Low-Damage Plasma Etching

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ECE 3450

April 22, 2015

What is Plasma Etching?

- The use of high energy plasma streams to etch IC wafers
- Ions and radicals in the stream react with the wafer surface
- Different gases are used for different materials

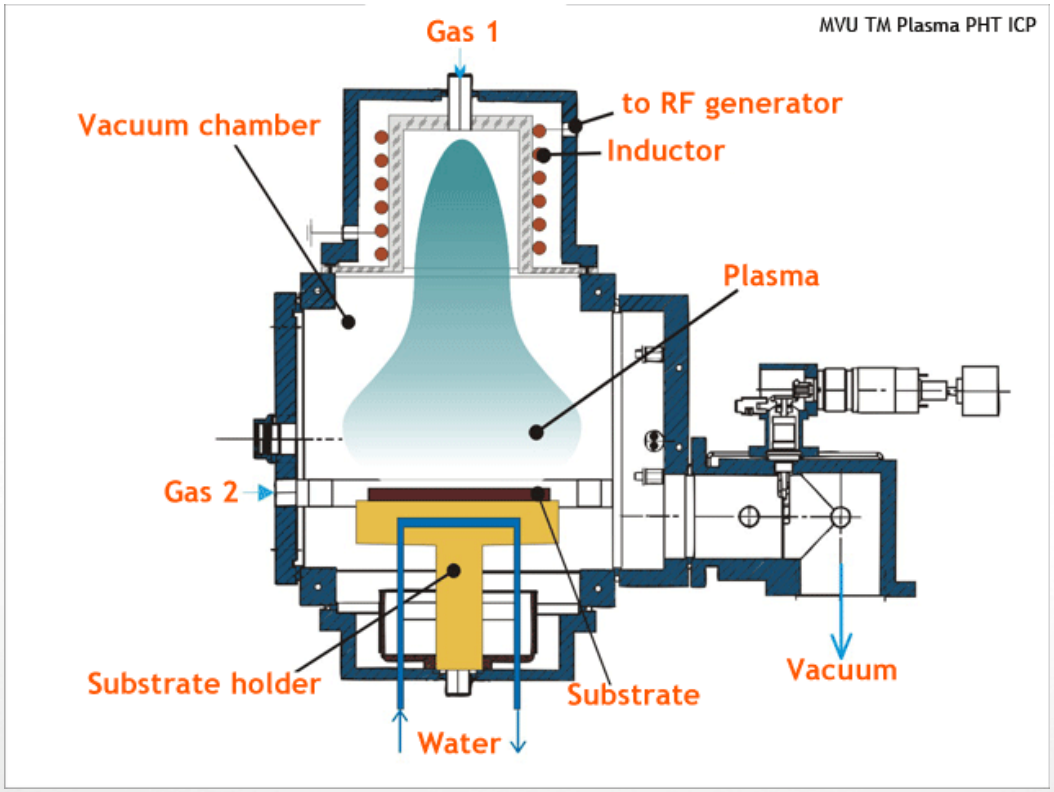

Figure 1: Typical Plasma Etching System

Why use Plasma Etching?

- Pros:
  - Produces more precise, anisotropic results than wet etching
  - Can be done a low temperatures
- Cons:
  - More expensive than wet etching
  - Damages the wafer surface being etched

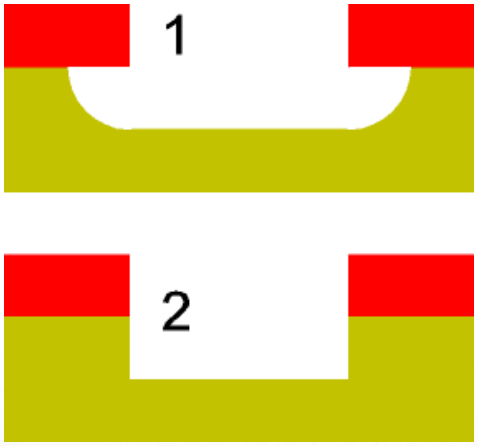

Figure 2.1: An isotropic etching result
Figure 2.2: An anisotropic etching result

Main Causes of Surface Damage

- High energy ions impacting the surface
- Volatile chemical reactions

Different Means of Minimizing Damage

- Lowing ion energy
- Use of certain gases
- Lowering Bias Voltage

Ion Energy

Effects of Ion Energy on Plasma Etching

- High ion energy increases damage, etch rates, and anisotropy (1)
- Reducing the ion energy decreases all of these effects

Compensating for Low Ion Energy

- High plasma ion density allows for low energy without sacrificing etch rate (1, 3)
    - Low energy reduces anisotropy
- Inductively coupled plasma, transformer coupled plasma, and electron cyclotron resonance produce high density

Different Gases

Effects of Using Different Gases

- Different gases react differently with the wafer surface
- Volatile reactions result in a higher etch rate, but also more surface damage

Fluorine Gas Based Plasma Etching

- High etch rate on silicon carbide due to volatile chemical reaction (2)
- Surface damage cannot be completely annealed away

