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Deep Trench Etching in Silicon With Fluorine Containing Plasmas

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Abstract

Single crystal silicon was etched with mixtures of SF_6, $CBrF_3$, Ar and O_2, using different electrode materials to obtain deep trenches. The etch rates, both vertically and horizontally increase when the relative flow of SF_6 increases. When using aluminium or stainless steel electrodes, the amount of SF_6 has to be limited to 10% of the total flow of fluorine containing gases to obtain wall profiles with an angle of over 80°. However, in all these cases considerable surface roughness is observed. A solution to this problem is the use of a graphite electrode, which permits the use of SF_6 as the sole halogen containing gas to obtain vertical walls. Depending on the Ar addition, processes with good anisotropy and without surface roughness can be obtained.

1. Introduction

Etching of trenches in silicon has become an important technology. In the first place trenches were etched in silicon for applications in the integrated circuits fabrication for isolation of transistors in bipolar [1] and CMOS [2] technologies. Trenches are also the basic structure for fabrication of capacitors in DRAM memories [3]. These trenches have depths of the order of a few micrometers.

For micromachining purposes, the vertical dimension of the trenches is of the order of several tens of micrometers. In general, the horizontal dimensions are also much larger. However, much of the other requirements are approximately the same: vertical walls (over 80°), good uniformity, no surface roughness at the bottom of the trench, good selectivity towards the mask, possibility to remove the mask layer (and possibly other layers) afterwards, good reproducibility.

Etching of trenches for IC fabrication is well documented [1–3], etching of deep trenches for micromachining has also received a lot of attention in the literature the last years [4–7]. Most successful etch processes in silicon have been developed with chlorine containing gases [6,7] and most often not in a simple RIE system, but in systems with increased pumping capacity [4], or in an ECR system [6] and/or using cryogenic cooling [5,7].

This paper describes the processes used to develop an etching process of deep trenches in silicon using fluorine based gases, in a simple RIE system, using only a water cooled electrode and a pumping stack of a mechanical pump combined with a roots blower. First tests on trenches of a few micrometer

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deep had given acceptable results [8], therefore these processes were used as the basis for a new investigation.

2. Experimental

The home built etch reactor is of the RIE type, with power generated at 13.56 MHz [8]. Samples were p type silicon (100), the resistivity was approximately 9 Ω cm, the total area was approximately 20 mm × 20 mm. The mask used was evaporated aluminium, which was patterned by wet etching of the aluminium through a photoresist layer. Approximately 10% of the wafer was covered by the aluminium mask.

Etch rates were measured by a Dektak 3030 step height meter, profiles were examined by a SEM 515 system of Philips.

We define the anisotropy, A, of the etch process as: $A = 1 - (r_{lat}/r_{ver})$ with r_{lat} the horizontal etch rate and r_{ver} the vertical etch rate.

3. Results and discussions

The influences of the used gases and the electrode material have been studied. Four different types of electrodes were used: silicon, aluminium, stainless steel and graphite. The following gases were used with different flows: $CBrF_3$, SF_6, O_2, and Ar. Total flow was always 25 sccm. SF_6 and Ar flows varied between 0% and 30% of the total flow. For these tests, pressure was held constant at 50 mTorr, while power was in general 100 W, for a few experiments increased up to 150 W.

The use of a silicon electrode was tested first. Its advantage is that there will be no micromasking by redeposited material from the electrode. Also the loading effect and uniformity will be better. On the other hand, the whole electrode is consuming the free fluorine and bromine. This causes the etch rate to become very low, too low even for this kind of etching: typically 60 nm/min for a process with pure $CBrF_3$. Therefore, this electrode material was not used anymore in further tests.

The second set of tests was performed with an aluminium electrode. First tests were performed with pure $CBrF_3$. $CBrF_3$ is a gas which easily forms polymers. This has a beneficial effect in the way that it protects the sidewalls of the trenches, in this way increasing the anisotropy. Trenches of 1 μm deep were successfully etched with a 100% $CBrF_3$ plasma [8].

