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Dynamics of physicochemical reactions in time-modulation of plasmas for advanced semiconductor processes[1]

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Plasma etching processes of high-aspect-ratio contact holes (HARC) and fine pattern fabrication with an atomic layer (ALE) are key technologies of semiconductor manufacturing. High-aspect-ratio contact hole (HARC) fabrications need to satisfy less damage and highly selective removal of materials, and less distortions in etched profiles, causing by the distortions of ion trajectories inside the deep contact holes due to charge build-up positively. Recently, the negative DC-bias imposition to the top electrode in the short-pulsing capacitively coupled plasma (CCP) etcher solves this issue. In atomic layer etching of silicon oxides and nitrides, fluorocarbon, hydrogen, oxygen and/or fluorine gas plasmas were alternatively performed. For such time-modulation plasmas, a rapid electron density decay was observed in the afterglow of the pulsed plasma, due to the attachment of electrons to large fluorocarbon radicals and/or parent molecules in the afterglow, which suggests the existence of an ion–ion plasma composed of negative and positive ions with negligible electrons. These dynamics of ions together with radicals in time-modulation plasma processes enables to control the physicochemical reactions on the materials towards the high performances of HARC and ALE.

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