Fabrication of Ohmic Contacts to 4H-SiC Created by Ion-Implantation*

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Abstract Doping by nitrogen ion-implantation is used to fabricate the Ohmic contacts of 4H-SiC. The implantation depth profile is simulated with the Monte Carlo simulator TRIM. Ni/Cr/Si-face 4H-SiC Ohmic contacts are measured by Transfer Length Method structures. The result for sheet resistance R_{sh} of the implanted layers is 30 kΩ/square. The specific contact resistances r_c of Ohmic contacts is 7.1×10^{-4} Ωcm^2.

Key words Silicon carbide; ion implantation; Ohmic contact; sheet resis tance

4H-SiC离子注入层的欧姆接触的制备*

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【摘要】用氮离子注入的方法制备了4H-SiC欧姆接触层。注入层的离子浓度分布由蒙特卡罗分析软件 TRIM 模拟提取，Si面4H-SiC-Ni/Cr合金欧姆接触的特性由传输线方法结构进行了测量，得到氮离子注入层的方块电阻R_{sh}为30 kΩ/square, Ni/Cr合金与离子注入层的欧姆接触电阻r_c为7.1×10^{-4} Ωcm^2。

关 键 词 SiC; 离子注入; 欧姆接触; 方块电阻

中图分类号 TN405 **文献标识码** A

Silicon carbide (SiC) is a wide-bandgap semiconductor and has outstanding properties, such as high breakdown field and saturation electron drift velocity. It has been used for fabricating high-temperature, high-power, and high-speed devices. Ion-implantation of dopants has been recognized as a crucial means of selective area doping because thermal diffusion rates of most dopants are very low in SiC at the temperatures lower than 1 800 ℃～2 000℃. Doping of SiC by ion-implantation and its effects on devices have been carried out by experimental and theoretical investigations[1~5]. Implantation range (the location of peak concentration and the longitudinal straggling of implanted ions) and damages after high temperature annealing are often simulated by Monte Carlo methods[6,7]. Metal-semiconductor field-transistors (MESFETs), high electron mobility transistors (HEMTs), static induction transistors (SITs) and so on, usually need to form Ohmic contacts by ion-implantations, so it is urgent to study the characteristics of Ohmic contacts of the implanted layer, such as the specific contact resistances r_c, and the sheet resistance R_{sh} of the implanted layer.

In this article the process of nitrogen ions implanted into P type 4H-SiC epilayer and the fabrication process of the Ohmic Contacts made on the implanted layers are presented in detail. The profile of ion-implantation into SiC is simulated using TRIM. Then the specific contact resistance of the Ni/Cr contacts made on the implanted layer

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and the sheet resistance of the implanted layers are analyzed by the linear TLM method [8,9]. This study is expected to have an assistance on the fabrication of multiple ion implanted 4H-SiC MESFETs hereafter.

1 Experimental Procedures

4H-SiC wafer used in this experiment was purchased from Cree Research Company. Orientation of the substrate is 8° off-axis <1 000> direction. The patterns are made on a *p*-type epitaxial layer with concentration of N_a=6.5×10^{15} cm^{-3} and depth of 1.8 μm based on the *n*-type silicon faced substrate with concentration of N_d=7.1×10^{18} cm^{-3}. *N*-wells are formed by multiple nitrogen ions implantation into epilayer at temperature of 500℃ after deposited 450 nm SiO_2 by LPCVD. The energies and doses for ion implantation are 55 keV and 1.07×10^{13} cm^{-2}, 100 keV and 1.53×10^{13} cm^{-2}, 160 keV and 1.95×10^{13} cm^{-2} respectively. Then N^+ regions for Ohmic contacts are formed with 30 keV energy and 3.54×10^{14} cm^{-2} high dose nitrogen ion implantation at temperature of 500℃ after re-patterned. The *N*-well area is 664×190 μm^2 and the N^+ region is 80×170 μm^2. The structure of the TLM pattern used in this study is shown in Fig.1. The spacings of seven rectangular N^+ regions are 4, 8, 12, 16, 20 and 24 μm. After chemically cleaned in BHF(buffer agent of hydrofluoric acid), the sample is annealed up to 1 480℃ in 100℃ per 30 m, lasting 30 m at 1 480℃ and then free-cooling without stopping argon source, by using a ceramic sintering furnace in pure argon atmosphere. Finally, the Ohmic contacts are patterned through conventional photolithography and lift-off techniques. Ohmic contacts windows are formed with an area of 60×150 μm^2, and Ni/Cr and Au are evaporated respectively and alloyed at 900℃ for 30 m in a vacuum furnace to realize Ohmic contacts.

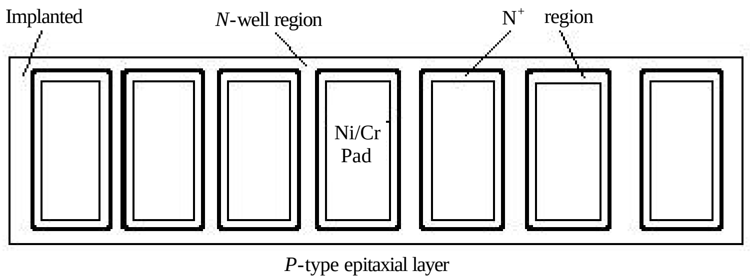

Fig.1 TLM structure used to determine the specific contact resistances and sheet resistance.

