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Co-development of stress and texture in TiN films, revealed by in situ film stress measurements

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Titanium nitride coatings (TiN) are used amongst other applications as wear-protective coatings or as diffusion barriers in IC technology. In these applications the film stress is a key factor determining the performance of the coating.
Two series of TiN films with thickness up to 100 nm were deposited on Si wafers by reactive DC magnetron sputtering at a temperature of 360 °C. In one series the substrate bias was kept at -155V, while the pressure was varied from 0.4 to 0.6 Pa. In the other series the pressure was kept at 0.4 Pa and the bias was varied from -120V to -155V. With a two-laser beam set-up we measured the change in wafer curvature and hence the film force during film growth. From the film force the average stress and the instantaneous stress are derived.
At a deposition pressure of 0.4 Pa and a bias voltage of -155V the films are dense, exhibit a high compressive stress and a dominant 001 texture at all thicknesses. Increasing the pressure to 0.6 Pa or decreasing the bias to -120V has an identical effect on the film stress. At the initial growth some stress develops, but not in the higher parts of the film; no more film force is added. This evolution we explain from the energy of the ions arriving at the growing film. Going from 0.4 Pa to 0.6 Pa the sheath is no longer collisionless (The most likely collision process for an argon ion in the sheath is resonant charge transfer [Phelps, J. Phys. Chem. Ref. Data 20 (1991) 558]) and the argon ions will on average have a lower energy than 155 eV due to collisions in the sheath. The same effect is obtained by reducing the bias voltage from -155 V to -120V. A less energetic ion bombardment will lead also to a 111 texture [Greene et al., APL 67 (1995) 2928]. In turn, the 111 texture is less open and therefore less susceptible to stress generation by ion bombardment. A texture change over film thickness from 001 to 111 will therefore result in a change in film force and hence film stress.

Keywords
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