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## Spin-on-carbon hard masks utilising fullerene derivatives

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# **Spin-on-Carbon Hard Masks utilising Fullerene Derivatives**

A.G. Brown<sup>a</sup>, A. Frommhold<sup>b</sup>, T. Lada<sup>c</sup>, J. Bowen<sup>d</sup>, Z. el Otell<sup>e</sup> and A.P.G. Robinson<sup>b</sup>

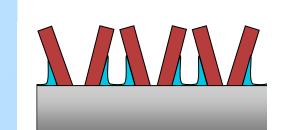
<sup>a</sup>Irresistible Materials Ltd., Langdon House, Swansea Waterfront, Swansea, SA1 8QY, UK <sup>b</sup>School of Chemical Engineering, The University of Birmingham, Birmingham, B15 2TT, UK <sup>c</sup>Nano-C Inc., 33 Southwest Park, Westwood, MA 02090, USA <sup>d</sup>Department of Engineering and Innovation, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK <sup>e</sup>IMEC, Kapeldreef 75, 3001 Leuven, Belgium



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## Introduction

of lithographic resolution requires advance The 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.



### Key hard mask properties

Key attributes for hard mask materials include

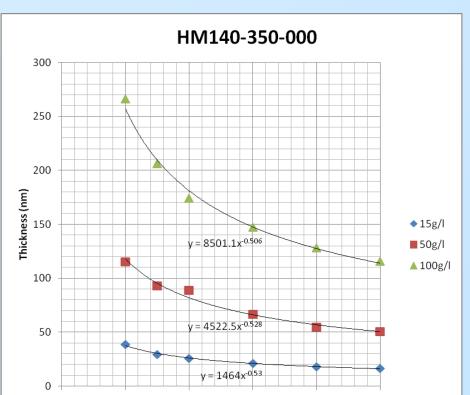
- Spin coating from standard solvents
- High thermal stability
- Low etch rate in halogen plasmas
- High etch rate in oxygen plasmas
- High resolution patterning (20 nm or better)
- Low "wiggle" at sub-30 nm

The etch resistance of the Irresistible Materials' fullerene

### HM100 series fullerene hard mask

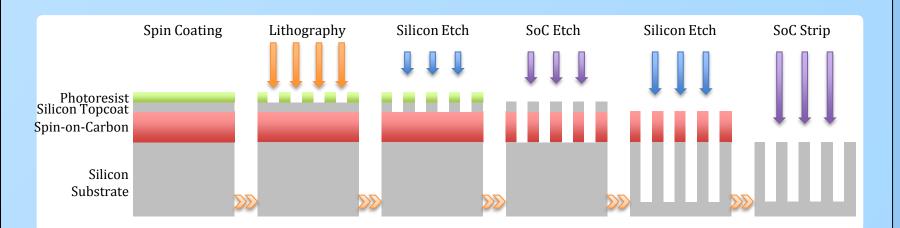
Previously reported good results for the HM100 series:

- Cyclohexanone casting solvent.
- Material available from MicroChem.



#### 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.

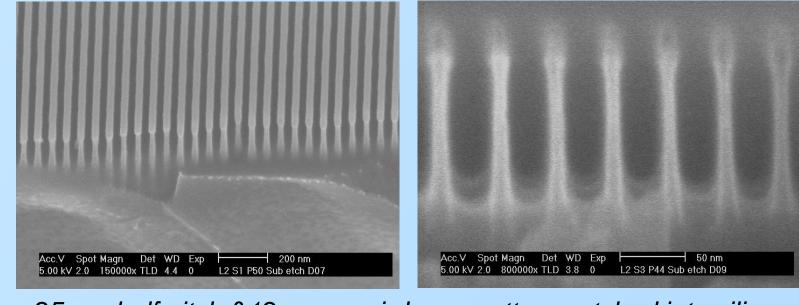


#### Process flow of tri-layer scheme

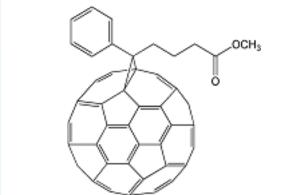
The high resolution image is captured in a thin resist top coat layer and transferred down through the stack to produce high aspect ratio carbon hard mask structures suitable for substrate etching.

based material allows high-aspect ratio plasma etching from a very thin film and at high-resolution.

