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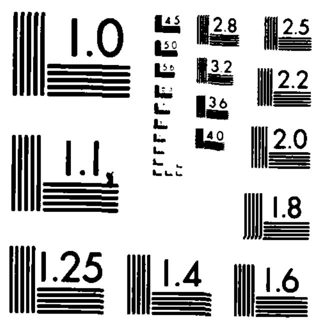

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Laser Chemical Etching of Vias in GaAs

A. W. TUCKER and M. BIRNBAUM
Electronics Research Laboratory
Laboratory Operations
The Aerospace Corporation
El Segundo, Calif. 90245

15 June 1983

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This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published for the exchange and stimulation of ideas.

Russell R. Herndon, 2nd Lt, USAF
Project Officer

Norman W. Lee, Jr., Colonel, USAF
Commander, Det 1, AFSTC

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Rapid drilling of vias in thick wafers (381 μm) of GaAs has been achieved by a laser assisted etching process. The technique utilized a CW visible argon ion laser and an etchant gas of low pressure Cl_2. Data on the dependence of the etch rate on the laser power, wavelength and Cl_2 gas pressure are presented.

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PREFACE

The authors thank Drs. John Hurrell and Roger Newman for their support and valuable discussions.

CONTENTS

FIGURES

Introduction

We report the rapid drilling of vias in thick wafers of GaAs by means of a laser assisted chemical etching technique which utilizes a visible CW argon ion laser and a gas-phase etchant (Cl_2) at low pressure. The controlled etching of elemental and compound semiconductors is important in fabricating many microelectronic structures including integrated optical elements and microwave devices[1-3]. The most recent publication[1] describes a process for GaAs via hole drilling which maintains the wafer in an aqueous solution during the laser irradiation. Only thin wafers (~ 5 mils) were drilled through but at a rate of 30 μm/min which is less than 1/50 that achieved with our process. A process utilizing CH_3Br or CF_3I for photochemical etching of GaAs and InP is described in ref. 2. However, ultraviolet light was required and was obtained by doubling the argon ion 514.5 nm output to produce a 4 mW beam at 257.2 nm. With such low UV intensities, the GaAs etch rate observed was about 10^{-3} μm/s or about 10^{-4} of the rate achieved with our method. Our results demonstrate high etch rates with 514.5 nm laser output thus circumventing the difficulties encountered in the prior work.[1,2]

Experimental Arrangement

The experimental arrangement is shown in Fig. 1. The reaction chamber was a 1.2 cm path length stainless steel gas cell with the GaAs wafer mounted 0.28 cm from the fused silica entrance window. An argon ion laser provided the energy required to photolyze the Cl_2 gas and to heat a reaction zone on the sample. The Pockel's cell and glan polarizer control the laser output power without varying the current through the laser tube. Thus, the focal spot diameter was constant, independent of the beam intensity. In order to obtain a focal beam diameter of 13 μm ($1/e^2$ intensity points), the laser beam was first expanded by 3x and then focused onto the wafer with a 2.5 cm focal length glass lens.

Accurate focusing was essential to optimize the etching rate. A simple and reproducible method consisted in drilling a small via hole and then adjusting the focal position for maximum light transmission through the via hole.

Prior to mounting the wafers in the cell, the wafers were cleaned in an ultrasonic shaker with successive three minute baths of trichloroethylene, acetone, and isopropyl alcohol. The GaAs wafers were then stripped of oxide using a 1:1 solution of HCl in deionized water for 30 seconds followed by a 3 minute rinse in running deionized water. After drying the wafer with N_2 gas, it was immediately mounted in the cell which was evacuated to 10^{-6} Torr, and remained on the pumped vacuum station for 12 hours before introduction of 1-5 Torr of Cl_2. Not shown on Fig. 1 is the ballast tube connected to the cell

