Spin-on-carbon hard masks utilising fullerene derivatives

Conference Item

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Spin-on-Carbon Hard Masks utilising Fullerene Derivatives

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\textbf{Introduction}

The advance of lithographic resolution requires extremely thin photoresist films for the fabrication of 1x nm\textsuperscript{2} structures, to mitigate resist collapse during development. But the use of such thin films will limit achievable etch depths.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{introduction.png}
\caption{Pattern collapse due to aspect ratio}
\end{figure}

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.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{multilayer.png}
\caption{Process flow of tri-layer scheme}
\end{figure}

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.

\textbf{HM140-350-100 performance}

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.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{HM140.png}
\caption{Results of independent etch trials at IMEC}
\end{figure}

Spin-on 20 nm hard mask features in HM140-350-000
Spin-on 30 nm half pitch patterns in HM140-350-000

\textbf{New HM340 Hard Mask}

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

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{HM340.png}
\caption{The very high carbon content of the 383 formulation (>95%) should give high etch resistance.}
\end{figure}

The material spins from the more acceptable anisole casting solvent. High solubility, \(>350\ g/L\) allows for a wide range of spin film thickness.

\textbf{Roughness Characterization}

Measurements of surface roughness performed by AFM

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{roughness.png}
\caption{Average Roughness}
\end{figure}

Bare silicon
HM340-383-010 50 nm film thickness
HM350-383-010 250 nm film thickness

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 Roughness: 2.637 nm, 3.294 nm, 3.288 nm

Roughness figure for 50 and 250nm thick films are similar, with slightly better results for the thicker film.

\textbf{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.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{etch.png}
\caption{Normalized etch rate - bio variants}
\end{figure}

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 upcoming etch trials.

\textbf{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.

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

IM hard mask materials are available from MicroChem, a supplier of specialist chemicals for microelectrographic applications (via a non-exclusive license agreement).

\textbf{Acknowledgements}