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## A Novel Approach for Controlling Process Uniformity with a Large Area VHF Source for Solar Applications

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Processing a large area substrate for liquid crystal display (LCD) or solar panel applications in a capacitively coupled plasma (CCP) reactor is becoming increasingly challenging because of the size of the substrate size is no longer negligible compared to the wavelength of the applied radio frequency (RF) power. The situation is even worse when the driving frequency is increased to the Very High Frequency (VHF) range.

When the substrate size is still smaller than 1/8 of the wavelength, one can obtain reasonably uniform process results by utilizing with methods such as tailoring the precursor gas distribution by adjusting through shower head hole distribution or hole size modification, locally adjusting the distance between the substrate and the electrode, and shaping shower head holes to modulate the hollow cathode effect modifying the plasma density distribution by shaping shower head holes to adjust the follow cathode effect. At higher frequencies, such as 40 MHz for Gen 8.5 (2.2 m×2.6 m substrate), these methods are not effective, because the substrate is large enough that first node of the standing wave appears within the substrate. In such a case, the plasma discharge cannot be sustained at the node and results in an extremely non-uniform process.

At Applied Materials, we have studied several methods of modifying the standing wave pattern to adjusting improve process non-uniformity for a Gen 8.5 size CCP reactor operating in the VHF range.

First, we used magnetic materials (ferrite) to modify wave propagation. We placed ferrite blocks along two opposing edges of the powered electrode. This changes the boundary condition for electro-magnetic waves, and as a result, the standing wave pattern is significantly stretched towards the ferrite lined edges. In conjunction with a phase modulation technique, we have seen improvement in process uniformity.

Another method involves feeding 40 MHz from four feed points near the four corners of the electrode. The phase between each feed points are dynamically adjusted to modify the resulting

interference pattern, which in turn modulate the plasma distribution in time and affect the process uniformity. We achieved process uniformity of  $<20\%$  with this method.

A third method involves using two frequencies. In this case 40 MHz is used in a supplementary manner to improve the performance of 13 MHz process. Even at 13 MHz, the RF electric field falls off around the corners and edges on a Gen 8.5 substrate. Although, the conventional methods mentioned above improve the uniformity, they have limitations, and they cannot compensate especially as the applied power is increased, which causes the wavelength becomes shorter. 40 MHz is used to overcome such limitations. 13 MHz is applied at the center, and 40 MHz at the four corners. By modulating the interference between the signals from the four feed points, we found that 40 MHz power is preferentially channeled towards the edges and corners. We will discuss an innovative method of controlling 40 MHz to achieve this effect.