PHOTOLUMINESCENCE STUDY OF METAL FILM'S IMPACT ON SILICON ENERGETIC STRUCTURE

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SİLİSİUMUN ENERGETİK STRUTURUNA METAL TƏBƏQƏNİN TƏSİRİNİN FOTOLÜMİNESSENSİYA ÜSULU İLƏ ÖYRƏNİLMƏSİ

XÜLASƏ

Silisium altlıq-müxtəlif metal təbəqələr kontaktlari əsasında Şottki diodlarının struktur və optik xassələrinin öyrənilməsi ücün infraqırmızı (İQ) fotolüminessensiya tətbiq edilmişdir. Şottki diodunun xassələrinə, ayrılma sərhəddinin elektron strukturuna və yükdaşınma mexanizminə metal təbəqənin təsirini öyrənmək məqsədilə 773K temperaturunda 10 dəq. ərzində tavlanmış Şottki diodları tədqiq olunmuşdur. Bu məqsədlə silisium altlıq və müxtəlif metal-yarımkeçirici kontaktların fotolüminessensiya spektrləri alınmış və müqayisə edilmişdir. Fotolüminessensiya spektrləri silisium altlığın elektron strukturuna metal təbəqnin təsirini aşkar etmişdirlər.

Acar sözlər. Metal-yarımkeçirici kontaktları; Qeyri-bircinsliklər; Fotolüminessensiya.

ИССЛЕДОВАНИЕ МЕТОДОМ ФОТОЛЮМИНЕСЦЕНЦИИ ВЛИЯНИЯ МЕТАЛЛИЧЕСКОЙ ПЛЕНКИ НА ЭНЕРГЕТИЧЕСКУЮ СТРУКТУРУ КРЕМНИЯ

АБСТРАКТ

Для исследования структуры и оптических свойств диодов Шоттки на основе контактов кремниевая подложка-различные металлические пленки был применен метод инфракрасной (ИК) фотолюминесценции. Для изучения влияния металлической пленки на свойства, электронную структуру и механизмы токопереноса диодов Шоттки были исследованы диоды, подвергшиеся отжигу при температуре 773К в течение 10 минут. Были получены и сравнены спектры фотолюминесценции кремниевой подложки и контактов металл-полупроводник с различными металлическими пленками. Полученные спектры выявили влияние металлической пленки на электронную структуру кремния.

Ключевые слова. Контакты металл-полупроводник, Неоднородности, Фотолюминесценция.

I.Introduction

Metal-semiconductor contacts (MSC) are an essential part of virtually all semiconductor electronic and optoelectronic devices. Traditionally, investigating the properties of metal-semiconductor contact the basic attention has been gave to the semiconductor. In this cases, metal and process of fabrication of contact structure influence on the surface of the semiconductor does not take into account [1]. The aim of our researches is to reveal the metal impact on the energetic structure of the semiconductor and opportunity of use of researched structures as light-emitting diodes.

Being based on above us investigated a photoluminescence of a silicon wafer and metal-semiconductor contacts as Al/n-Si, Al-TiW/n-Si Al-TiW-Pd_2Si/n-Si and Al-PdAl/n-Si.

II. Experimental procedure

Metal-semiconductor contacts have been fabricated on the surface of n-type (P doped) single crystal silicon wafer 3 inc diameter and 313.5 μm thickness [2-5] with (111) surface orientation. Diodes structures have been fabricated by a method of a standard photolithography. Al/n-Si and Al-PdAl/n-Si metal-semiconductor contact structures have been fabricated by using electron-beam evaporation method. At the fabrication Al-PdAl/n-Si structure the metal film PdAl has been deposited by simultaneous thermal evaporation of aluminium (Al) and palladium (Pd). To fabricate Pd_2Si/n-Si layer of Al-TiW-Pd_2Si/n-Si diodes, palladium was deposited on Si wafer by using thermal evaporation method until the thickness of Pd film was about 0.6μm, subsequently annealed at 773K for 15min. To prevent the disadvantage of Al to Pd_2Si/n-Si interface the TiW alloy played the role of the diffusion barrier between Pd_2Si and Al was deposited on Pd_2Si layer [2-4]. Metal-semiconductor contacts Al-TiW/n-Si has been fabricated by the magnetron sputtering method [5].

