New Deep Reactive Ion Etching process for through wafer via manufacturing

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Introduction

• Metalized through wafer connections - more and more important for different applications, mainly for micro-electro-mechanical structures (MEMS) manufacturing, like multi-wafer devices or 0-level encapsulation.

• Manufacturing involve two problems: through wafer via holes manufacturing and holes filling with a conductive layer.

Via holes manufacturing methods: anisotropic wet etching, powder blasting, laser ablation, laser melt cutting or deep reactive ion etching (DRIE); geometries with aspect ratio between 1 and 20.

From all fabrication techniques DRIE shows its superiority in respect of pattern transfer and minimum dimensions – aspect ratio even bigger than 20 it is possible to achieve, while the accuracy will be provided by the photolithography.

Via holes filling:

- copper – critical advantage of being able to fill high-aspect ratio holes by electroplating

- polysilicon - heavily doped, conformal deposition by low-pressure chemical vapor deposition (LPCVD)

(For some specific applications, like RFMEMS, these two methods cannot be used due to the technology implementation problem or large resistivity.)

The alternative is to use gold as conductive layer - poor adhesion to dielectrics and the need for barrier and/or adhesion layers.

DRIE basic processes:

- Anisotropic etching - the most used process type due to the capability to achieve high aspect ratio geometries, like deep cavities with vertical walls; Bosch and cryogenic cooling of the wafer process types
- Isotropic etching - suspended components in complex devices by isotropic etching of the sacrificial layer

Transition from one process type to another can be achieved by changing the plasma composition and can be performed during the same processing step. By mixing these two basic processes (anisotropic and isotropic) it is possible to obtain new shapes, that cannot be obtained using only one of two techniques.

Using the possibility of mixing anisotropic and isotropic etching of silicon substrate during the same DRIE processing step, a new technological flow was developed in order to achieve a new through wafer via holes shape, V-like.

Our aim in this investigation was to prove that is possible to use a variable isotropy process for manufacturing through wafer via holes with a very good control of the walls angle.

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• 200µm thick, high resistivity, <100> oriented silicon wafers
•Alcatel AMS200 ICP system

DRIE processing steps:
• anisotropic etching, Bosch process type (alternatively etching and passivation steps are used)
• isotropic etching – basically, passivation agent is removed from the plasma.
• plasma oxygen - before isotropic etching, to remove the passivation from the walls

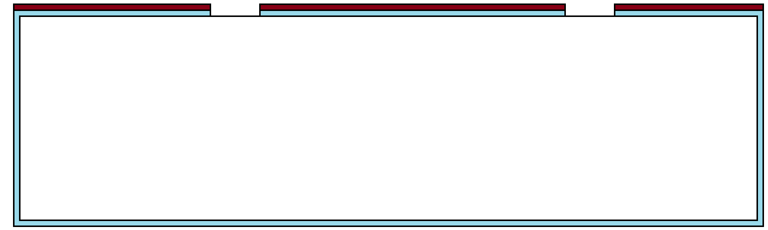
Anisotropic/isotropic etching cycle is repeated until the opposite wafer surface is reached.

The via holes shape – strongly influenced by the number of anisotropic/isotropic etching cycles used and length of each etching step.

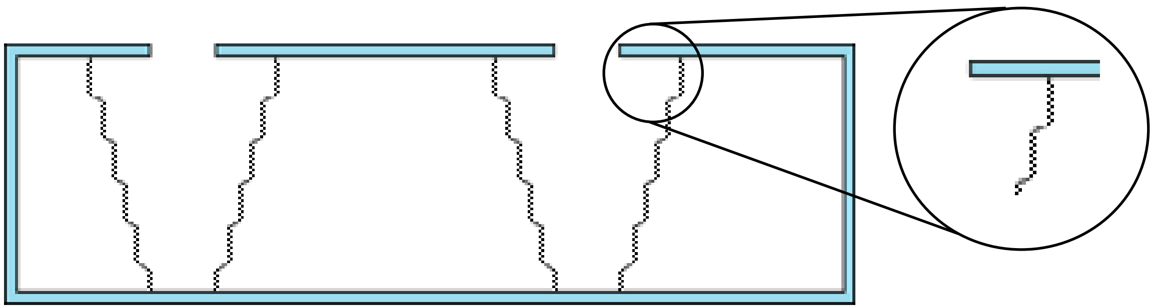
Size of the holes (diameter) is given by the initial etching window on one side, while on the opposite side will be greater, being influenced by the number and length of isotropic etching steps used.

