GROWTH OF GaN:Mn DMS AND GaN/GaN:Mn STRUCTURE ON SILICON SUBSTRATE BY PA-MOCVD METHOD FOR MTJ DEVICE APPLICATION

Aip Saripudin [(1)], Budi Mulyanti [(1)], Pepen Arifin[(2)]

[(1)]Jurusan Pendidikan Teknik Elektro, Fakultas Pendidikan Teknologi dan Kejuruan, Universitas Pendidikan Indonesia, Bandung. [(2)]Lab Fisika Material Elektronik, Program Studi Fisika, Fakultas Matematika dan Ilmu Pengetahuan Alam, Institut Teknologi Bandung, Bandung

ABSTRACT

Heterostructure of GaN:Mn/GaN on silicon substrate has been grown succesfully. GaN film has been grown on silicon substrate by using PA-MOCVD (*plasma assisted metal organic chemical vapor deposition*) method at temperatur of 650^{o}C – 700^{o}C. On the other hand, GaN:Mn film has been done on GaN film by using ion implantation technique. Mn ion has been implanted on top layer of GaN film. The successful of heterostructure of GaN:Mn/GaN grown was shown by SEM and EDX characterization. Electrical properties measurement show that Mn doping has not change semiconductor properties of GaN as host semiconductor.

Keywords: GaN, GaN:Mn, PA-MOCVD, Ion Implantation, SEM, EDX

INTRODUCTION

The basic and important spintronics device is *magnetic tunnel junction* (MTJ). This device consist of two layer of ferromagnetic material spaced by very thin nonferromagnetic layer. When spin of electrons in both side of ferromagnetic material have the same orientation (paralel), the applied voltage caused electrons to tunnel the interface of two material. On the other hand, if the orientation of electron's spin are not the same (antiparalel), no electron tunnel the interface of two material. MTJ is a base of MRAM (*magnetic random acces memory*) developed by Motorola, *Inc.* dan IBM, *Corp*, one per memory cell (Zorpette, 2001).

The main requirement that a material can be realized as spintronic device is that the material has ferromagnetic properties at room temperature and high spin injection efficiency, ~ 100%, (Reed, 2003). One of the material that satisfy the requirement is ferromgnetic metal used as contact. But, it's spin efficiency still poor (Schmidt, *et al*, 2002) because of interface layer formation between ferromagnetic metal and nonmagneic metal is not fully ohmic (Pearton, *et al*, 2003). Therefore, it need a new material, i.e., *diluted magnetic semiconductor* MS) that has ferromagnetic properties at room temperature (Ohno, *et al*, 1996).

The new material developed by researcher is GaN:Mn because GaN:Mn shows erromagnetic properties above room temperature. It is ideal for spin injection and match with established semiconductor technology.

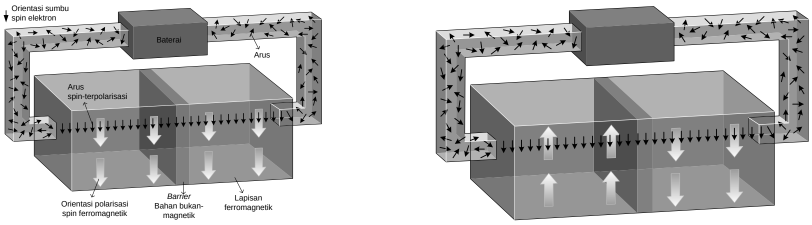
This research is focused on growth of GaN:Mn/GaN heterostructure on silicon substrate for MTJ device application.

LITERATURE VIEW

1. MTJ Device

The basic and important spintronics device is *magnetic tunnel junction* (MTJ). This device consist of two layer of ferromagnetic material spaced by very thin nonferromagnetic layer. The basic principles of this device is shown in **Figure 1**.

When spin of electrons in both side of ferromagnetic material have the same orientation (paralel), the applied voltage caused electrons to tunnel the interface of two material. On the other hand, if the orientation of electron's spin are not the same (antiparalel), no electron tunnel the interface of two material. MTJ is a base of MRAM (*magnetic random acces memory*) developed by Motorola, *Inc.* dan IBM, *Corp*, one per memory cell (Zorpette, 2001).



(a) (b)

Figure 1 The basic principles of *magnetictunnel junction* (MTJ). When spin orientation of two ferromagnetic layer is paralel, electron current will flow (a). When spin orientation is antiparalel, no current flow (b) (Zorpette, 2001).