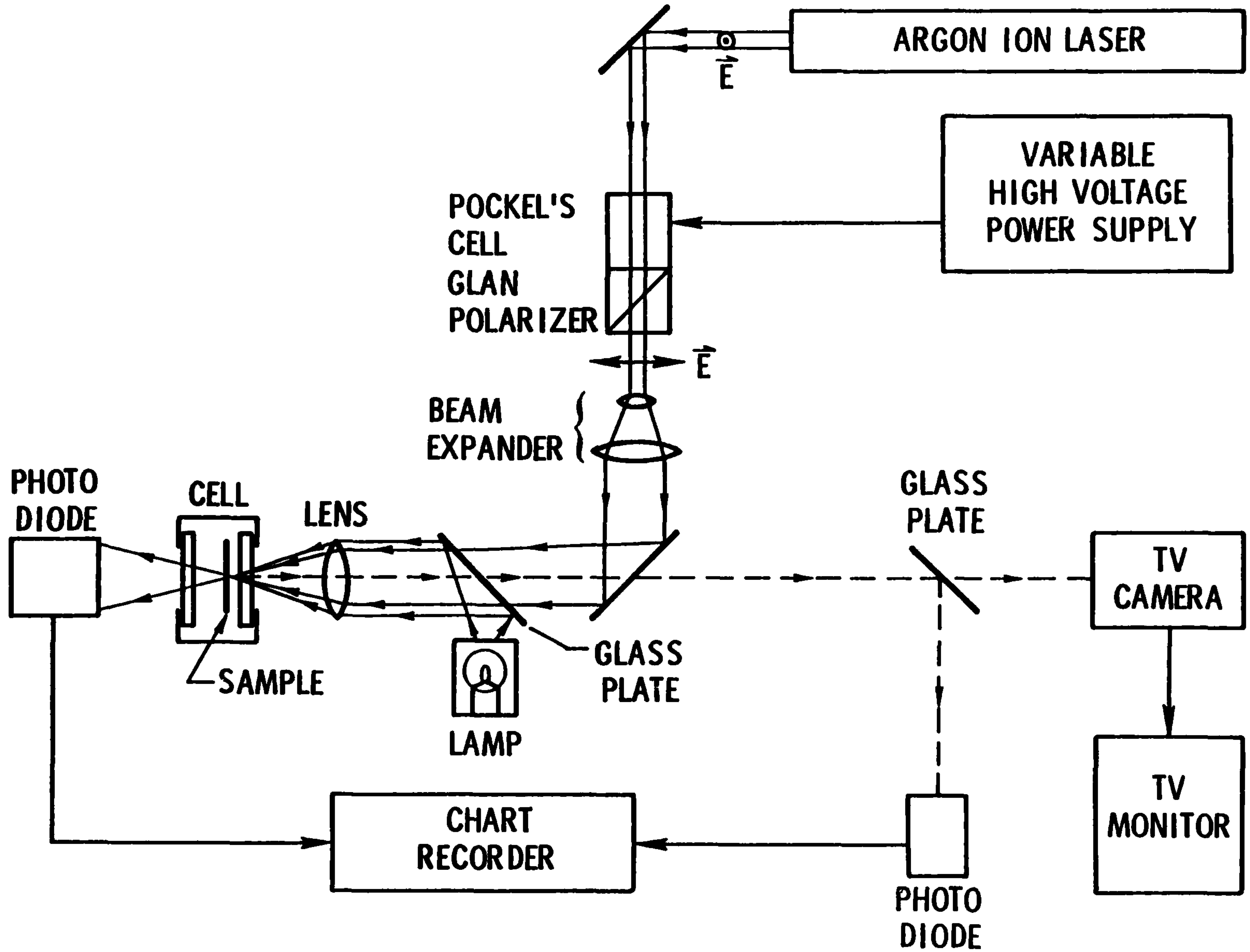


Fig. 1. Block diagram of experimental arrangement.

which provided an adequate supply of Cl_2 at a constant pressure. Pressures of Cl_2 of 10 Torr and higher produced a noticeable etching even in the absence of the laser beam.

The focused laser beam heats the GaAs surface and dissociates the Cl_2 gas in the immediate neighborhood of the focal spot for a rapid reaction of the Cl atoms with the GaAs. The final reaction products $AsCl_3$ (m.p. -18°C) and $GaCl_3$ (m.p. 78°C) are vaporized under the experimental conditions leaving essentially no residue on the sample. However, in many cases, a barely noticeable oily film (probably $AsCl_3$) was observed on the inside of the entrance cell window in the path of the laser beam. The presence of this film greatly increased the etching time and much care and effort was expended in eliminating this film. Experiments were carried out to assess the maximum number of vias that could be drilled at constant power without reduction in the etching rate. The window was cleaned after two or three via holes were drilled.

