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Marbled texture of sputtered Al/Si alloy thin film on Si

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ABSTRACT

DC magnetron sputtering is a commonly used technique for the fabrication of silicon based electronic devices, since it provides high deposition rates and uniform large area metallization. However, in addition to the thickness uniformity, coating optical uniformity is a crucial need for semiconductor industrial processes, due to the wide use of optical recognition tools.
In the silicon-based technology, aluminum is one of the most used materials for the metal contact. Both the pre-deposition substrate cleaning and the sputtering conditions determine the quality and the crystalline properties of the final Al deposited film. In this paper is shown that not all the mentioned conditions lead to good quality and uniform Al films. In particular, it is shown that under certain standard process conditions, Al/Si alloy (1% Si) metallization on a [100] Si presents a non-uniform reflectivity, with a marbled texture caused by flakes with milky appearance. This optical inhomogeneity is found to be caused by the coexistence of randomly orient Al/Si crystal, with heteroepitaxial Al/Si crystals, both grown on Si substrate. Based on the microstructural analysis, some strategies to mitigate or suppress this marbled texture of the Al thin film are proposed and discussed.

1. Introduction

Aluminum is a widely used metal both as primary interconnect material in integrated circuits and as forming Ohmic (to p-type silicon region and to heavily-doped n regions) or rectifying contacts (to lightly doped n regions) in discrete silicon devices (e.g. diodes or transistors) [1].

In addition to the properties of the material (namely conductivity, overall processability, good adherence to the silicon dioxide surface, easy to be patterned), which make aluminum ideal for silicon metallization, the variety of Physical (PVD) and Chemical (CVD) Vapor Deposition techniques allow to achieve high productivity and reliability at industrial level.

Among PVD deposition techniques, DC magnetron sputtering is very popular in the semiconductor industry, because it allows the control of the metal layer composition, overcoming oxide formation problems associated with conventional sputtering, the thickness control accuracy and a high deposition rate [2]. Moreover, it allows the direct deposition of Al/Si alloys, which is the most commonly adopted method to inhibit the aluminum silicon interdiffusion at the contacts, causing junction spiking [3].

However, the polycrystalline structure of deposited Al films can influence the electronic properties of electronic devices, through atomic (electro or stress induced) migration along grain boundaries [4–7].

The hetero-epitaxial growth of Al on Si is then required to avoid the inter-grain atomic diffusion. However, Al on Si hetero-epitaxy requires an accurate control of the deposition parameters to get a uniform metal coverage over the entire Si wafer substrate and to ensure high product reliability especially for batch deposition.

During a systematic study aimed to individuate the optimal Al/Si deposition conditions to fabricate Si Schottky diodes, it was find an apparent marbled textured Al/Si film as shown in Fig. 1A. This photograph, taken under standard diffuse illumination conditions of the Al/Si layer deposited by DC magnetron sputtering on a 6″ Si wafer, shows the presence of "milky" flakes, randomly dispersed throughout the wafer surface.

Although there is no evidence of remarkable effects on the electronic properties of the Al/Si contacts, this optical non-uniformity must be reduced not only for an aesthetic issue, since it can affect both the automatic alignment accuracy and critical size obtained during photolithographic processing [8].

To the best of our knowledge, this "marbled texture" has not been previously reported and explained. In this study, the results of different analyses are described and the correlation between the microstructure, surface roughness and crystal orientation with the optical reflectivity of

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