The Challenges for Local Material Manufacturers, The Past, Present, and Future

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More than Moore’s Law?

"https://www.reddit.com/r/askscience/comments/32f8us/did_moores_law_calculate_correctly/"
Local Manufacturing of IC Materials/Chemicals

- Starting from an ITRI- Chemical Lab project in 1995
- Topics for CMP slurry, photo resist, CVD precursors, molding compounds have been studied.
- Government funding with 3-5 years efforts had been invested.
- Few companies have been founded/technology transferred.
- Nanmat Technology Co. was founded 1998 to focus on CVD precursors and Sol-gel nano-materials.
The Starting Point of Nanmat

• Technology transfer from US in 1998
• Toll manufacturer for major suppliers of CVD precursors
• New precursors developments for tool company
• First Taiwan local brand of CVD/ALD precursors
• Toll manufacturing for precursors of III-V compound semiconductor(LED, LD, ---)
Core Technology
From synthesis, formulation, polymerization to applications of Nano-Materials

(MOCVD)

Gaseous

OR

OR - M - OR

OR

(M=Si,Al,Zr,Ti....)

Organo-Metallic Compound

Liquid(Sol-gel)

Nano Solution

Nanomaterials = NanoMate®

Ceramics (oxides, carbides, nitrides..), Metals, Organic-Inorganic Hybrids
Precursors for CVD Process

1. Inorganic Compounds
   Hydrides of Metals or Metalloids (MHx, M1M2Mx, …)
   Halides (MClx, MFx, …)
   Halohydrides

2. Organometallic Compounds

   Alkyl and aryl derivatives of Metals

   ![Chemical structures]

   Alkoxides
   Acetylacetonates
   Carbonyls
Total Solution of CVD:

1. BPSG
   - TEOS  • TEPO / TMPO / TMPI  • TEB / TMB

2. ILD & Low K Dielectrics
   - TEOS  • Smart– K 2.8 SOG  • New CVD Low-k

3. Interconnect (Metal)
   - Al precursor – DMAH, TMA, MPA*
   - Cu ( I ) / Cu ( II ) Precursor *

4. Diffusion Barriers
   - TDMAT / TDEAT (TiN Precursor )
   - TiCl4 (Ti / TiN Precursor )

5. High K Dielectrics
   - TAETO (Ta2O5 Precursor )

*Spin on High K

( DM of 2000 )
The Challenges for Local Material Manufacturer in the past

• Brand
• Quality Assurance/ Quality Control (ISO, TS---)
• Technical service
• Analytical methods/instruments
• Cost/Price/Market Size
• Product lines
• Extra values for customers ----
1. LEVEL-SENSING TECHNOLOGY

NANMAT TDMAT Gram Reader System
On-line Continuous Sensing during Bubbling and Refill
1. LEVEL-SENSING TECHNOLOGY (cont’d)

- Precise control on TDMAT usage for different processes to eliminate the risk of run-out
- Easy planning for ampoule change and reduction Preventative Maintenance (PM) down time
- Average wafer count per ampoule ramps up from 22,000 to 30,000

*Estimated 40% CoO reduction!*

*Based on customer’s 12-month data with 25 TxZ systems*

**More than 1,200 installed bases in the past 5 years**
2. PACKAGE SCALE-UP

• Helps end-user modify AMAT Star System TDMAT canisters from 2.5 L to 3.8 L
3. LEAK CHECK & VALVE OVERHAUL

- Eliminate risks of leaking and improve process performance
- Reduce Cost of Consumables by reclaiming valves/pipeline
- Service covers different CVD materials/tools such as TEOS, TEPO, TEB, TDMAT
Total ALD/CVD precursor solution

- The only CVD material company in the world with full line capabilities on front end (synthesis, purification, analysis, manufacturing---) and back-end (packaging, container, technical service, valve overhaul/cleaning--) of CVD precursors

### Dielectrics PMD/IMD
- TEOS
- TEPO/TMPO
- TEB / TMB

### Low K Dielectrics
- 3MS.4MS
- OMCATS
- TOMCATS
- DMDMOS
- Advanced porous low K precursors
- New CVD Dense Low-k Smart– K 2.5

### High K Dielectrics
- TAETO (Ta2O5 Precursor )
- TEMAH/ HfCl4; TEMAZ/ ZrCl4 (ALD HfO2/ZrO2 Precursor); CpZr
- TMA (Al2O3 Precursor); TMGa, DEZn
- STO/ BST/ PZT Precursor; GST Precursor
- SiCl4/ 3DMAS (Hf and Zr based silicates)

### Metal Gate and Interconnect Metal
- TDMAT / TDEAT (CVD/ALD TiN Precursor )
- TiCl4 ( Ti / TiN Precursor )
- TBTDET, PDMAT (ALD TaN Precursor )
- Al precursor – DMAH, TMA, MPA,
- Cu ( I ) / Cu ( II ) Precursor

### Low-Temp Nitride/Oxide
- HCDS
- 3DMAS
- LTN/ LTO Precursor,C8H22N2SI

### Dopants
- POC13

### MO source
- TMG,TEG,TMA,TMIn,DEZ,Cp2Mg
Gambling At 0.13 μm

(Semiconductor International)
The Challenges for Local Material Manufacturers in the Present

• Technology barriers (patents, know-how, ---)
• No tool company in Taiwan (the only major semiconductor country without tool maker)
• No global recognition and oversea market share
• No advance or basic research by the customers
• Less joint effort with customers
The Challenges for Taiwan Local Material Manufacturers in the Future

• Less investment on R&D for future technologies
• Still no process tool company in Taiwan
• Less joint effort between customers, research institutes, and local suppliers
• Too fast for upgrading of analytical instruments
• Too many directions for new material applications
New Fluorocarbon Hybrid SiO$_2$ by PECVD with Proprietary Precursors by Nanmat

These films were grown with substrate temp. at 175° C, and annealed at 400° C for 1 hour. The new material shows excellent thermal stability with high F/C contents even after annealing.
These new fluorocarbon hybrid SiO$_2$ films showed low dielectric constants with excellent stability even after annealing.
SEM cross section of new fluorocarbon hybrid SiO$_2$ films showed dense nature of the material.
FTIR of Porous Low-K and Nanmat’s Dense Low-K
Reactants are separated from one another in the flow stream by a purge gas. Each reactant pulse chemically reacts with the wafer surface, making ALD a self-limiting process capable of precise monolayer growth. (Source: ASM)

New Cu CVD/ALD Process

• Deposition temperature as low as 250°C
• High deposition rate
• Process stable and low cost CVD precursor
• Pure Cu composition
• Excellent step coverage
• Excellent adhesion
• Potential for an all dry process
12 nm Copper film by MOALD with uniform thickness as possible seed layer

Substrate: TaN
Deposition time: 220 sec
Annealing time: 220 sec

Deposition temp: 260 °C
What CVD/ALD can do?

- IC
- Solar
- Optics
- MEMS
- OLED
- 3D Packaging
- LED
- Deliver System
- Parts Components
- ALD Systems Turnkey

CVD/ALD Systems Turnkey
What else on Periodic Table?
Space, the Last Frontier