III/V CMP Development

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Outline

- III/V CMP background
- III/V CMP slurry formulation development at BASF
  - Basic concept development
  - Additive, component screening
  - Test on III/V patterned wafers
- Conclusion
Drivers of the electronic Industry: Speed, Efficiency, Size and Cost

The electronic industry innovates in three dimensions:

- Shrinking nodes (More and smaller transistors)
- 3D Architecture (Stacking/Combination)
- New Materials (eg. Ge, III/V compounds, Graphene)

- 100x faster transistors
- 60% less energy need

Pictures: techspot, soccentral, INTEL, Wikipedia, lbl
The introduction of high mobility materials is one of the preferred solutions to fulfill the device performance below 16nm. Ge has a very high hole mobility and is thus considered as an interesting candidate for pMOS transistors. III/V materials have very high electron mobility and thus are potential materials for nMOS transistors.(1) Chemical mechanical planarization plays a critical role to enable the integration of Ge, III/V materials, requiring good planarization performance as well as control of toxic gas release to meet EHS requirements.

Ge and InGaAs are candidates to replace Si as channel material for high-mobility devices.

Table 1 – overview III V materials for CMP

<table>
<thead>
<tr>
<th>Epi Sequence</th>
<th>CMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. InP/In_{0.52}Al_{0.48}As/In_{x}Ga_{1-x}As</td>
<td>In_{x}Ga_{1-x}As</td>
</tr>
<tr>
<td>1. p-InP</td>
<td>InP</td>
</tr>
<tr>
<td>2. Recess + In_{x}Ga_{1-x}As</td>
<td>In_{x}Ga_{1-x}As</td>
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<tr>
<td>3. Recess + In_{x}Ga_{1-x}As</td>
<td>In_{x}Ga_{1-x}As</td>
</tr>
</tbody>
</table>

*In_{x}Ga_{1-x}As - x: 0.53-1

Possible need for InP, In_{x}Ga_{1-x}As and In_{0.52}Al_{0.48}As CMP processes

References:
(1) Patrick Ong, Liesbeth Witters, Niamh Waldron and L.H.A. Leunissen, ECS Trans. 2011 volume 34, issue 1, 647-652
How did We Identify the Mechanism in III/V (GaAs, InP) CMP

![Graph showing etching and polishing rates vs pH for GaAs and InP](image_url)

- Etching rate (InP)
- Etching rate (GaAs)
- Polishing rate (InP)
- Polishing rate (GaAs)
Zeta Potential of III/V Substrates

Zetapotential with GaAs Wafer

Zetapotential with InP Wafer
III/V-InP Surface Analysis

**XPS**

- **Information depth**: ~5-10 nm
- **Penetration**: µm scale
- **Al Kα X ray**: 1486.6 eV

**TOF-SIMS**

- **Analysis Parameters**:
  - **Pi**: Bi1
  - **Energy**: 25 keV
  - **Current**: 1.000 pA
  - **Area**: 250 x 250 µm²
  - **PIDD**: 4.91E+012 ions/cm²

**Before polish**

<table>
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<th>Element</th>
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<th>after</th>
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<tr>
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<td>As</td>
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<tr>
<td>Ga</td>
<td>32.0</td>
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<td>20.8</td>
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<td>O</td>
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**After polish**

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III/V CMP Performance Improvement
Passivation v.s Activation

GaAs

Baseline

With additive

InP

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A Balance of Polishing Rate and Surface Finish in III/V CMP

Surface quality (visure check):
- very good
- nice
- bad

GaAs Surface Finish (White light interferometry)

Baseline: RMS>0.8nm
Add a (Gen 1): RMS>0.8nm
Add b (Gen 2): RMS>0.8nm
Add c (Gen 3): RMS<0.5nm
Add d (Gen 3): RMS<0.5nm

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BASF Additives Enable a Broad Range of Selectivity in III/V CMP

A.U.

0
0,0
20,0
40,0
60,0
80,0
100,0
120,0
140,0
MRR(GaAs)/MRR(InP)

GaAs
InP
GaAs/InP

Baseline
+Y/Add.01
+Y/Add.02
+Y/Add.03
+Y/Add.04
+Y/Add.05
+Y/Add.06
+Y/Add.07
+Y/Add.08
+Y/Add.09
+Y/Add.10
+Y/Add.11
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+Y/Add.28
+Y/Add.29
+Y/Add.30
+Y/Add.31
+Y/Add.32

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Gas Releasing Control in III/V CMP

Waste slurry
- Centrifugate: remove abrasives
- Dissolve abrasives
- Complete waste slurry

Top solution
- Inductively coupled plasma atomic emission spectrometry (ICP-AES)

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Selectivity on Oxide Layer

- 2 slurry prototypes (Planapur® G 3001 & Planapur® G 3002) identified with InP: SiO₂ selectivity > 100:1
300mm Patterned Wafer Study: InGaAs STI with Planapur® G 3002

- Planarization achieved with about 110sec CMP
- Oxide loss < 20A in 110 sec polishing

InGaAs – POST CMP
- Low dishing (<50A)
- Low erosion (<50A)
Defects on eharp Oixde

- Slurry formulation showed strong impact on defects performance on oxide substrates
- Correlation study ongoing: defects on oxide, defects on III/V

![Defects Chart](image)

**PG 3001**
EHARP – 176 @0.15um

**PG 3002**
EHARP – 230 @0.15um

**PG 3003**
EHARP – 74 @0.15um
BASF has Strong Chemical Know-how in-house to Develop CMP Slurries

- Complexing Agents
- Inhibitors
- Oxidizers
- Abrasives
- Polymers

BASF Chemical Toolbox ➔ CMP Formulation ➔ Customer Samples

→ Fast R&D samples

End Customer
Conclusions

- III/V materials polishing models are developed based on substrate analysis and polishing experiments
- BASF additives provide a broad window for selectivity and surface finish tuning in III/V CMP
- III/V patterned wafer (300mm) test confirmed high planarization, low erosion, dishing with BASF formulations
- Methodology under development for more detailed defects study on III/V materials