Fullerene derivative based spin-on-carbon hard masks for advanced lithographic applications

Conference or Workshop Item

How to cite:


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Version: Version of Record

Link(s) to article on publisher’s website:
https://www.academia.edu/14286697/Fullerene_derivative_based_spin-on-carbon_hard_masks_for_advanced_lithographic_applications

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Fullerene Derivative Based Spin-on-Carbon Hard Masks for Advanced Lithographic Applications

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1. Introduction

The advance of lithographic resolution requires extremely thin photoresist films for the fabrication of 1x nm structures to mitigate resist collapse during development, but the use of such thin films will limit achievable etch depths.

Pattern collapse due to aspect ratio

Multilayer hard mask stacks are a possible solution. We have developed a fullerene based spin-on carbon hard mask material capable of high aspect ratio etching.

Process flow of layer scheme

The high resolution image is captured in a thin resist top coat layer and transferred down through the stack to produce high aspect ratio carbon hard mask structures suitable for substrate etching.

2. Mechanical Characterization

Measurements of surface roughness and mechanical characteristics performed by AFM and nanoindentation.

Bare silicon | IM-HM-110 | IM-HM-120
---|---|---
Average Roughness | 0.28 nm | 0.36 nm | 0.28 nm
RMS Roughness | 0.35 nm | 0.49 nm | 0.36 nm
Peak to Valley | 4.57 nm | 4.81 nm | 3.12 nm
Young’s Modulus | 130 – 170 GPa | 5 – 6 GPa | 4.7 GPa
Hardness | 8.7 GPa | 860 MPa | 1.15 GPa

3. Fullerene Derivatives

A range of fullerene derivatives have been investigated for etch behavior. Etch tests on 10 μm patterned strips have been performed to measure the etch rates in silicon etching, compared to a control resist.

4. Fullerenes

The etch resistance of the fullerene based material allows high-aspect ratio plasma etching from a very thin film and at high-resolution.

5. Fullerene Hard Mask

Fullerene derivatives are dissolved in cyclohexane, mixed in equal parts with a crosslinker and spin coated onto silicon substrates. After baking on a hotplate at 300 °C the material is rendered insoluble in common solvents.

6. Summary and Outlook

The use of multilayer hard masks is now essential for the semiconductor industry to produce devices at ever shrinking dimensions, particularly given recent developments in three dimensional device architectures, such as FinFET and Intel trigate devices.

The fullerene based hard mask materials outperform existing state of the art materials across several critical performance metrics, whilst maintaining the advantages of spin-on materials over CVD deposited carbon.

New formulations under development offer:
- further improved thermal stability
- increasedetch resistance
- alternative casting solvents

The Irresistible Materials HM-140 hard mask formulation is currently available from MicroChem, a US based supplier of specialist chemicals for microlithographic applications (via a non-exclusive license agreement).

Acknowledgements

The authors gratefully acknowledge support from the EPSRC and the UK Semiconductor Industry.