2. DMS

At early development, i.e., at the end of 1960 and the first of 1970, semiconductor properties and ferromagnetic properties is found in a semiconductor material such as *Europium chalcogenides* (e.g. EuO) dan *Spinel semiconductor* (e.g. $CdCr_2Se_4$). It's magnetics element is arranged periodically (**Fig. 2b**). In that magnetic semiconductor, exchange interaction between electron in semikonductor's band and elektron localized at magnetic ion can result in important properties such as energy band gap displacement when the ferromagnetism is generated. But, the growth of that cristal is very difficult because it needs a long time to prepare. Another difficulty is that there were not semiconductor that have lattice match. On the other word, its material is not match with established semiconductor tecnology (Ohno, 1998).

Second generation of ferromagnetic semiconductor is non magnetic semikonductor doped by magnetic elemen (transition metal ion). The magnetic ion as dopant give a magnetic moment of its electron. Alloy between non magnetic semikonductor as host and magnetic element is known as *diluted magnetic semiconductor* (DMS) or ferromagnetic semikonductor which the composition of magnetic element is very low, less than 2 % (**Fig. 2c**). The term "*diluted*" is used because of very low concentration of magnetic element. By using DMS material, it is expected that spin injection from this material into nonmagnetic material is very high.

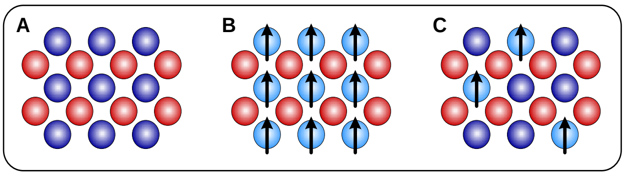


Figure 2 The classification of semikonductor materials: (a) conventional mikonductor, (b) magnetic semikonductor, andn (c) DMS (Ohno,1998).

RESULTS AND DISCUSSION

The growth of GaN thin film on silicon substrate has been done using PA-MOCVD (*Plasma Assisted Metal Organic Chemical Vapor Deposition*) method. The growth temperature is between 650^{o}C and 700^{o}C. The result is characterized by SEM and EDX as shown in **Figure 3.**

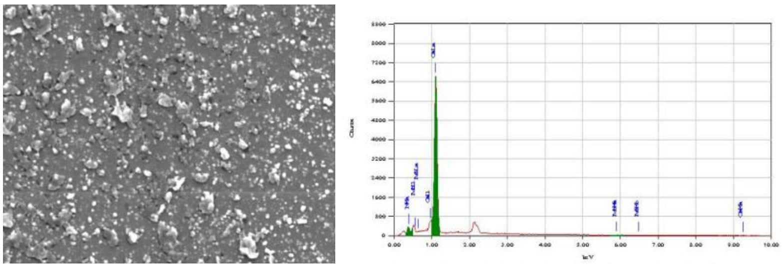


Figure 3 SEM and EDX of GaN thin film

EDX characterization shows that the peak arise at 0,4 keV is N and at 1 keV is Ga. This result shows that GaN thin film has been grown succesfully.

GaN:Mn thin film has grown by ion implantation technique. Using this technique, Mn ion beams is bombarded onto GaN thin film. The width of GaN layer doped by Mn ion was setted up so that only a part of GaN layer was doped. SEM and EDX result for one GaN:Mn thin film is shown in **Figure 5**.

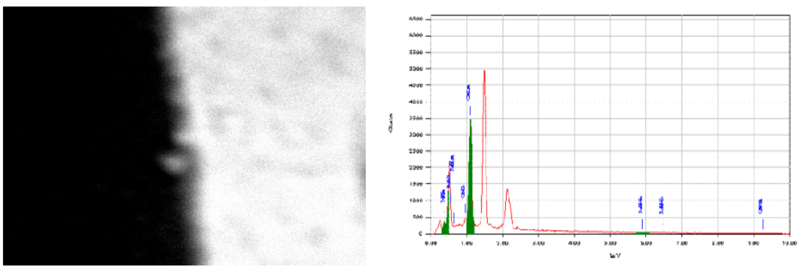


Figure 5 SEM and EDX of GaN:Mn thin film.

From **Figure 5,** it is shown that the energy peaks are 0,302 keV, 1,098 keV, and 5,894 keV for N, Ga, dan Mn respectively. EDX characterization shows the persentage of Ga = 27,25%, N = 72,13%, dan Mn = 0,57%. This result shows that

Mn ion has been implanted into GaN thin film so that GaN:Mn film has been grown succesfully.

GaN:Mn thin film's width of each sample is less than GaN thin film's width. It shows that only top layer of GaN doped by Mn ion using ion implantation technique. This fact was expected so GaN:Mn/GaN heterostructure has been grown succesfully.

CONCLUSSIONS

The GaN:Mn/GaN heterrostructure has been grown succesfully by combination methode, i.e., using PA-MOCVD method and ion implantation technique. PA-MOCVD method used to grow GaN thin film and ion implantation technique used to form GaN:Mn thin film on GaN thin film.