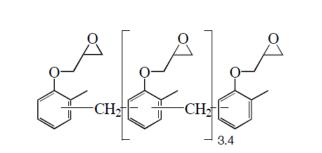
The materials have low levels of aliphatic hydrogen, which is proposed as a solution to the "wiggling" of features below 30nm, during the plasma etch step to transfer of the features to the underlying layer. - Wiggling is not observed with IM hard mask materials.



25 nm half pitch &12 nm semi-dense patterns etched into silicon



Phenyl C<sub>60</sub> Butyric Acid Methyl Ester



Poly[(o-cresyl glycidyl ether)-co-formaldehyde

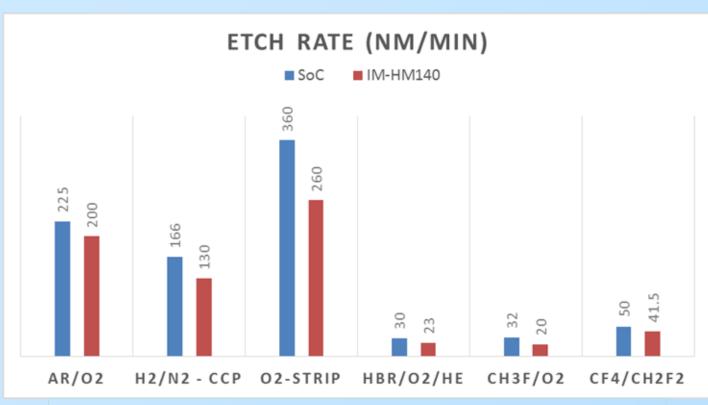
Film thickness vs. spin speed curves for HM140-350-000 series

Very good etch performance has demonstrated been by researchers at McGill University, Montreal.

#### Tests at IMEC show HM140-350-100:

- is more etch resistant than "standard" SoC for the etching amorphous-Si, SiN and SOG
- has an etch performance approaching amorphous carbon (see below).