Results

The etching rate as a function of laser power is shown in Fig. 2 for 1 Torr and 5 Torr fills of the cell. A significant feature of the data is the saturation of the etch rate at about 2.7 W. This can be readily understood by noting that the parameter most effective in controlling the reaction rate is the surface temperature of GaAs which remains fixed once the melting temperature (1237°C) is reached. The rates of the etching process were similar to those described in ref. 2 which implies an Arrhenius type behavior with a characteristic activation energy.

In Fig. 3, data on the wavelength dependence of the etch rate (E) is shown. The saturation of the etch rate at the higher power levels is again evident. The ratio of the maximum etch rates E_{488}/E_{514} is 1.4 at the melting temperature of GaAs. These wavelength dependent rate differences are less than those reported in experiments on laser assisted chemical etching of Si with Cl_2.[3] In ref. 3, rate differences of 20 to 1 over the wavelength range of 457.9 to 514.5 nm was reported, which was attributed to the wavelength dependence of the Cl_2 absorption in the dissociative continuum. Experiments are in progress to determine the absorption coefficients of Cl_2 at 488.0 and 514.5 nm in the 1 to 5 Torr pressure range.

The etch rates shown in Figs. 2 and 3 were determined by measuring the time taken to etch through the 15 mil (381 μm) wafer. Two photo diodes and a chart recorder (Fig. 1) were used to determine the etch rate. When the sample was exposed to the laser beam, the reflectivity of the wafer decreased and indicated the start time of the etching. A second diode placed in back of the wafer detected light exiting from the via hole the instant the hole was etched through. The time interval between start and finish was determined