On the other hand, if the polymer grows too thick, it can impede even vertical etching. This phenomenon occurred after etching of approximately 3 μm of silicon. Increasing the power did not influence this result very much. On the other hand, no micromasking from redeposited aluminium was observed in the SEM.

A way to decrease the polymer formation is to increase the F/C ratio [9]. Addition of SF_6 will decrease the polymer formation and increase the etch rate. On the other hand, if too much SF_6 is added, horizontal etching occurs. A mixture of 90% $CBrF_3$ and 10% SF_6 etches with a constant etch rate of 310 nm/min for at least 45 min. A very slight undercut was observed immediately under the aluminium mask, but afterwards a slope of approximately 70° was observed. The bottom of the trench was slightly bowed, but no roughness was observed in the SEM.

The slope can be explained by an increasing deposition of carbon on the wall of the reactor, masking it in this way and impeding a vertical etching. An increase of ion bombardment is expected to improve the result.

Tests were performed with a mixture of 80% $CBrF_3$, 10% SF_6 and 10% Ar. The vertical etch rate increases up to 420 nm/min and remains constant for at least 30 min. The walls are more vertical, but they remain slightly bowed and in the upper 3 μm, some undercut occurs. In general, spaces of less than 10 μm width had a smooth bottom surface. Larger spaces however showed a much rougher surface.

Fig. 1 shows the profile of a 10 μm wide trench, etched for 30 min. The undercut in the upper 3 μm can be explained by a catalytic reaction at the surface of the aluminium mask which increases the concentration of atomic fluorine [10]. This leads to a local increase of the F/C ratio, thereby decreasing the polymer protection of the sidewall.

A series of tests was performed with a stainless steel electrode. First tests were performed with the 80% $CBrF_3$, 10% SF_6 and 10% Ar mixture, again at 50 mTorr and with 100 W rf power. The etch rate

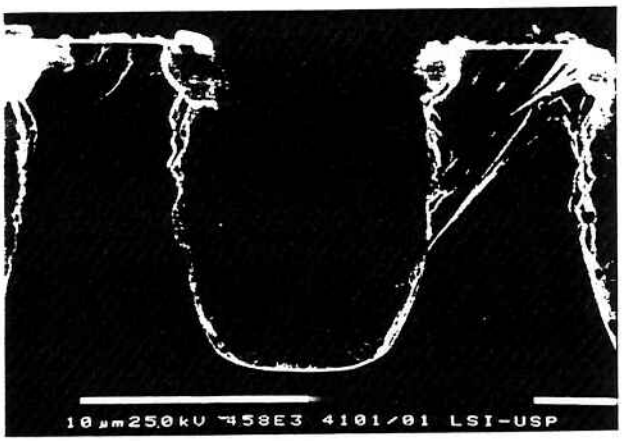

Fig. 1. Profile of a 10 μm wide trench with the following etch process: 80% $CBrF_3$ flow, 10% SF_6 flow, 10% Ar flow, 100 W power, aluminium electrode, etch time 30 min.

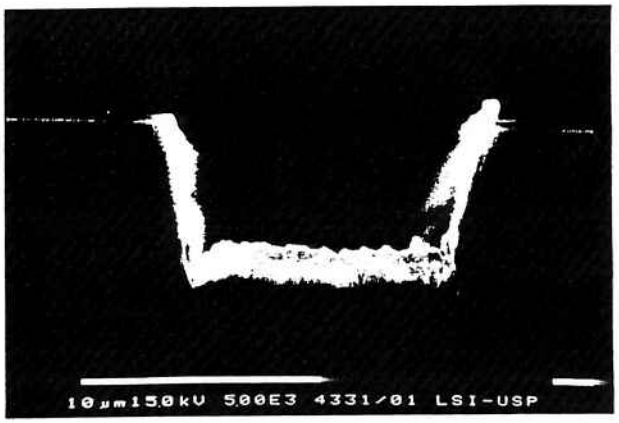

Fig. 2. Profile of a 10 μm wide trench, with the following etch process: 90% $CBrF_3$ flow, 10% SF_6 flow, 100 W power, stainless steel electrode, etch time 30 min. 100 nm of PECVD oxide was deposited to enhance the contrast.

decreased to 220 nm/min, but the walls were vertical, without any bow or undercutting. Unfortunately, the bottom of the trench was quite rough: peaks up to 10% of the total etch depths were found.