Schematic view of the technological flow used for through wafer via manufacturing

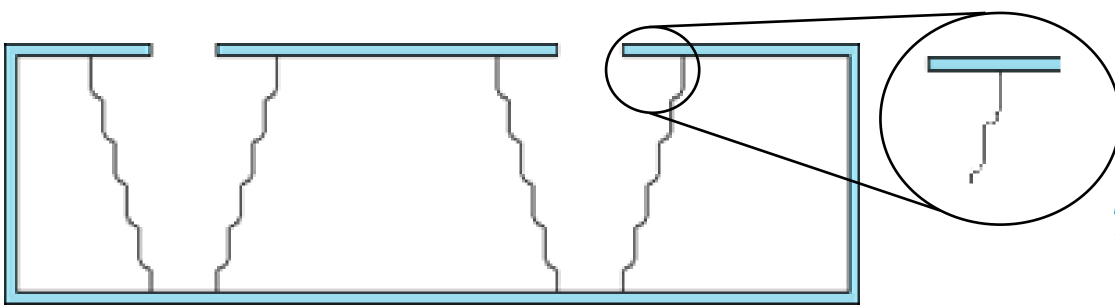
Thermal oxidation, 300nm



Resist deposition and patterning;
SiO2 etching



Variable isotropy DRIE process for V-shape through wafer via holes manufacturing



TMAH – selective corrugation removal

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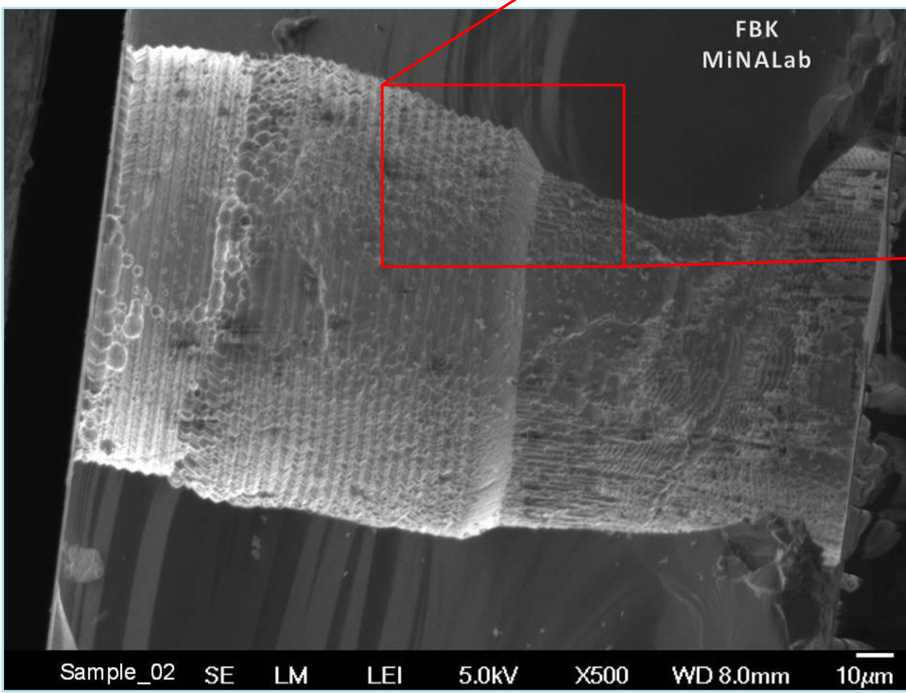
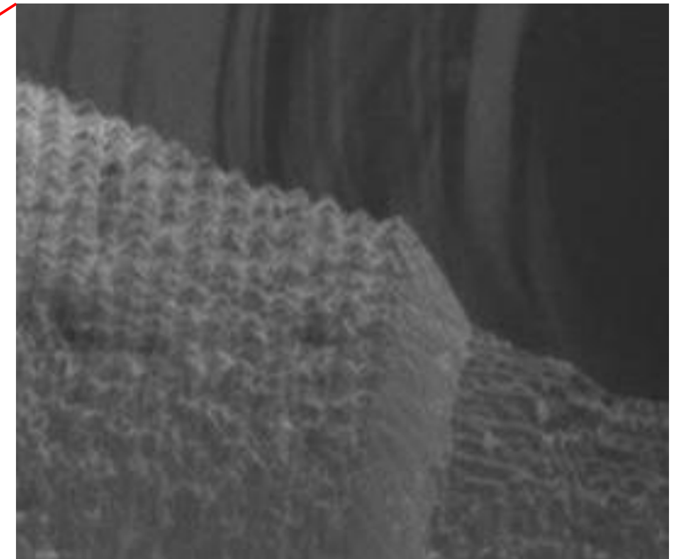
- ARDE effect (Aspect Ratio Dependant Etching) – different opening etching sizes provide us extremely different etching rates
- Mask – circles, 100 diameter
- anisotropic etching rate: ~ 10μm/min
- isotropic etching rate: ~ 4μm/min