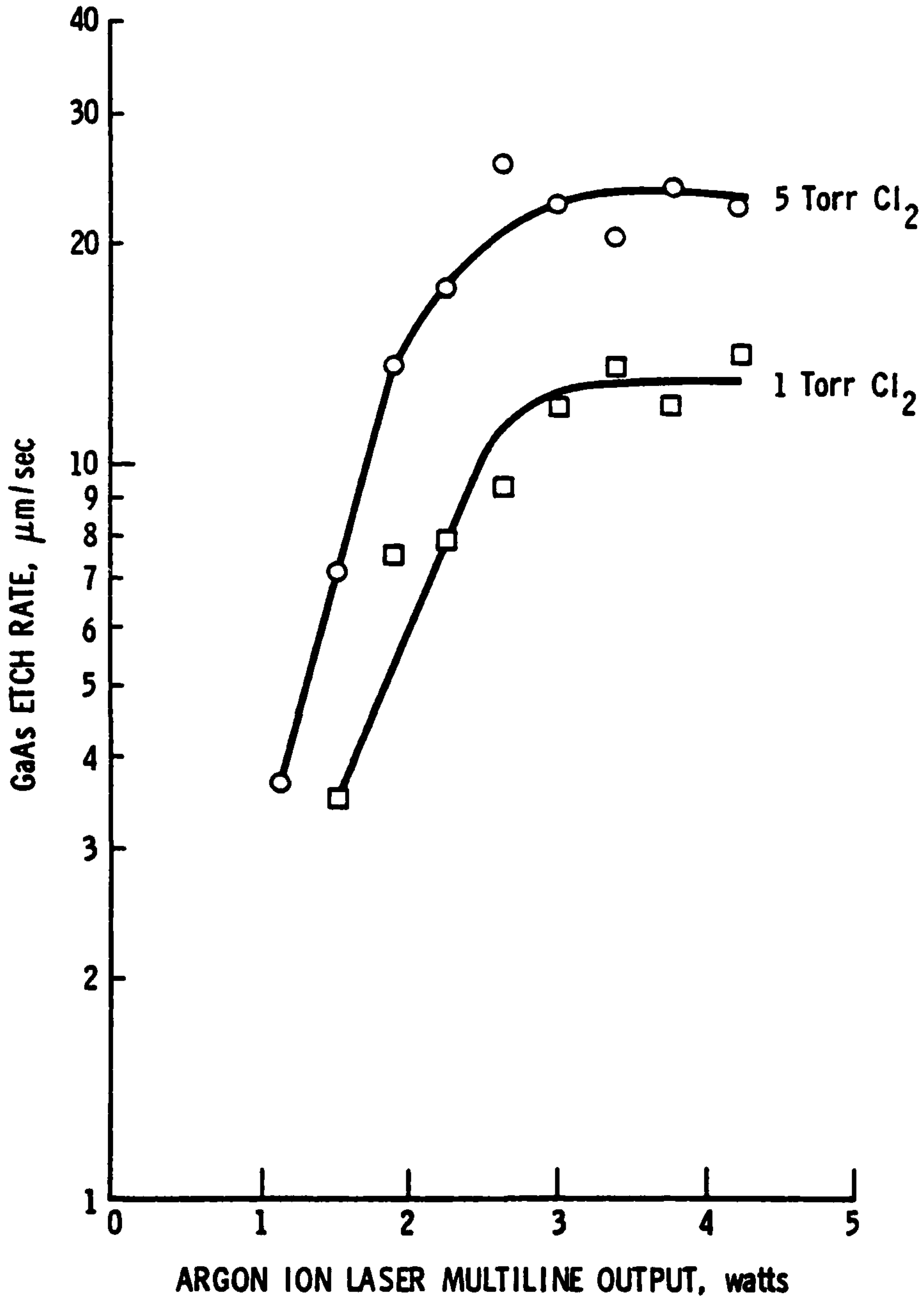


Fig. 2. GaAs etch rate vs laser intensity for cell fills of 1 and 5 Torr Cl_2.

