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STRUCTURE AND GETTERING PROPERTIES OF POLYCRYSTALLINE SILICON LAYERS

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The polycrystalline silicon layers deposited on the backside of semiconductor wafers prior to any high temperature process are used for removing unwanted impurities from the device area already for about 30 years. Solubility of heavy metals in the polycrystalline silicon at a high temperature (around 1000°C) is generally more than an order of magnitude higher than in the silicon substrate. Polycrystalline layer enhances the gettering capability of the semiconductor wafer by about two orders measured by the Method of Controlled Contamination (MCC) [1] and it is very sufficient for gettering of heavy metals as copper, nickel or iron. Unlikely after the first high temperature process the polycrystalline layer partially recrystallizes and thus loses a great part of its gettering capability.

By the measurement of gettering capability by the MCC we found that the gettering capability of the polycrystalline layer decreases after the high temperature annealing (1100°C) by about 1.5 orders. As the polycrystalline layer is deposited nearly at the beginning of the process of device fabrication, it will experience several high temperature annealing steps. After each annealing the grain size of polycrystalline silicon layer significantly increases and this results in the loss of gettering sites and consequently of the gettering capability (see Fig.1). The solubility of metals in the annealed layer is going to be close to their solubility in the crystalline substrate.

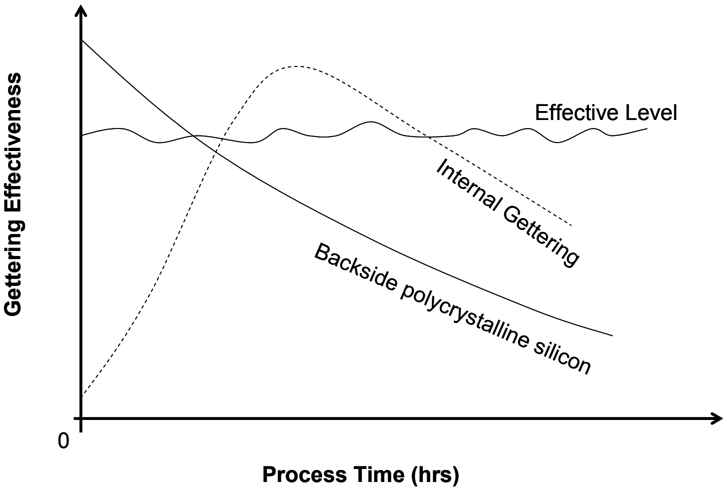

Fig. 1. Effectiveness of gettering techniques as a function of process time. During high temperature process the backside polycrystalline layer partially recrystallizes and thus loses a great part of its gettering capability. Excerpted from [4].

Recrystallization involves the transdiffusion of silicon atoms from one grain to the others as the grains agglomerate. This transdiffusion involves the breaking of Si-Si bonds. By introducing the silicon dioxide layers inside the polycrystalline silicon layer it is possible to create a lot of Si – SiO_2 interfaces directly inside the polycrystalline layer. At these interfaces the Si atoms are bonded to oxygen atoms. It is easier to break the Si-Si bond with the binding energy of 42 kcal/mol than Si-O bond with the binding energy of 185 kcal/mol [2]. Therefore, the silicon atoms involved in the oxide bonding would be left essentially undisturbed during annealing. Where the oxide layer does not exist, the Si atoms are free to diffuse unhindered regardless of their location in the film. If the oxide layers are present in the polycrystalline layer, Si atoms are limited in diffusion and simultaneously recrystallization of the polycrystalline layer is limited.

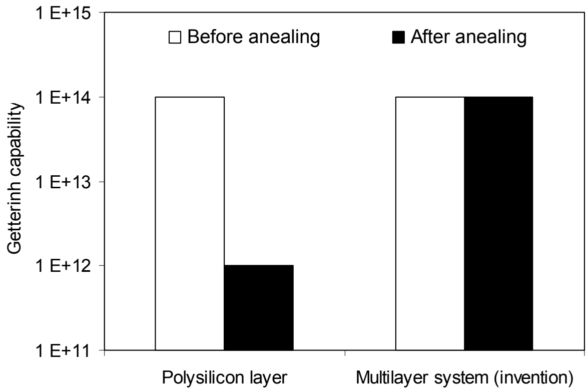

Fig. 2. Gettering capability measured by MCC method before and after high temperature annealing (3 hours on 1100°C). Multilayer system does not lose its initial gettering capability after annealing.

By introducing silicon dioxide layers into the polycrystalline the multilayer system of polycrystalline silicon – silicon dioxide layers is created (developed in ON Semiconductor [3]). Number and thickness of the silicon oxide layers as well as polycrystalline silicon layers are critical in order to achieve good properties of the whole multilayer system. Thick silicon dioxide layer can create diffusion barrier for diffusing impurities and prevent impurities from reaching the polycrystalline layer. Very thick polysilicon layer is not convenient because Si atoms will be not restricted in diffusion and grains of the layer will agglomerate. Therefore, engineering of the multilayer system growth is very important and determines the future properties and mainly the gettering capability of the multilayer system. Fig. 2 shows comparison of gettering capabilities of common polycrystalline silicon layer and multilayer system measured by MCC method before and after high temperature annealing (3 hours at 1100°C). Multilayer system does not lose its initial gettering capability after annealing.

Utilization of multilayer system of polycrystalline silicon – silicon dioxide for backside gettering as well as the idea of its function is subject of US Patent proceedings and is proprietary of ON Semiconductor Czech Republic.

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