Cu Seed Layers: Do It Right By Design (Why Repair?)

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Seed Layers: What Do We Need?

- Excellent continuous sidewalls coverage, yet thin enough inside openings to avoid pinching-off or sealing the features
- Sufficient thickness on the field (at least 1,000Å), for adequate surface conduction, to minimize IR drop ("Terminal Effect")
- Excellent adhesion to the barrier
- High throughput deposition equipment
- Consistent and highly reliable process

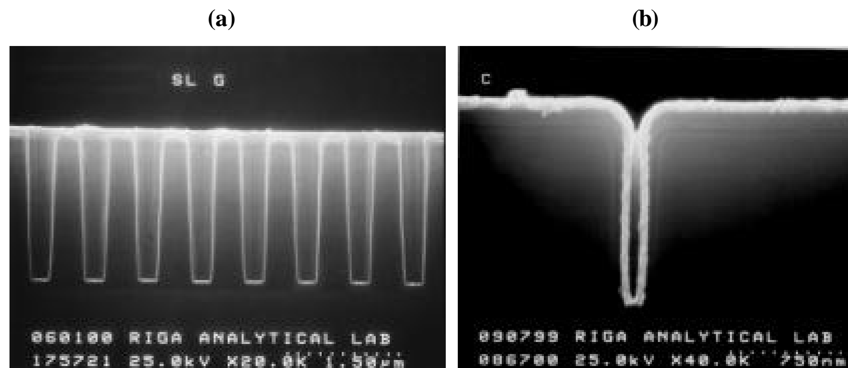
Problems with Cu Seed Layers

EE TIMES

Telcos' future: automation up, staffing down

Next-gen processes stare into the void

Problems With Cu Seed Layers



Conventional Cu seed layers. (a) PVD seed layer; combined (Cu plus barrier): ~2,000Å on field and ≤100Å on lower sidewalls; vias: ~0.25µm wide; 1.90µm deep; AR ~ 7.6:1. (b) CVD seed layer; combined (Cu plus barrier): ~450Å on field and sidewalls; trenches: ~0.13µm wide; 1.4µm deep; AR ~ 10.8:1

Problems with Cu Seed Layers

- **PVD Cu S.L. Þ Low Reliability/Yields**
  - » Dual Damascene features have nooks and crevices
  - » Line of sight PVD deposition results in inadequate sidewall (or step) coverage, leading to filling voids.
  - » Patchy, discontinued Cu S.L. exposes both barrier and Cu S.L. to electrolyte, resulting in accelerated corrosion of the Cu S.L. Interfacial S.L./Barrier stress also accelerates Cu S.L. corrosion.
  - » Microvoids coalesce (under thermal and electrical stresses) to larger voids, resulting in void pulls (cf. EE Times of August 26, 2002).

Problems with Cu Seed Layers (continued)

- **Conformal (CVD or Electroless) Cu S.L.**
  - » Too thick on sidewalls yet too thin on field
  - » Slow deposition results in low throughput
  - » Poor adhesion/nucleation on barrier layer
  - » Poor uniformity and rough deposited surface
  - » High impurities and resistivity levels
  - » Electroless requires additional equipment tool

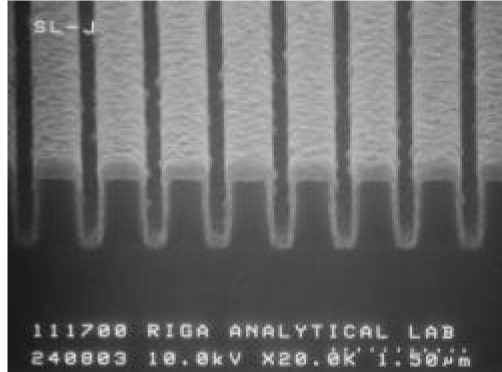
Problems with Cu Seed Layers (continued)

- **Electroless "Repair" (on PVD) S.L.[7-10]**
  - » Extremely hard to control process: Inconsistent initiation and deposition rate due to bath aging
  - » Requires relatively thick (≥ 300-500Å) Cu on the sidewalls, thereby limited to ≥ 0.13μm features
  - » Too thick on sidewalls yet too thin on the field
  - » High level of impurities and resistivity of seed
  - » Slow deposition results in low throughput
  - » Requires additional equipment tool

Advantages of Conformal/Non-Conformal Multiple Cu Seed Layers[1-6, 11]

- Excellent, uniform bottom and sidewalls coverage
- High yields and reliability (cf. C. H. Lee et al.[5] and C. Block et al.[6])
- Adequate field thickness: 1,000-2,000Å
- High deposition throughput: ~ 60 WPH
  - » Need only about 100-300Å of conformal (CVD or ALCVD) Cu, similar to CVD barrier. Overall deposition throughput similar to current PVD

Multiple Seed Layers



PVD/CVD seed layers: ~600Å (including barrier) on sidewalls and ~1,700Å on field. Trenches: ~0.23µm wide (bottom); 0.85µm deep; AR ~ 3.7:1; tilt =30°.

