Manufacturing Qualification of an All Dry De-veil Plasma Process

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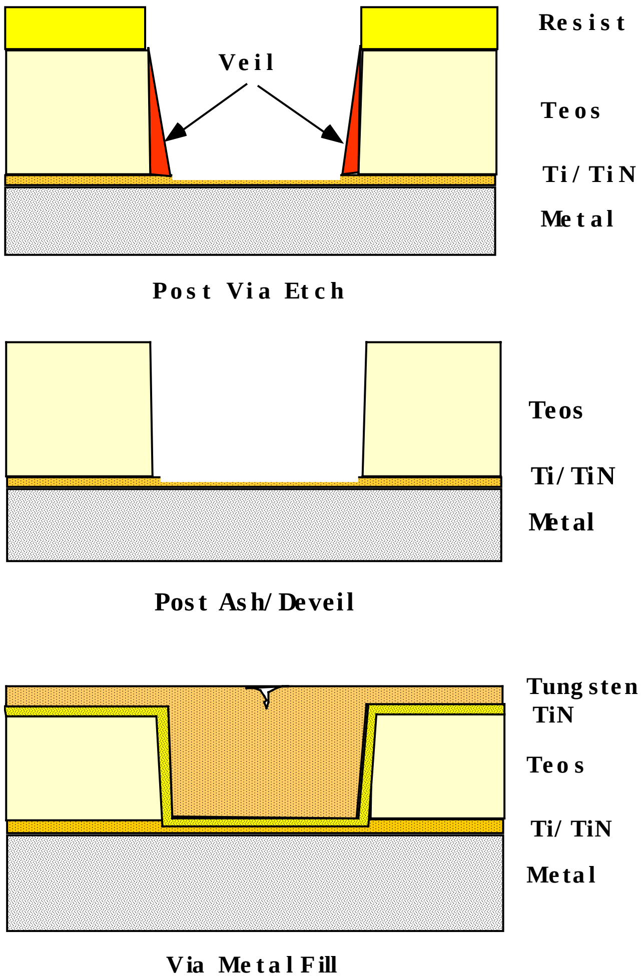
Digital DNA from Motorola

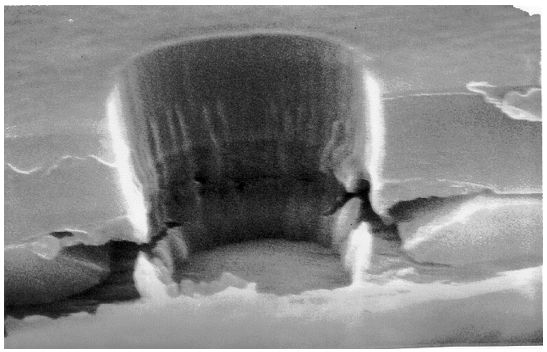
Via Process Integration

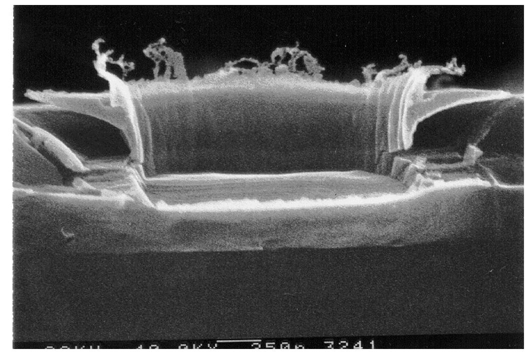


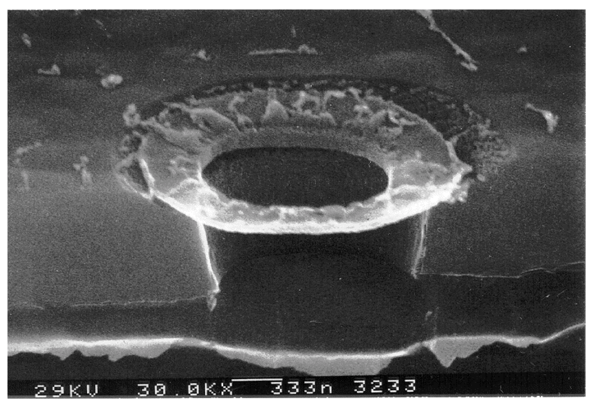
Problem Statement

- Via veil, or metallized polymer, is an unwanted by-product of via etch. Traditionally, these veils are removed with organic or inorganic solvents. Inorganic solvents, while effectively dissolving veils under ideal conditions, are costly and inconsistent under non-ideal conditions. Solvents are also environmentally incompatible. For these reasons, a dry solution has been explored.