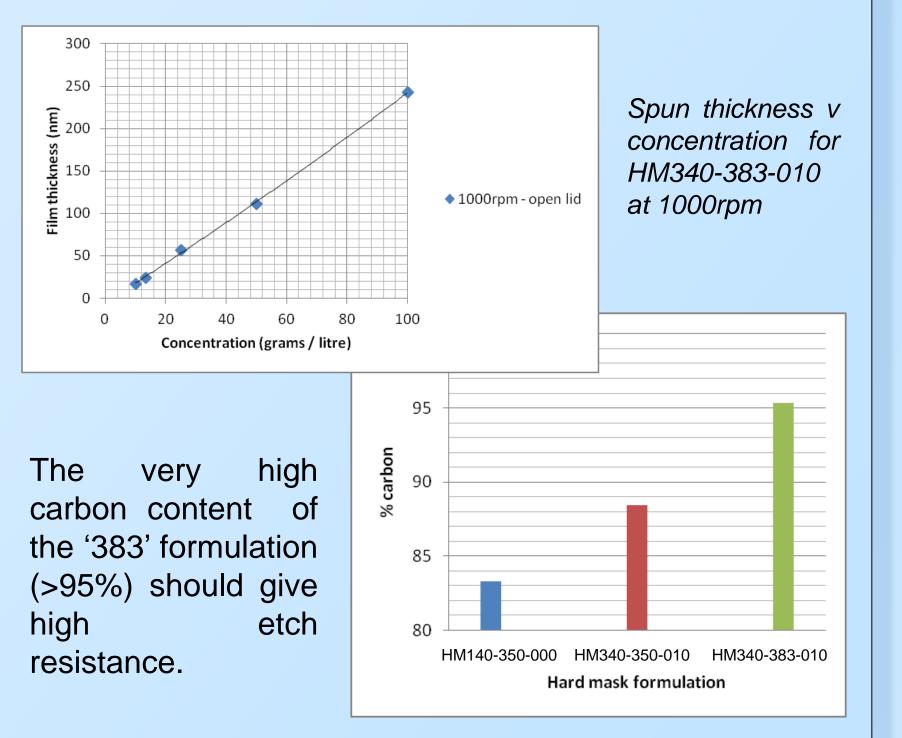
## HM140-350-100 performance



## New HM340 Hard Mask

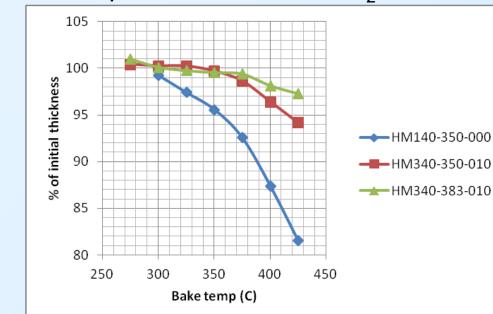
Combining the increased thermal stability and etch resistance of the new 300 series, with increased fullerene to crosslinker ratio.

The material spins from the more acceptable anisole casting solvent. High solubility, >350 g/l allows for a wide range of spun film thickness



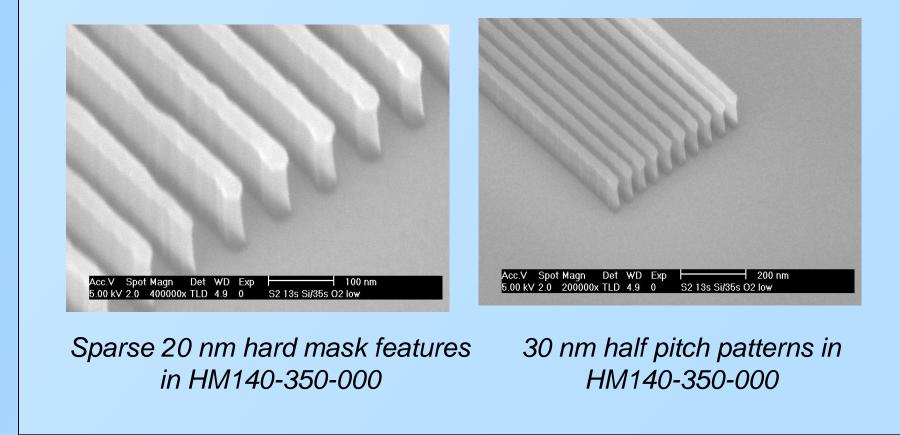
### Improved thermal stability

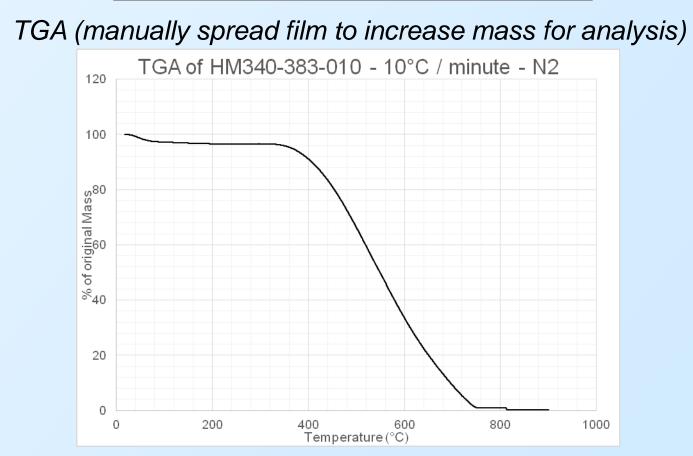
Film thickness loss with temperature - 250 nm spun films, baked in  $N_2$  for 5 minutes



#### Results of independent etch trials at IMEC

The HM140-350 series formulations use a low cost to produce mixed fullerene multi-adduct derivative, which gives no degradation in the performance as a result of the cost reduction measures.