The reduction of etch rate, compared to the aluminium electrode, can be explained by the fact that on a stainless steel surface, the catalytic reaction which increases the fluorine atom concentration at the aluminium surface, does not occur (or at least in a much lesser degree) [10]. With a stainless steel electrode, less atomic fluorine is generated, thereby decreasing the silicon etch rate and the F/C ratio. More polymer will be formed to obtain a vertical wall profile.

To increase the etch rate, the power was increased up to 150 W; in an effort to decrease the roughness, the mixture was reduced to 90% $CBrF_3$ and 10% SF_6. This change resulted in an etch rate increase of approximately 50%. The walls remain vertical, but once again the bottom of the trench remains rough. Immersion in a 80%H_2SO_4–20%H_2O_2 mixture removes some of the surface roughness, indicating it consists partially of a polymer, but even so, silicon peaks up to 10% of the trench depth remain. Fig. 2 shows a profile of a 10 μm wide trench, etched for 30 min.

More tests were done in which the relative flow of SF_6 was varied, while retaining 10% of Ar flow. The higher the SF_6 flow, the higher the vertical etch rate, but also the more undercutting occurred. Surface roughness seems to be inversely proportional to undercutting, i.e. when large undercutting occurs, no surface roughness is observed, but when the walls are vertical, the bottom surface of the trench is much rougher.

Some tests were performed adding oxygen in place of Ar, but this resulted in considerable undercutting; the oxygen (even when only 10% of the total flow) removed the polymer formed on the walls, allowing horizontal etching.

A new series of tests has been performed with a graphite electrode using only SF_6 + Ar. The carbon necessary to form the sidewall comes from the graphite.

The influence of Ar addition on etch rate and anisotropy is shown in Fig. 3. Ar addition decreases the etch rate, but maximum anisotropy can be found at an Ar flow of approximately 50% of total flow. For this process, the silicon etch rate is 1.2 μm/min and the anisotropy is 0.75. The surface roughness

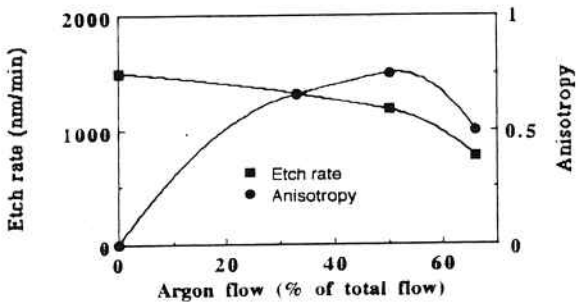

Fig. 3. Silicon etch rate and anisotropy as a function of Ar content in a SF_6–Ar plasma with a graphite electrode.

remains very good for all these processes; it can not be detected, nor by SEM, neither by measurement of the bottom layer with a step height meter. One can conclude that if there are silicon peaks at the bottom surface of the trench, their height is less than 5 nm, on a total etch depth of over 10 μm.

When adding Ar to SF_6, several phenomena occur. In the first place, the fluorine containing molecule density decreases for these processes, causing a reduction in etch rate. At the same time, the DC bias voltage becomes more negative and ion bombardment becomes more intense. More carbon atoms will be sputtered away from the graphite electrode. These atoms will deposit and can protect side walls from horizontal etching. With pure SF_6, little carbon is sputtered away from the electrode and a pure isotropic etch process is the result. Increasing the Ar flow increases the ion bombardment and thereby the anisotropy. A reduction of anisotropy was observed for all processes with more than 50% Ar. This must be caused by another, for the moment unknown, mechanism.