Chlorine Gas Based Plasma Etching

- Lower etch rate on silicon carbide than fluorine (2)
- Surface damage can usually be completely annealed

Mixed Cl/F Gases

- Increasing F gas concentration raises etch rate and surface damage (2)
- Optimal Cl/F ratio depends on material being etched and how much damage is acceptable

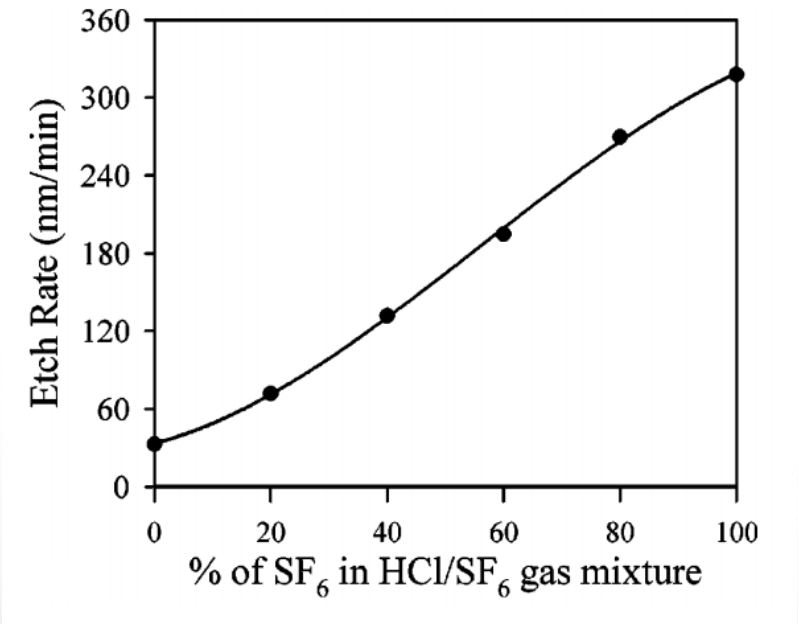

Figure 3: Etch Rate vs F/Cl Gas Ratio on SiC (2)

Bias Voltage

Effects of Bias Voltage on Surface Damage

- High bias voltage results in higher etch rates and more surface damage (2)
- High bias increases ion energy
- Lower bias means longer etching time

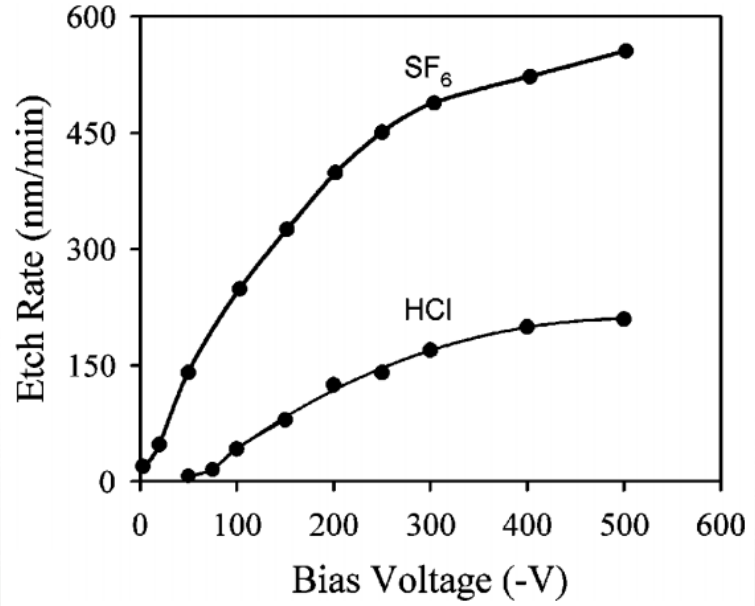

Figure 4: Etch Rate vs Bias Voltage for F and Cl plasma on SiC (2)

Conclusions

- Reducing surface damage usually reduces etch rate and/or anisotropic precision
- No solution is perfect, but there are many options to choose from

Sources

- 1) Anisotropic etching of InP with low sidewall and surface induced damage in inductively coupled plasma etching using SiCl4Etrillard, J. and Ossart, P. and Patriarche, G. and Juhel, M. and Bresse, J. F. and Daguet, C., Journal of Vacuum Science & Technology A, 15, 626-632 (1997), DOI: http://dx.doi.org/10.1116/1.580695

- 2) Low-Damage Etching of Silicon Carbide in Cl2-Based Plasmas, J. Electrochem. Soc. 2002 149(7): G420-G423;doi: http://dx.doi.org/10.1149/1.1482059

- 3) High-density plasma etching of compound semiconductorsShul, R. J. and McClellan, G. B. and Briggs, R. D. and Rieger, D. J. and Pearton, S. J. and Abernathy, C. R. and Lee, J. W. and Constantine, C. and Barratt, C., Journal of Vacuum Science & Technology A, 15, 633-637 (1997), DOI: http://dx.doi.org/10.1116/1.580696

Questions?

- Physical and digital copies of the slides are available