The photoluminescence spectrum measurements were performed at room temperature by use of an Ar-lazer (488nm). At the investigations uniform method has been used. Radiation has been directed onto whole backside of wafer.

III. Result and discussion

In present investigation firs a photoluminescence spectrum of a silicon wafer has been obtained (Fig. 1). The silicon band-edge radiation is always accompanied with an additional low energy peak, which we regard as a phonon replication of the band-edge peak. The energy of observed wide peak (1.11eV) corresponds to width of the band gap of silicon at room temperature. Fig.2, Fig.3 , Fig.4 and Fig.5 show PL spectra of Al/n-Si, Al-PdAl/n-Si, Al-TiW-Pd_2Si/n-Si and Al-TiW/n-Si metal-semiconductor contact structures. On all spectra the peak corresponding to width of the silicon band gap is observed. However, its intensity and width differ for various structures.

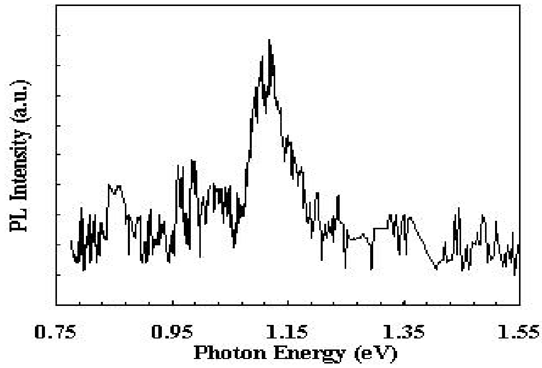

Fig.1. PL spectrum of silicon wafer

As shows Fig. 1 on a PL spectrum of silicon wafer there is the wide peak, corresponding to direct recombination

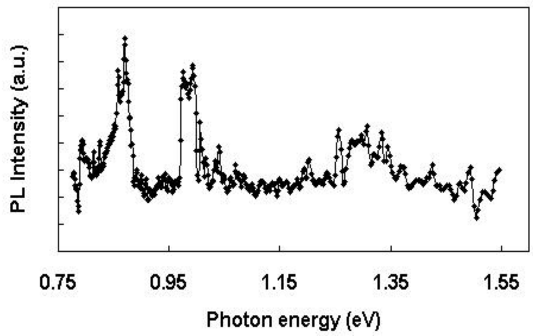

Fig.2. PL spectra of Al/n-Si metal-semiconductor contact

of the carriers through the band gap and weak features, maxima intensity of which correspond to energy value 0,955eV, 0,975eV and 1,02eV, respectively. Probably, these features are the result of technological processing.

The PL spectrum of Al/n-Si structure (Fig.2) is characterized by two split peaks with high intensity: at the energy 0,87eV and 0,97eV - 0,99eV. Besides, some features and weak wide peak are observed at 0,79eV, 0,93eV, 1,07eV and 1,26-1,33eV, respectively.

Recently, dislocation-related luminescence of silicon, caused by radiation of extended defects, presents great interest [6-10]. In these researches the structural defects entered by various methods on the area of a sample in a range of waves lengths 1,1 - 1,6 μm radiated a series of the lines named D1-D15. In this case, intensity of line D1 (1,54μm) and D2(1,42μm) dominates and grows with increase in annealing time from 15 till 60 minutes [6,7]. Preliminary heat treatment does not prevent occurrence of dislocation luminescence but influences position of their maxima and intensity.

In the PL spectrum of Al/n-Si MSC the peak (0,87eV) probably caused dislocation PL of D2 (Fig.2). The second peak (0,98eV) corresponds to transition from a level of aluminum with the participation of cross-section optical phonon TO (E_{ph}=0,055eV).