4. Conclusions

Etching of deep trenches in single crystal silicon was investigated. It was shown that vertical walls can be obtained using $CBrF_3$ as an etch gas, with additions of SF_6 and Ar. Surface roughness was observed when the sidewalls are vertical and without undercutting.

Processes with a graphite electrode and no carbon containing gas result in steep wall profiles with no surface roughness.

Depending on the requirements of the resulting structure, one of these processes can be used to etch deep trenches.

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References

[1] L.C. Hsia, J. Electrochem. Soc. 138 (1991) 239.
[2] H.P. Vyas et al., IEEE Trans. Electron Devices ED-32 (1985) 926.
[3] Y. Miyai et al., J. Electrochem. Soc. 135 (1988) 150.
[4] E. Gogolides, S. Grigoropoulos and A.G. Nassiopoulos, Microelectron. Eng. 27 (1995) 449.
[5] J.W. Bartha, J. Greschner, M. Puech and P. Maquin, Microelectron. Eng. 27 (1995) 453.
[6] M.J. Zdeblick et al., Sens. Actuators 15 (1988) 427.
[7] W.H. Juan and S.W. Pang, in: Proc. Transducers '95 – Eurosensors IX, pp. 560–563.
[8] R.K. Yamamoto and H.S. Maciel, in: Proc. VIIth Congr. Sociedade Brasileira de Microeletrônica, São Paulo, 1992, pp. 259–269.
[9] B. Chapman, Glow Discharge Processes (Wiley, New York, 1980).
[10] T.H. Fedynyshyn, G.W. Grynkewich, B.A. Chen and T.P. Ma, J. Electrochem. Soc. 136 (1989) 1799.

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BT/PEE/9503 - Utilização de Redes Neurais Artificiais para Detecção e Identificação de Falhas em Circuitos - MÁRCIO YUKIO TERUYA, ROBERTO AMILTON BERNARDES SÓRIA, EUVALDO CABRAL JR.

BT/PEE/9504 - Uso de Redes Neurais Artiificiais no Reconhecimento de Locutores no Domínio Temporal - BENEDITO JOSÉ BARRETO FONSECA JÚNIOR, EUVALDO CABRAL JÚNIOR

BT/PEE/9505 - Projeto de Filtros Passivos e Ativos em Técnicas de Circuitos Integrados de Microondas - DAVID VIVEIROS JÚNIOR, DENISE CONSONNI

BT/PEE/9506 - Uma Análise de *Clustering* para as Frases de Projeto NESPER - RONALDO OLIVEIRA MESSINA, EUVALDO F. CABRAL JR.

BT/PEE/9507 - Controle com Estrutura Variável e Modos Deslizantes - Um Estudo para Aplicação em Controle Carga-frequência da Geração - JOSE PAULO F. GARCIA, JOCELYN FREITAS BENNATON

BT/PEE/9508 - Recuperação das Margens de Ganho e de Fase para Sistemas de Fase Não Mínima por Realimentação da Saída - MARCO H. TERRA, VITOR M. P. LEITE

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T/PEE/9510 - Sistema de Partículas Uma Poderosa Técnica de Animação em Computação Gráfica - RENATO CURTO RODRIGUES, JOÃO ANTÔNIO ZUFFO

BT/PEE/9511- Efeito de Ruídos em Sinais de Voz Visualizados em Trajetórias Neurais de Kohonen - CELSO S. KURASHIMA, EUVALDO F. CABRAL JR.

BT/PEE/9601 - "Um Reconhecedor de Sinais Sonoros Utilizando LVQ" - ALEXANDRE TORNICE, EUVALDO CABRAL JR.

BT/PEE/9602 - "Coleção *Artificial Neural Networks*: Uma Visão Geral dos Sistemas Neurais Artificais de Stephen Grossberg" - CHIU HSIUNG HUANG

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BT/PEE/9604 - Aspectos em Tradução de Linguagens Naturais Através de Redes Neurais Artificiais - CARLOS EDUARDO DANTAS DE MENEZES, EUVALDO F. CABRAL JR.