DRIE processes used for through wafer via holes manufacturing. Etching depth (μm) and material etched

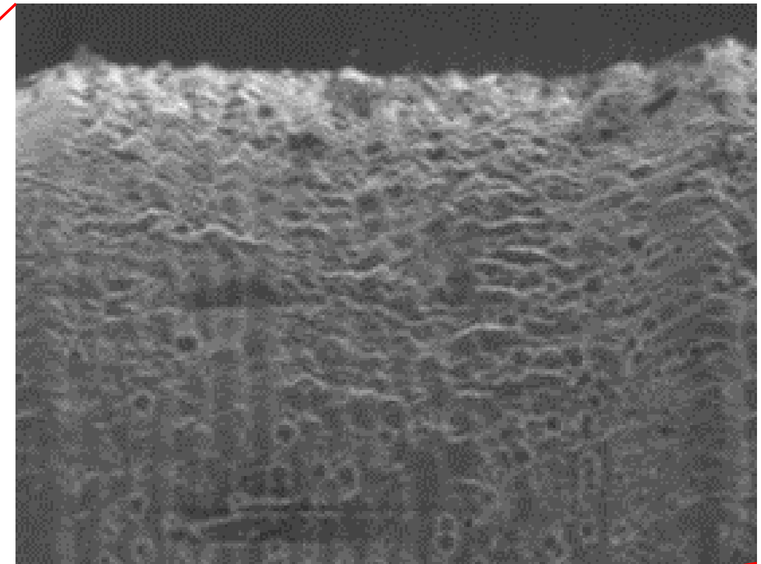
	Process type	
Process step	1	2
High etch rate rcp	Si, 60	Si, 30
O2 plasma	P*, -	P*, -
Isotropic etching rcp	Si, 20	Si, 10
High etch rate rcp	Si, 60	Si, 30
O2 plasma	P*, -	P*, -
Isotropic etching rcp	Si, 20	Si, 10
High etch rate rcp	Si, 40	Si, 30
O2 plasma	-	P*, -
Isotropic etching rcp		Si, 10
High etch rate rcp	-	Si, 30
O2 plasma	-	P*, -
Isotropic etching rcp		Si, 10
High etch rate rcp	-	Si, 40

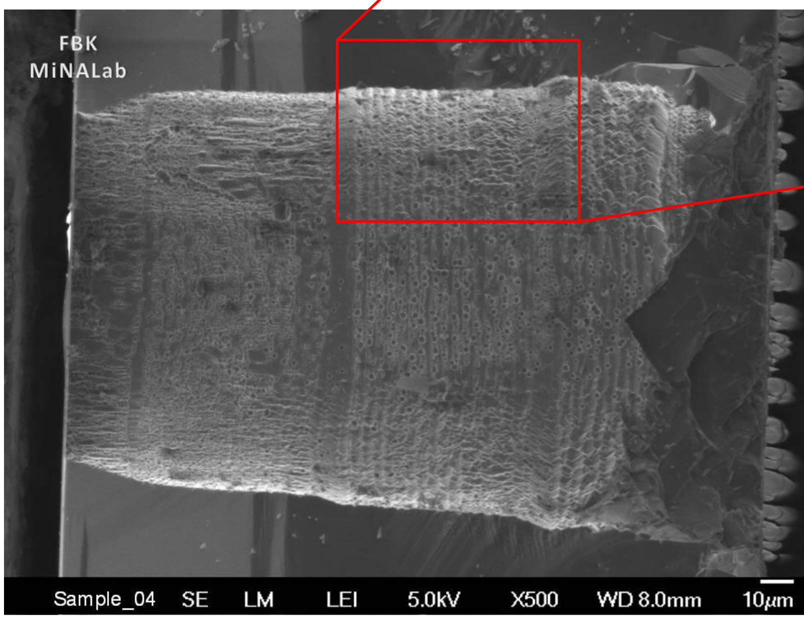
P* - passivation layer





SEM photos of a via hole manufactured by DRIE variable process (3 anisotropic & 2 isotropic steps)





SEM photos of a via hole manufactured by DRIE variable process
(5 anisotropic & 4 isotropic steps)

Measurements:

