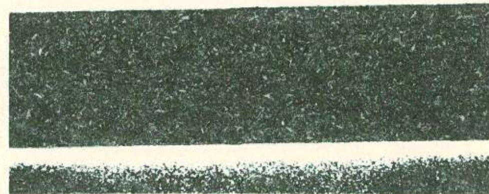


Fig.4

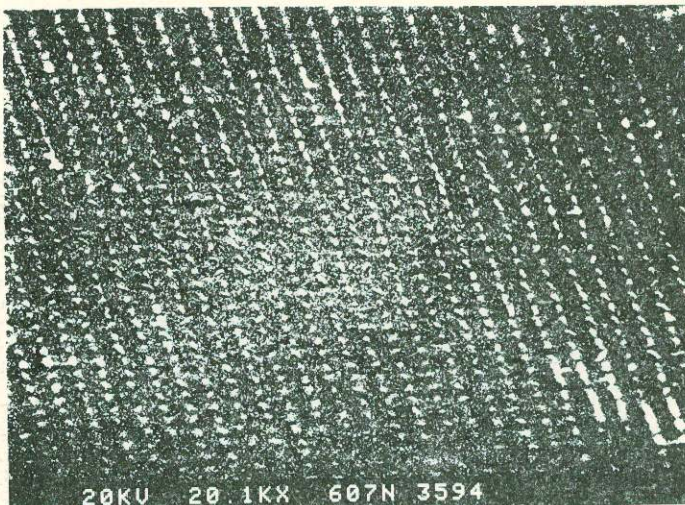


Fig.5