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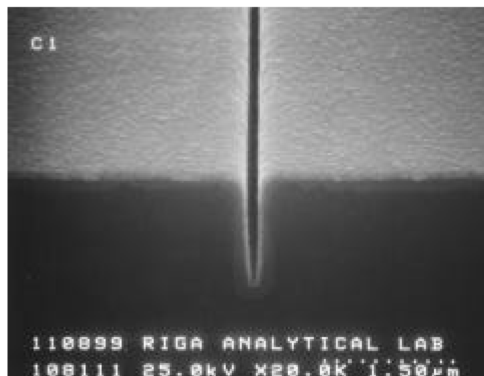
Multiple Seed Layers



PVD/CVD seed layers: ~450Å (including barrier) on sidewalls and ~1,000Å on field. Trenches: ~0.13µm wide (bottom); 1.4µm deep; AR ~ 10.8:1; tilt =30°.

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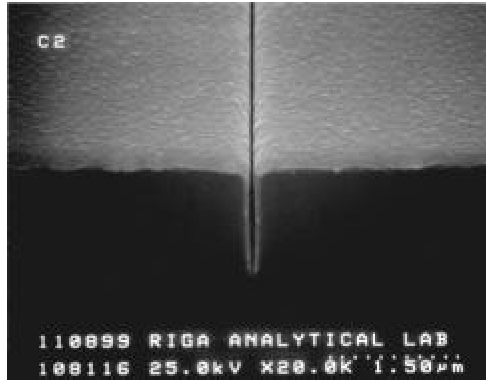
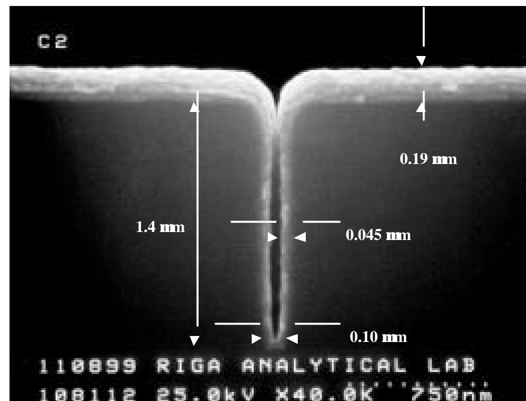
Multiple Seed Layers



PVD/CVD seed layers: ~450Å (including barrier) on sidewalls and ~1,900Å on field. Trenches: 0.10µm wide (bottom); 1.4µm deep; AR = 14:1; tilt =30°.

Multiple Seed Layers



PVD/CVD seed layers: ~450Å (including barrier) on sidewalls and ~1,900Å on field. Trenches: 0.10µm wide (bottom); 1.4µm deep; AR = 14:1; No tilt.

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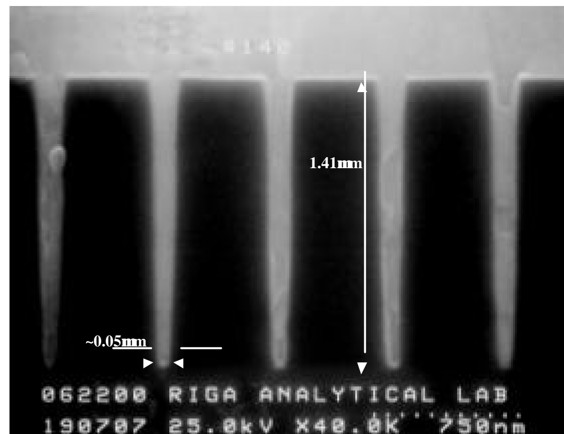
Future Seed/Barrier (What We Want?)

- Excellent, uniform bottom and sidewall coverage for features ≤ 0.10µm: by CVD or ALD (AL-CVD)
- Adequate field thickness: 1,000-2,000Å: by PVD
- Excellent adhesion to the barrier
- High yields and reliability
- High deposition throughput
- CVD/PVD or PVD/ALD Cu Seed can provide all of the above!
- Demand PVD/CVD or PVD/ALD Cu Seed tools!

Jets-ECD Cu-Filled Trenches



Lightly etched cross-section. Trenches: ~ 0.05µm wide (bottom); ~ 1.41µm deep; AR ~ 28:1.

Summary

- **Demonstrated:** Conformal/Non-Conformal Cu S.L. for ≤ 0.10μm features with excellent continuous step coverage and thick Cu S.L. on the field
- **Excellent:** CVD/PVD Cu S.L. for openings below 0.10μm (and AR ≥ 14:1):~ 40-50nm on sidewalls, and ~ 190nm on field.
- **litigation:** Semitool has sued Applied Materials, Novellus, and Ebara regarding "repair" seed layer[10]
- **UC Consulting**: One issued Cu Seed Layers Patent (6,136,707), two Allowed Applications, and four Pending Applications

REFERENCES

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2. U. Cohen et al., 17th Intl. VLSI Multilevel Interconnect Conference (VMIC), pp. 21-26, June 2000.
3. U. Cohen et al., SEMI Technical Symposium, Semicon West, pp. 819-834, July 2001.
4. U. Cohen, 18th Int. VLSI Multilevel Interconnect Conference (VMIC), pp. 165-167, September 2001.
5. C. H. Lee et al., 2000 International Interconnect Technology Conference (IITC), pp. 242-244, June 2000.
6. C. Block et al., 2001 International Interconnect Technology Conference (IITC), pp. 210-212, June 2001.

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10. L. L. Chen, U.S. Patent No. 6,197,181 (03/06/2001).
11. P. Gopalraja et al, U.S. Patent No. 6,274,008 (08/14/01).
12. V. M. Dubin et al., U.S.Patent No. 6,432,821 (08/13/02).