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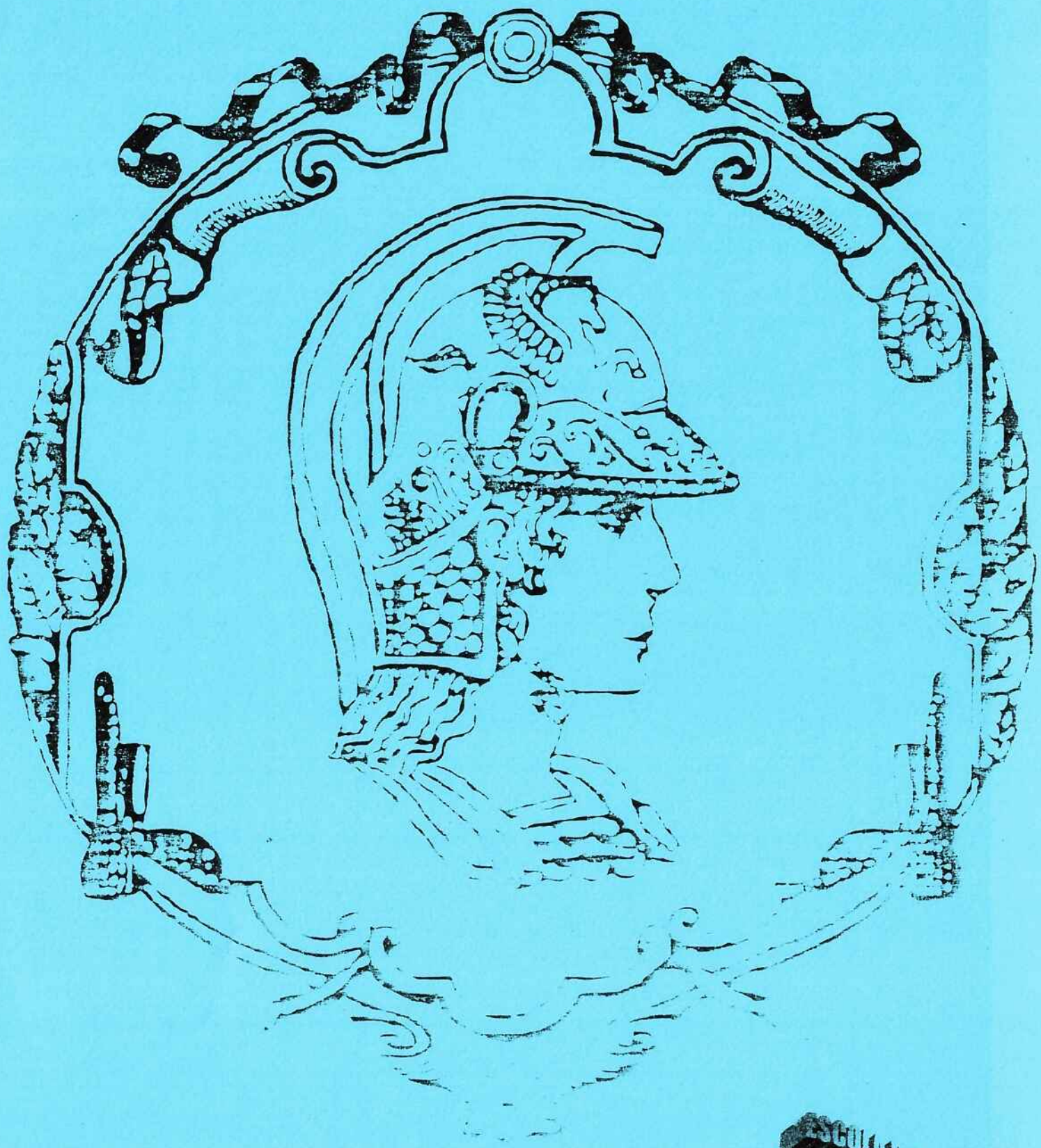

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