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Layer by layer etching of $LaAlSiO_x$

HISATAKA HAYASHI, Toshiba corporation

In order to fabricate a gate transistor with high-k oxide materials, removal of high-k oxide films after gate electrode etching is necessary for the formation of ohmic contacts on source and drain regions. It is crucial that the removal process of high-k oxide film by dry etching is highly selective to and low in damage to the Si substrate in order to avoid the degradation of device performances. Sasaki et al. have achieved a high $LaAlSiO_x$-to-Si selectivity of 6.7 using $C_4F_8/Ar/H_2$ plasma [1]. In the $LaAlSiO_x$ etching process using $C_4F_8/Ar/H_2$ plasma, H_2 plays a role in breaking the metal-oxygen bond to enhance etching of $LaAlSiO_x$ [1]. Based on this result, the process was decomposed into two steps: a surface modification step using H_2 plasma to break the metal-oxygen bond, and a removal step using C_4F_8/Ar plasma. A sequential layer by layer etching could realize low damage etching, similar to atomic layer etching. Therefore, a sequential $LaAlSiO_x$ etching process using a H_2 surface modification step followed by a removal step using C_4F_8/Ar plasma is investigated. Experiments were carried out on 300 mm diameter wafers using the 100/13.56 MHz dual frequency superimposed capacitively coupled plasma reactor. The etching gases were H_2 and C_4F_8/Ar for each step, respectively. Plasma process conditions were 100 MHz power of 1000 W (plasma generation), 13.56MHz power varied from 0 W to 300W (ion energy control). The substrate temperature was 40 C. 15nm thick $LaAlSiO_x$ blanket film was used for evaluation of the etched amount. Film thickness was measured by X-ray fluorescent analysis thickness meter before and after plasma exposure. The etched amount of $LaAlSiO_x$ by the C_4F_8/Ar plasma step doubled with H_2 modification. It is confirmed that when the C_4F_8/Ar plasma treatment time is sufficient to remove the surface modification layer, a self-limiting reaction is realized. Furthermore, it is confirmed that the etched amount per step can be controlled by control of the ion energy of H_2 plasma. [1] T. Sasaki, K. Matsuda, M. Omura, I. Sakai, and H. Hayashi: Jpn. J. Appl. Phys. 54 (2015) 06GB03.