The radiation corresponding to transition through the band gap has very weak intensity. The similar situation was observed in works [11], where occurrence of dislocation lines was accompanied by disappearance of a signal from silicon at 1,11eV. Peaks are displaced aside small values of energy. Probably, features (1,26eV- 1,55eV) are caused by defects created by the contact fabrication processing [1, 12].

From PL spectrum of Al-PdAl/n-Si structure has revealed 5 peaks:

1) at 0,79eV caused by D1, 2) at 0,87eV caused by palladium or D2, 3) at 0,97-0,99eV, caused by aluminium, 4) at 1.15eV caused by recombination of the carriers through the band gap, 5) a wide weak peak at 1,4eV– observed at the all spectra (Fig.3).

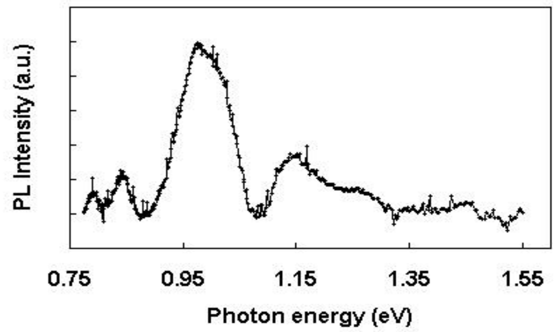

Fig.3. PL spectrum of Al-PdAl/nSi metal-semiconductor contact

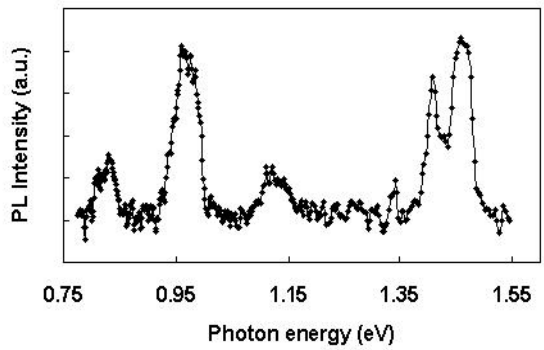

Fig.4. PL spectra of Al-TiW-Pd_2Si/n-Si metal-semiconductor contact

PL spectrum of Al-TiW-Pd_2Si/n-Si MSC (Fig.4) is characterized by four peaks: the first peak (0.81-0.828 eV) characteristic for structures with a D1, the second peak (0.96) is caused by ionization of silicon, the third peak caused by a straight line transition 1,11eV. The fourth peak (1.4-1.455 eV) possessing the big intensity is found out on all contact structures, actually.

PL spectrum of Al-TiW/n-Si (Fig.5) structure is characterized by three basic peaks with high intensity of radiation: 0,856eV, 1,11eV and 1,43eV, respectively. The first peak is identified as radiation from a level of tungsten. The second peak is caused by direct transition through the bang gap of silicon. The weak peak at 0,985eV is similar to dislocation feature D4 [10]. The third wide peak (energy of a photon about 1,43eV) is caused by extended defects as it has been specified in [8,12]. Insignificant displacement of peaks in low-energy area, reduction of the intensity, degradation of maxima is typical of defective formations.

Insignificant displacement of peaks in the field of low energy, reduction of intensity and degradation of maxima are typically for defective formations. In the paper [12] devoted to PL at an ionic irradiation the long-wave peak is connected with amorphous silicon and short-wave peak connected with residual nano-patch of crystal phase of Si. The degree of PL stability of the irradiated silicon is of interest at the room temperature storage. Recently, a lot of investigations are devoted to PL study of silicon nanostructures.