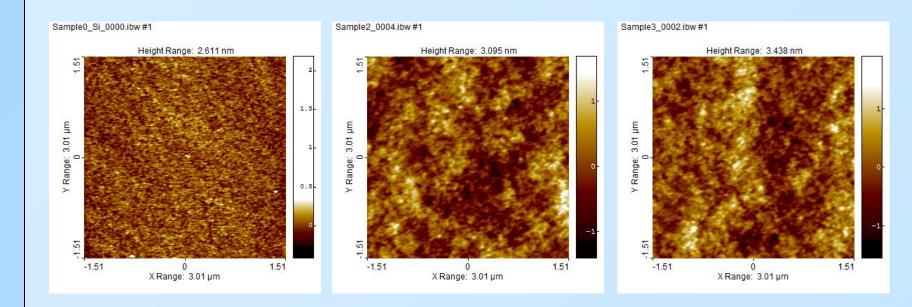




The new HM340-383-010, with a higher content of the more thermally stable fullerene derivative and a slightly higher crosslinking bake temperature, has shown improved thermal stability, both in terms of thickness loss with temperature and mass loss with temperature.

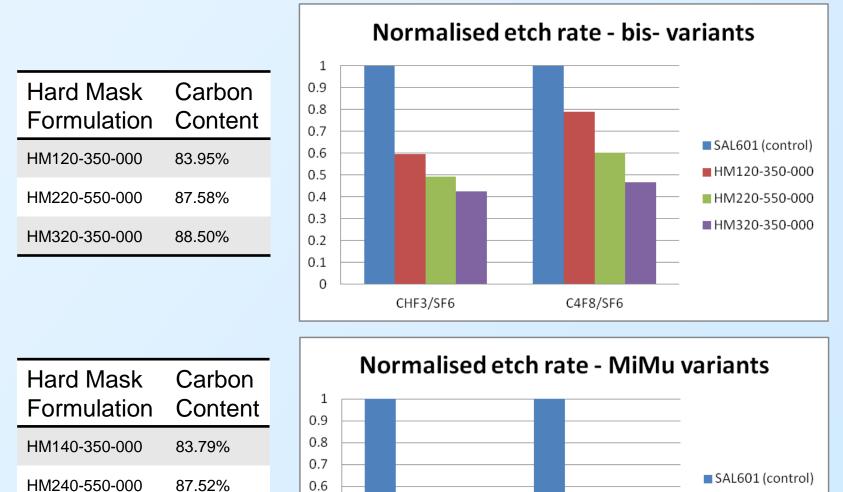
## **Roughness Characterization**

#### Measurements of surface roughness performed by AFM



### **Etch Performance**

From the etch performance data, the HM300 series was shown to give better etch performance than the HM100 series, and the HM340 is predicted to have a significantly better etch performance than the HM140.



CHF3/SF6

With the further increased carbon content (from 88.4%)

to 95.3%), the etch resistance of the HM340-383-010 is

expected to be very good. This will be verified in

0.2

HM340-350-010 88.43%

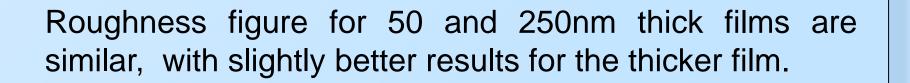
upcoming etch trials.

## Summary and Outlook

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

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

Bare silicon	HM340-3 50 nm film		M340-383-010 nm film thickness
	Bare Silicon	HM340-383-010 50nm	HM340-383-010 250nm
Average Roughness	0.070 nm	0.337 nm	0.333 nm
RMS Roughness	0.094 nm	0.422 nm	0.417 nm
Peak to Valley	2.637 nm	3.294 nm	3.288 nm



resistance. IM hard mask materials are available from MicroChem, a HM140-350-000 HM240-550-000 HM340-350-010

supplier of specialist chemicals for microlithographic applications (via a non-exclusive license agreement).

### Acknowledgements



The new HM340-383-010 has a high thermal stability and a very high carbon content, offering high etch