2 Results

The location of peak concentration and the Longitudinal straggling of *N* are calculated with the Monte Carlo simulator TRIM. Fig.2 shows the ion implantation profiles with the Gaussian model to simulate the ion implantation ranges.

S. Seshadri received 6.3 percent activation by 1 300℃ annealing and near complete activation by annealing at temperatures above 1 500℃ for nitrogen[1]. As a contrast an experiment late carried out by E.M. Handy indicated that a 15 m implant activation at 1 500℃ results in 15 percent nitrogen activation[2]. Thus it can be seen, the activation of ions are dependent on not only the annealing temperature but also conditions such as the heating, duration and descending time, the container, and the environment gas and so on. As expected, The activation of *N* by annealing in the range of 1 400℃～1 500℃ is about 10%～20%. The implanted profile shown in Fig.2 is expected to result in an effective doping concentration of 1.5×10^{17} cm^{-3}.

Fig.3 shows the variations of the total resistance R_T between adjacent TLM pads as a function of gap spacing *L*. In order to reduce the errors, the linear curve shown in Fig.3 is the median values from multiple measurements. By assuming that the length of each contact is long enough, the total resistance R_T can be expressed in the form[8]:

$$R_T = 2R_C + \frac{R_{sh}L}{W} \tag{1}$$

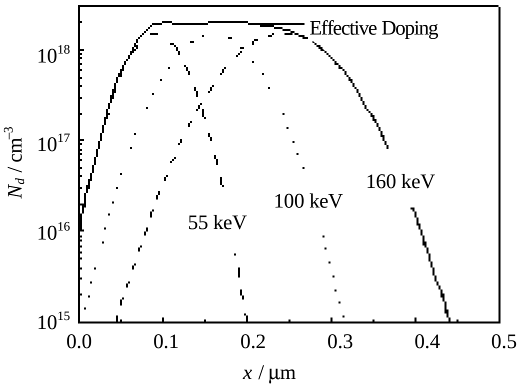

Fig.2 Simulated ion implantation profiles for N implants into 4H-SiC

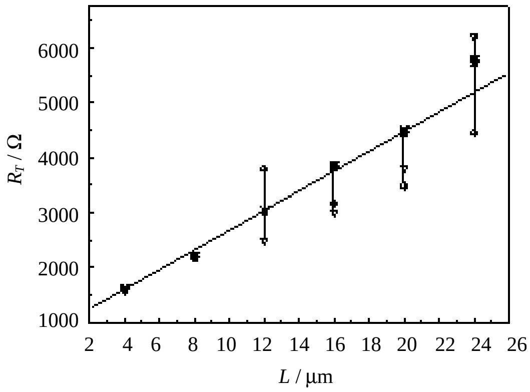

Fig.3 TLM total resistance versus gap spacing

where W is the width of the contacts, $2Rc$ is the y-interception of the linear curve. The specific contact resistances r_c can be given as

$$r_c = \frac{(R_c W)^2}{R_{sh}} \tag{2}$$

Therefore, sheet resistance R_{sh} is W multiplied by the slope dR_T/dL of the linear curve shown in Fig.3. The resulting values for sheet resistance R_{sh} of the implanted layer are 30 kΩ/square. The specific contact resistances r_c of Ni/Cr/4H-SiC calculated from (2) are 7.1×10^{-4} Ωcm^2.

The depth d of N implanted layer is 0.24 μm simulated by TRIM. So the resistivities $r(R_{sh}\times d)$ of the implanted layer is 0.72 Ωcm.

The specific contact resistances r_c is high compared with the results of Zhang [10], whose specific contact resistances of Ni/Cr (4:1 at weight) alloy on N-type 6H-SiC epilayer is 8.4×10^{-5} Ωcm^2. The doping concentration of the N-type epilayer of Zhang is 8.0×10^{17} cm^{-3}, while the Ohmic contacts in this work is made on ions implanted layer. The high value of the specific contact resistances r_c is perhaps low activation efficiency of N implanted layer and low alloying temperature (900℃) for Ohmic contacts.

3 Conclusions

An array of TLM structures is formed on N-wells created by N ion implantation into Si faced p-type 4H-SiC epilayer. In stead of mesa isolation by reactive ion etching, the electrical isolation was PN junction. Each set of the TLM pattern consists of seven rectangular N^+ regions by N implantation, with varied spacings (4～24 Ωm). Ni/Cr and Au are evaporated respectively and alloyed at 900℃ for 30 m in a vacuum furnace to realize Ohmic contacts. The resulting values for sheet resistance R_{sh} of the implanted layer are 30 kΩ/square. The specific contact resistances r_c of Ni/Cr/4H-SiC are 7.1×10^{-4} Ωcm^2.

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    coclass BridgeComponent
    {[default] interface IbridgeComponent };
};
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2.4 效果

在测试中，通过客户端程序发送一个客户信息和定货号，通过桥接组件连接到CORBA服务器调用函数计算价格，然后CORBA服务器返回价格到客户，总共时间开销为5~6 ms，符合开发的要求。在实际开发中要解决一些问题，如控制CORBA服务器的生存期、数据库的同步、获取数据及类型的完整性等。

3 结 束 语

创建跨平台分布式系统已成为开发大型软件系统的一种重要选择。可以充分发挥UNIX等操作系统的稳定性，又可以利用Windows平台下图形化界面良好的可操作性，还可以避免对某一种平台的过分依赖。本文利用COM与CORBA的桥接，成功地把原有的系统扩展为跨平台的分布系统，充分利用UNIX和Windows的优点，改善了原系统的不足。

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