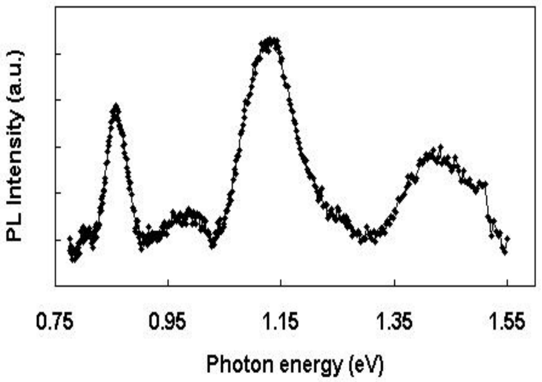

Fig.5. PL spectra of Al-TiW/n-Si metal-semiconductor contact

Were revealed, that intensive luminescence of amorphous –nanocrystalline structure observed at the room temperature, which strips are displaced to high energy area. The photoluminescence in a range of wavelengths 0,7-1mkm at an irradiation of silicon by ions of inert gas (Ne) has been found out. These spectrum specified formation of nanocrystalline structures, which promotes formation of extended defects at annealing. The similar structure has been generated at implantation of ions of silicon also [12].

Thus, our investigation has revealed metal film impact on structure of semiconductor. Due to technological process of metal-semiconductor contact fabrication the dislocations and nano-crystallynes have been created in semiconductor [1,12].

IV. Conclusion

PL spectrum of silicon wafer and Al/nSi, Al-TiW/nSi Al-TiW-Pd_2Si/nSi, Al-PdAl/nSi metal – semiconductor contacts demonstrate impact of metal film on energetic structure of silicon wafer. On the interface there are following changes: 1) Sedimentation of a metal film and the subsequent annealing lead to introduction of extended structures, which form the optical active centers or promote their formation. 2) Owing to diffusion of metal in silicon the effective doping degree can be differ than in volume in comparison. 3) Metal-semiconductor interface is dim. Its thickness many times over exceeds internuclear distance. 4) Vacancies can be electrical active. These physical changes result in significant disorder of electric parameters of contacts. 5) Such metal-semiconductor contacts one can use as structure radiating in IR diapason, simultaneously. 6) Intensity of lines eventually does not change, that testifies to stability of devices.

REFERENCES

1. P.N. Krylov, Journal of Udmurt University, Fizika. 4 (2006) 125 [in Russian].
2. I.M Afandiyeva, I.Dökme, Ş.Altındal, L.K Abdullayeva, Sh.G Askerov. Microelectr. Engineer. 85 (2008) 365.
3. I.M Afandiyeva, I. Dökme, Ş.Altındal, M.Bülbül, Tataroğlu, Microelectr.Engeneer. 85 (2008) 247.
4. I. Dökme, Ş.Altındal, I.M.Afandiyeva, Semiconduct Science and Technology, 23 (2008) 035003, 1-6.
5. I.M.Afandiyeva, Sh.G Askerov, L.K Abdullayeva, Sh. S Aslanov. Sol.State Electr. 51(2007),1096.
6. N.A Sobolev, B.Y. Ber, A.M.Emel'yanov, A.P. Kovarskii, E.I. Shek Physics and technics of semiconductors, 41,3(2007),295 [in Russian].
7. N.A.Sobolev, Emel'yanov A.M, V.I. Sakharov., I.T. Serenkov, E.I.Shek, D.I.Tetel'baum., Physics and technics of semiconductors, 41,5(2007),555 [in Russian].

8. E.A.Steinman, Physics and technics of semiconductors, 47, 1(2005), 9 [in Russian].
9. R.I. Batalov, R.M. Baazitov, N.M. Husnulin, E.I. Terukov, V.H. Kudoarova, B.A. Andreev, D.I. Kridzkov, Physics and technics of semiconductors, 47, 1(2005), 13 [in Russian].
10. T. Arguirov, W. Seifert, G. Jia, M. Kittler, Physics and technics of semiconductors, 41,4(2007),450. [in Russian].
11. V.V. Kveder, E.A. Steinman., S.A. Shevchenko., H.G. Grimmeiss, Phys.Rev.B 51, 10520 (1995).
12. A.A. Yedzevskiy, M.Y. Lebedev, S.V., Morozov, Solid State's Physics,, 47, (2005) 22 [in Russian].