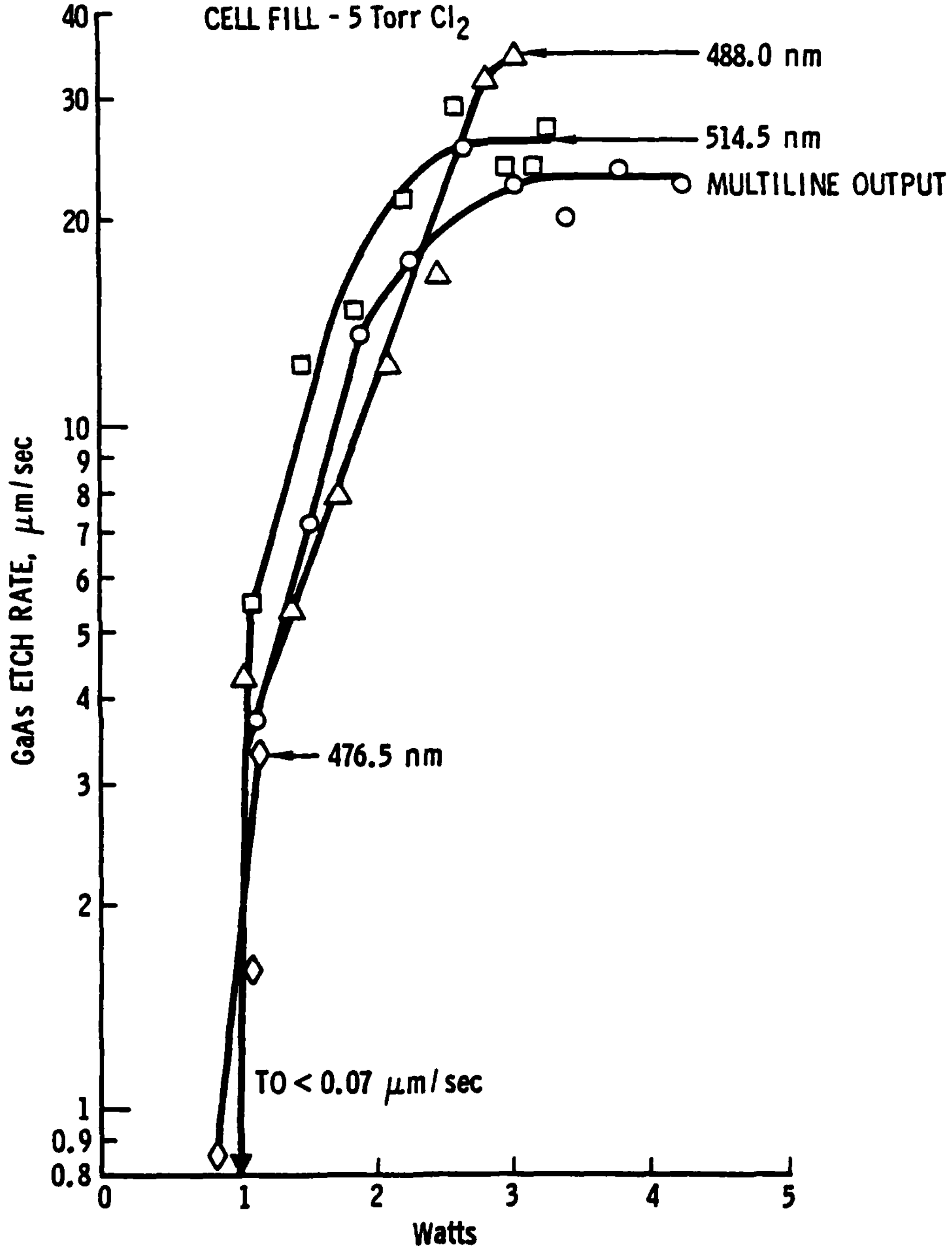


Fig. 3 GaAs etch rate vs laser intensity for cell fill of 5 Torr Cl_2 for single line 488.0, 514.5, 476.5 nm and mutiline argon ion Ar^+ laser irradiation.

from the two signals on the chart recorder and provided the etch rates plotted in Figs. 2 and 3. The highest etch rates (33 μm/sec) were obtained at a cell fill of 5 Torr and 3.3 W at 488 nm producing a via hole in 15 mil GaAs in about 12 sec.

Data on the multiline etching rates and via hole dimensions are shown in Fig. 4. Width and height dimensions are shown for both the entrance and exit holes and are indicative that the holes are irregular in shape. At the slowest etching rates, the exit and entrance hole diameters of about 20 μm and 70 μm, respectively, are observed implying an aspect ratio of about 3.5. Typical via holes at 2.5 w at 5 Torr Cl_2 fill are shown in Figures 5a and 5b. Observations of the crater diameters (melt zones) on the GaAs wafer with a fill of 3 atm of He were in rough agreement with the observed hole diameters.

