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Chemical Bonding Structures of Low-k SiOCH films with HMDSO and O_2 precursors deposited by PECVD

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SiOC(-H) films were deposited on p-type Si(100) substrate by using hexamethyldisiloxane [HMDSO, $(CH_3)_3$-Si-O-Si-$(CH_3)_3$] and oxygen precursors and inductively coupled plasma chemical vapor deposition. The total flow rate of the precursors are maintained at 20 sccm and the flow rate ratio of R(%) = [HMDSO/(HMDSO+O_2)]100 % are varied as 25, 40, 55, 70 and 85 %. The RF power is maintained at 800 W. Film thickness and refractive index are measured by field emission scanning electron microscopy and ellipsometry, respectively. Fourier transform infrared (FTIR) spectroscopy and X-ray photoelectron spectroscopy (XPS) are used to study the various chemical bonding species, such as the Si-O-Si network: ring, open, and cage linked Si-O-C bonds: Si-CH_3: C-H_x: and -OH related bonds, in the SiOC(-H) films. As-deposited SiOC(-H) films prepared with lower flow rate ratio showed higher dielectric constant, as the flow rate ratio increases the dielectric constant gradually decreased to a lowest value of 2.1 for the flow rate ratio of 85 %. The more amount of CH and CH_3 groups and cage structure of Si-O bonds in the film is responsible for the lowering the dielectric constant in the SiOC(-H) films, and some of the Si-O-C open-linked bonds change into cage-linked bonds in which CH and CH_3 groups are incorporated in the Si-O-C bonding structure.