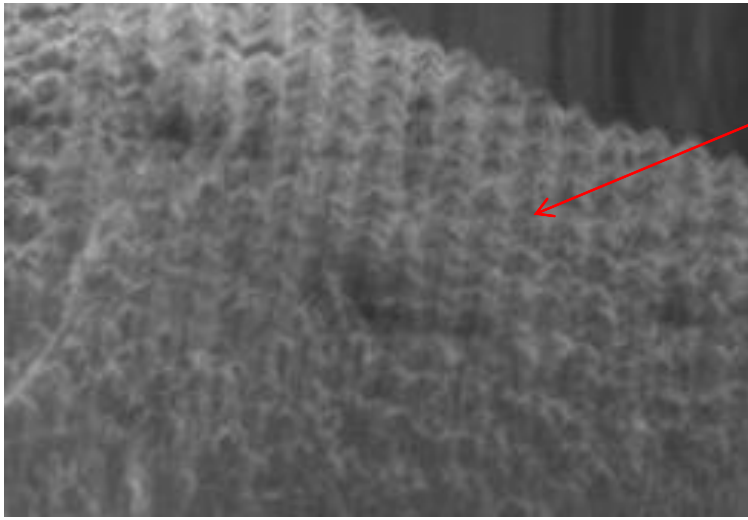
• SEM analysis – only 2 anisotropic and 1 isotropic etching steps can be seen in first case, while in second case 4 anisotropic and 3 isotropic etching steps => different etching rates

• anisotropic etching:

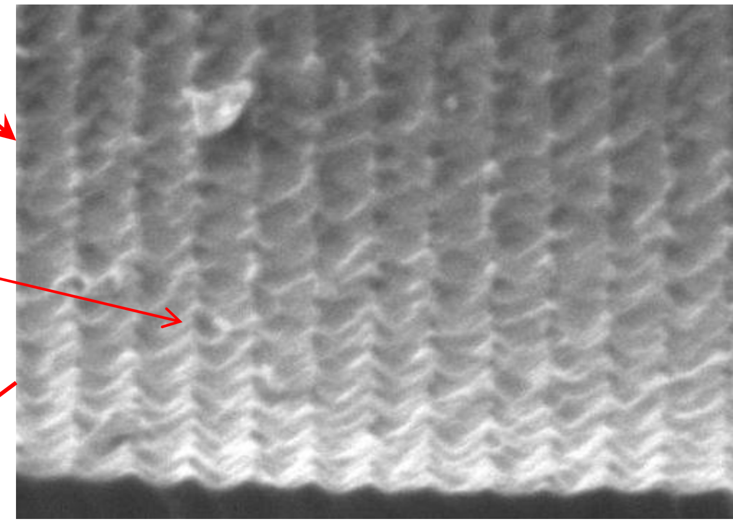
- ✓ first recipe: etching time - 6 min.; depth - ~104µm => ~ 17µm/min (only the first step was measured)
- ✓ second recipe: etching time - 3 min.; depth – 52…53µm => ~ 17µm/min (first to third etching steps)

• isotropic etching:

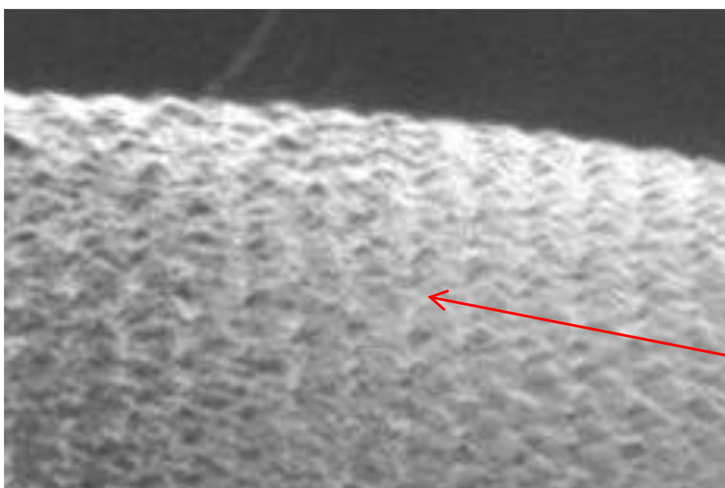
- ✓ first recipe: etching time - 4 min.; depth - ~ 6.5µm
- ✓ second recipe: etching time – 2min. 30 sec.; depth - ~ 3.5µm
- ✓ in this case we suspect that polymer from the walls was not completely removed by oxygen plasma and the etching rate it's smaller at the beginning; we can consider etching rate ~ 2µm after 2min. and 30sec.



Corrugation after DRIE process – Bosch type, high etching rate



Selective corrugation removal – TMAH, 25%, 74 C, 5 min.



Selective corrugation removal – TMAH, 25%, 74 C, 5 min.

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- Variable isotropy process can be used to achieve V-shape type through wafer via holes

- TMAH can be used to reduce the walls roughness, enabling seed layer deposition

  - allows a very good control angle
  - makes possible seed layer deposition (better adhesion and barrier layer)
  - via holes can be made with different sizes on opposite sides of the wafers

•The main problem of this method - the dependence of the etching rate on the aspect ratio, the usual problem for the DRIE processing.

•The process needs to be fine tuned for every hole dimension and manufacturing in the same step of via holes with different opening size will be difficult if not impossible.