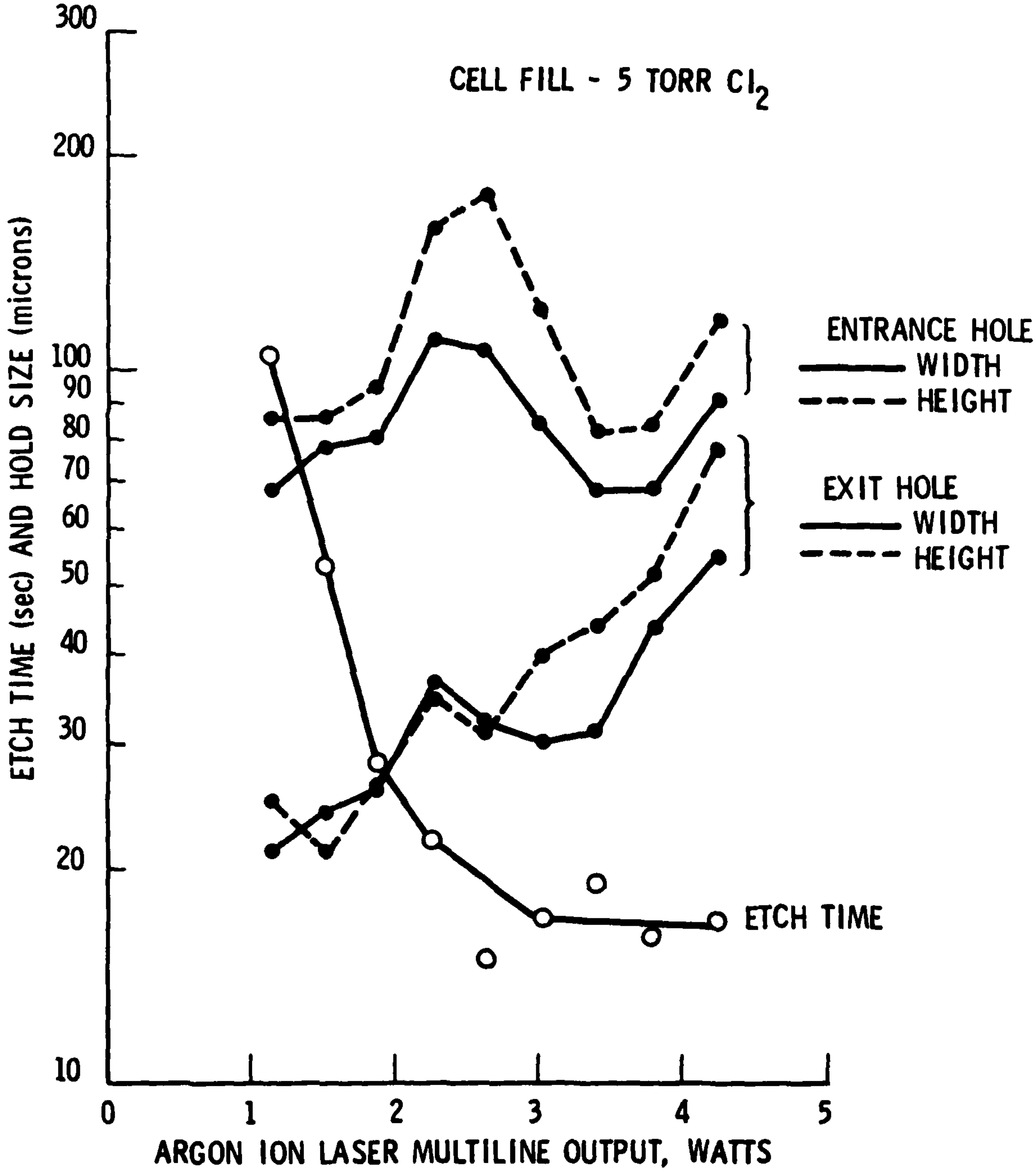
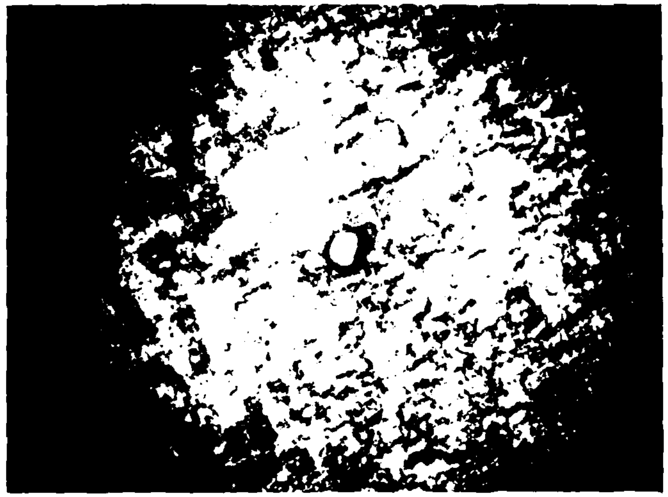


Fig. 4. GaAs etch time and via hole dimensions vs multiline Ar^+ laser irradiation.

5a.



5b.

Fig. 5. (a) Entrance hole diameter (~ 80 μm), 2.5 W at 514.5 with 5 Torr Cl_2. (b) Exit hole diameter (~ 20 μm), 2.5 W at 514.5 nm with 5 Torr Cl_2.

Conclusions

Our results show that the gas phase laser assisted etching process can provide a rapid and convenient technique for drilling vias in thick GaAs wafers. It appears likely that this method will also be useful in fabricating gratings and other μm size structures required in microelectronic applications.

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