The Problem: Via Veils

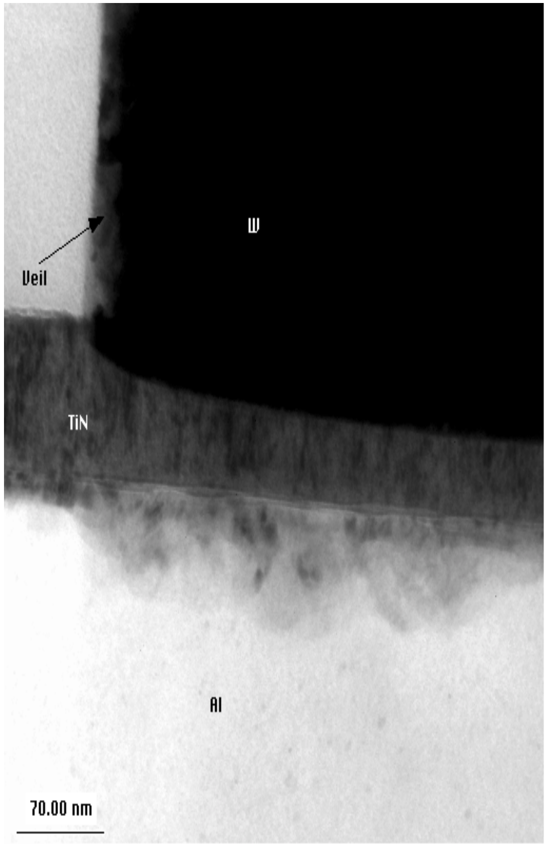






* veils produced using stop-on-Al via test structures

Via Veil: Stop-on-TiN Via



* ash only processing
no de-veil.

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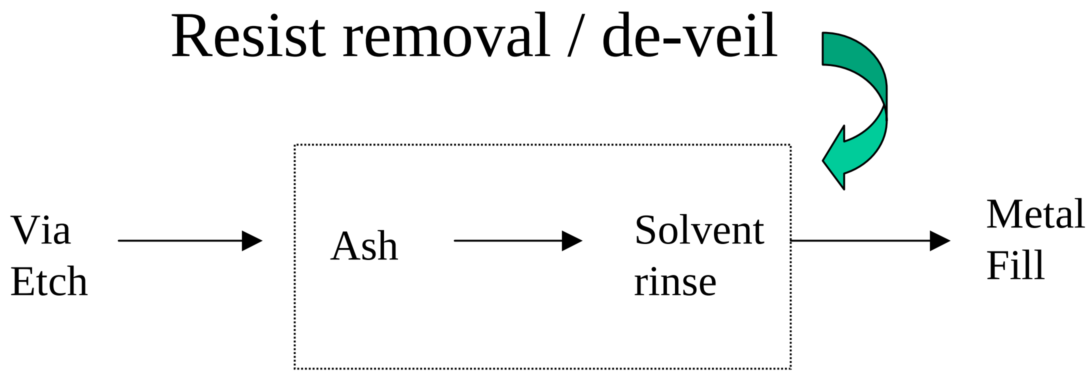
Solvent De-veil Process



1. O_2/N_2 ash to remove resist. >240 ^{O}C process temp
2. Hydroxyl amine (HA) solvent de-veil done in hood or spray tool.

Spray Process: HA (80 ^{O}C) rinse followed by isopropyl alcohol and DI water rinse.

Solvent De-veil Process, cont'd

• HA chemical effectiveness dependent on temperature and water concentration.

• Spray tools are difficult to control and to monitor. Hoods require large floor space.

• Aggressive nature of HA tends to pit AlCu and degrade valves and seals.

• Chemicals, chemical facilities, and chemical management are costly and relatively unfriendly to the environment.

These difficulties lead to product variation, scrap, high cost and environmental burden.

Solvent Spray Tool

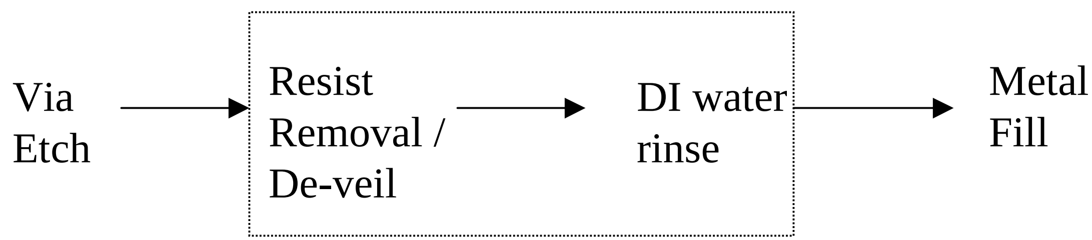
Solvent Handling Facilities

* 5700 gal chemical reclaim tanks

Dry De-Veil Theory

- The addition of free fluorine to the O_2 /N_2 Ash chemistry at reduced temperature will make the veil more soluble, thus more readily removed with DI water only. This is based on the fact that Al_2F_3 is more soluble than Al_2O_3.

Dry De-Veil Process



1. Resist removal and veil treatment using NF_3/O_2 plasma process at 25-90 ^{O}C.

2. Room temperature DI water rinse.

Dry De-Veil Process, cont'd

- Dual process steps: bulk resist removal and veil treatment
- Chemistry: NF_3 or CF_4, O_2, N_2 or H_2N_2 (forming gas, 2%H_2)
- Dual power sources:
  - Downstream microwave: 0-2000W
  - RF for reactive ion etch: 0-650W
- Low temperature processing: 25-90 ^{O}C
- Optical Endpoint

Dry De-Veil Results

- Product yield and resistance data is equivalent or better than solvent process
- Metal fill glue deposition is more uniform
- Solvent failure mechanisms have been eliminated.
- Product has been running with the new process since Q4'99.

