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Development of Cleaning Solution for Germanium (Ge) Wafer

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Abstract
In this paper, we worked on development of cleaning solution for Ge surface and characterization from the electrical point of view. Samples supplied from two companies (Umicore and TDY Corporation) were cleaned by three different cleaning solutions (HF, HCl, and mixed HF-HCl), and subsequently heated by an electric furnace. Carrier mobility and bulk carrier concentration were measured by Hall system and compared these values for different samples. Cleaning by HCl gives better performance than HF and mixed HF-HCl solutions.

1. Introduction

Semiconductor materials has many applications in modern devices because their electrical properties can be easily changed by adding impurities and silicon (Si) substrate is commonly used for these applications. However, the scaling of advanced MOS devices is approaching its technological and fundamental limits. [1] Because continuous reduction in the process technology and gate length causes leakage current flows through the gate and mobility deration problems in the substrate. Therefore, new high-*k* material and high mobility substrates are mandatory.

Many researchers have found several candidates [2-4] of high mobility channel material including germanium (Ge). Ge offers higher hole and electron mobility than Si [4], and has good affinity with Si. In order to fabricate the devices on Ge, surface contaminants should be in minimum levels with minimal increase in surface roughness.

There is well established cleaning method [5] for Si surface. For Ge surface cleaning, scientists have applied various chemicals [6] to remove contaminants as well as used different equipment [7-9] to measure surface roughness. Till now there is no widely accepted cleaning method for Ge surface.

2. Methods

2.1. Cleaning Procedures

Eight 1x1 cm^2 n-type Ge wafers are collected from Umicore and TDY Corporation (four from each company). All samples are degreased by acetone with ultrasonic for 3min, and then washed five times in running deionized (DI) water followed by DI water with ultrasonic for 2min, and washed in running DI water. Three concentrations of HF (45% HF: DI water=1:5), HCl (35% HCl: DI water=1:1), and mixed HF-HCl (45% HF: 35% HCl: DI water=1:1:5) are prepared. Two samples from different vendor are immersed into HF solution for 1min and then washed in running DI water. Again these samples are dipped into HF for another 1min and washed. This procedure is repeated for five times. Other two pairs of sample are immersed into HCl and mixed HF-HCl solution respectively for 1min. Subsequently washed in running DI water for five times. Finally, all samples are dried by N_2 gas and placed into an electric furnace. Heat treatment is performed at 600^{0}C for 30min in presence of N_2 gas inside of the chamber.

2.2. Electrode Formation

Electrode is formed on cleaned wafer for further measurement and Titanium nitride (TiN) is suitable for making Ohmic contact in n-type Ge, and is formed by sputtering. Ar

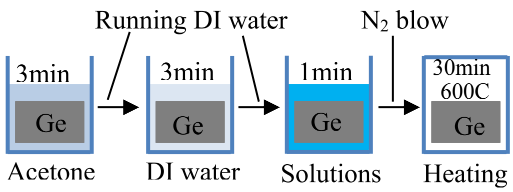

Fig 1. Flow of Ge surface cleaning

and N_2 gases of 30 and 0.1sccm respectively are introduced when the chamber was pumped down to vacuum level. After addition of these gases, set pressure to 6Pa with RF power 200W for 1min 30sec to grow 27nm of TiN on Ge samples. TiN was developed close to the four corners by the help of a metal mask that had four holes (Fig. 2a). For better probe connection and measurement, aluminum (Al) is deposited on TiN position because the grown TiN is hard and is done by evaporation technique after placing small Al pieces into the evaporator. The machine is turned OFF, once 200nm thick Al is deposited on TiN (Fig.2b).

3. Results and Discussion

Samples that experienced chemical cleaning and heating are placed into a Hall system, and obtained data from electrical point of view. The measured data contained different parameters. Among them, mobility and bulk carrier concentration are important because others can be calculated by putting these values into numerical equations and comparison of these values between samples gives the impact of different cleaning solutions. Data are measured for one pair of samples without cleaning and referred to as 'As received', and is used to compare with the data that obtained after cleaning. Fig.3 and 4 shows the majority carrier mobility and bulk carrier concentration for Umicore and TDY samples respectively.

From Fig.3, it can be clearly seen that HCl cleaning offers comparatively higher values of mobility than HF and mixed HF-HCl cleaning solutions for both companies. However, this values is smaller than samples value when no cleaning solution and heating are employed. In Fig.4, both HF and mixed HF-HCl cleaning solution exhibits higher

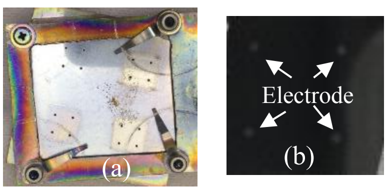

Fig 2. (a) Metal mask, (b) Top view of a sample after electrode formation

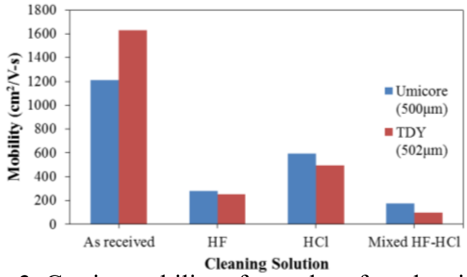

Fig 3. Carrier mobility of samples after cleaning

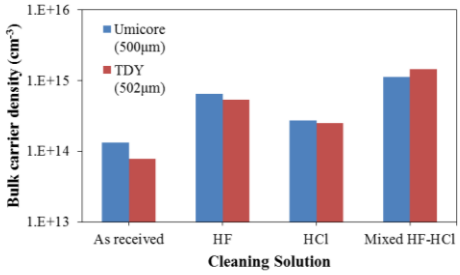

Fig 4. Carrier concentrations after cleaning

values of carrier concentration than HCl. Higher values of carrier concentration is due to the effect of contaminants i.e. less removal of contaminants from the surface. Mixed HF-HCl solution gives worst results in both cases of mobility and carrier concentration.

4. Conclusion

Three different chemical solution was employed for Ge surface cleaning and found HCl solution brought better impact for Ge cleaning in terms of mobility and carrier concentration regardless of the samples provided by two companies.

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