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HIPIMS Arc-Free Reactive Deposition of Non-conductive Films Using the Applied Material ENDURA 200 mm Cluster Tool

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In nitride and oxide film deposition, sputtered metals react with nitrogen or oxygen gas in a vacuum chamber to form metal nitride or oxide films on a substrate. The physical properties of sputtered films (metals, oxides, and nitrides) are strongly influenced by magnetron plasma density during the deposition process. Typical target power densities on the magnetron during the deposition process are ~ (5-30) W/cm2, which gives a relatively low plasma density. The main challenge in reactive sputtering is the ability to generate a stable, arc free discharge at high plasma densities. Arcs occur due to formation of an insulating layer on the target surface caused by the re-deposition effect. One current method of generating an arc free discharge is to use the commercially available Pinnacle Plus+ Pulsed DC plasma generator manufactured by Advanced Energy Inc. This plasma generator uses a positive voltage pulse between negative pulses to attract electrons and discharge the target surface, thus preventing arc formation. However, this method can only generate low density plasma and therefore cannot allow full control of film properties. Also, after long runs ~ (1-3) hours, depends on duty cycle the stability of the reactive process is reduced due to increased probability of arc formation. Between 1995 and 1999, a new way of magnetron sputtering called HIPIMS (highly ionized pulse impulse magnetron sputtering) was developed. The main idea of this approach is to apply short ~ (50-100) μs high power pulses with a target power densities during the pulse between ~ (1-3) kW/cm2. These high power pulses generate high-density magnetron plasma that can significantly improve and control film properties. From the beginning, HIPIMS method has been applied to reactive sputtering processes for deposition of conductive and nonconductive films. However, commercially available HIPIMS plasma generators have not been able to create a stable, arc-free discharge in most reactive magnetron sputtering processes. HIPIMS plasma generators have been successfully used in reactive sputtering of nitrides for hard coating applications and for Al2O3 films. But until now there has been no HIPIMS data presented on reactive sputtering in cluster tools for semiconductors and MEMs applications. In this presentation, a new method of generating an arc free

discharge for reactive HIPIMS using the new Cyprium plasma generator from Zpulser LLC will be introduced. Data (or evidence) will be presented showing that arc formation in reactive HIPIMS can be controlled without applying a positive voltage pulse between high power pulses. Arc-free reactive HIPIMS processes for sputtering AlN, TiO_2, TiN and Si_3N_4 on the Applied Materials ENDURA 200 mm cluster tool will be presented. A direct comparison of the properties of films sputtered with the Advanced Energy Pinnacle Plus + plasma generator and the Zpulser Cyprium plasma generator will be presented.

Keywords: HIPIMS, plasma, sputtering, pulse