Dry De-Veil Process Tools

* Dry de-veil tools and DI water Spin/Rinse/Dry tool

De-veil Cost Comparison:

Assume: 10K wafer starts/wk, Triple layer metal (2 via layers)

Cost Item	*Solvent Process*	*Dry De-veil Process*
HA Solvent Cost	$2,080,728 (41,614 gallons)	$0
Isopropyl alcohol	$2,741,566 (312,109 gallons)	$0
DI Water	$4,498 (391,134 gallons)	$3,632 (315,900 gallons)
Process gas	$8,786	$98,758
Process power	$969 (11,847 KWH)	$765 (9,359 KWH)
Waste disposal	$17,153	$0
TOTAL PROCESS COST	$4,853,700	$103,155
TOTAL PROCESS COST/WAFER PASS	$4.66	$0.10
TOTAL PROCESS COST/WAFER	**$9.33**	**$0.20**

Cost Comparison, cont'd

	Solvent Process	***Dry De-veil Process***
Equipment list	5 Spray Solvent Tools 4 Dry Ashers	7 Dry De-veil Tools 2 Spin Rinse Dryers
Annual amortization 5 yr. depreciation	$860,664	$802,800
Idling power costs	$10,000	$15,085
Annual component replacements	$400,000	$91,000
Tool set floor space requirement	243 sq ft	117 sq ft
TOTAL ANNUAL OVERHEAD COST	$1,270,664	$908,885
ANNUAL OVERHEAD COST/WAFER PASS	$1.22	$0.87
OVERHEAD COST/WAFER	**$2.44**	**$1.74**
PROCESS COST/WAFER	**$9.33**	**$0.20**
TOTAL ANNUAL COST/WAFER	**$11.77**	**$1.94**

Net Annual Savings at 10,000 wsw: $5,111,600

NF_3 Emission Analysis

1. Gases employed to process 520,000 product wafers[1] (2 passes/wafer)

O_2:	1,074,320	liters
NF_3:	57,200	liters
H_2N_2:	44,720	liters

2. Approximate raw exhaust gas composition during process, by volume[2]:

NF_3:	1.3%	CO_2:	0.4%
HF:	0.2%	CO:	0.8%
COF_2:	0.7%	O_2:	96.6%

3. Using a GWP(Global Warming Potential) of 8,000 for NF_3[3]
Estimated MMTCE (million metric tons carbon equivalent) from NF_3:
7.5E-5
Based on 52 wafer fabs[4], MMTC from NF_3: 3.9E-3
(The Semiconductor Industry generated approx. 1.4 MMTCE in 1996[5])

1. Assuming a 10,000 wafer start/wk fab.
2. RGA data taken on production equipment with representative process.
3. Source: US EPA, Scott Bartos, SSA Annual Meeting, 2000.
4. Assuming 27 million wafers produced in 2000. Source: Rose Associates
5. Source: S. Karecki L. Pruette, R. Chatterjee, R. Reif, *Alternative Chemistries for Dielectric Etch Processes, 1999.*

Process Qualification
Normalized Device Yield Results

Process	Yield	Standard Deviation	Number of Lots
Solvent Clean	1.0	11.56	481
Dry Deveil	0.998	13.39	170

Process Qualification
168 Hour Reliability Yield Results

Split	168 Hour Burn-in Failures
Control Ulvac	0/197 0/197
Control Ulvac	0/80 0/80
Control Ulvac	0/100 0/84

Process qualification VIA Failure Results

PART	TOOL	LAYER	N LOTS	%KLVN FAIL	%CHAIN FAIL	QBD SHIFT
A	Solvent Dry	Via 1 Via 1	25 19	-- --	0.144 0.030	NO
	Solvent Dry	Via 2 Via 2	25 19	-- --	0.018 0.000	NO
C	Solvent Dry	Via 1 Via 1	25 19	0.027 0.000	0.000 0.000	NO
	Solvent Dry	Via 2 Via 2	25 19	0.027 0.000	0.027 0.000	NO
D	Solvent Dry	Via 1 Via 1	24 13	0.058 0.000	0.019 0.000	NO
	Solvent Dry	Via 2 Via 2	22 9	0.042 0.000	0.021 0.000	NO
E	Solvent Dry	Via 1 Via 1	30 17	0.150 0.000	0.075 0.000	NO
	Solvent Dry	Via 2 Via 2	26 13	0.329 0.216	0.225 0.036	NO

Summary

• A reliable, cost effective alternative to solvent de-veil processing has been developed.

- Same or improved yield and device performance
- Solvent failure mechanisms have been eliminated
- Process wafer cost is reduced to <15% of the solvent process

• Dry De-veil technology is better for safety and less overall burden to the environment

- Eliminates hazardous waste disposal
- Reduces overall DI water consumption
- Requires less safety equipment

• This via de-veil technology is extendable to other solvent de-veil processes: (i.e. metal etch, poly etch, ion implant, etc.)