Hittite Journal of Science and Engineering, 2019, 6 (1) 51-56
ISSN NUMBER: 2148-4171
DOI: 10.17350/HJSE19030000124

The Analysis of The Researches on Metal-Semiconductor Structures with and without Interfacial Layer in Turkey

Serhat Orkun Tan
Karabuk University, Department of Electronics and Automation, Karabuk, Turkey

ABSTRACT

Today, there are fairly large number of theoretical and experimental studies on metal-semiconductor structures or Schottky structures which formed by a tight contact of the metal and semiconductor. Having different physical, chemical and electrical properties many materials have been used to produce metal-semiconductor structures with and without interface layer from past to present. The distinctive properties which are not exist at other diodes, open for improvement and widespread use of electronic technology has led scientists to make studies on the metal-semiconductor structures. Considering the scientific studies on metal-semiconductor structures, the examination of the metal-semiconductor and the metal-semiconductor with interfacial layer structures, the observation of its progress over time and the statistical analysis of academic studies in this area in Turkey have been made in this study. The analysis of the academic studies which are scanned in Web of Science database and made in Turkey were performed with data mining by using automated data collection methods and SQL Server Management Studio program. The statistical analysis results show that the academic studies made for every type of MS structure in Turkey increase for almost every year. Considering the academic studies conducted in 2018, the studies on MS and MPS have reached the highest level in all years with 118 and 13 publications. The last five years rate of the number of publications form nearly %45 of all-time publications and the academic studies made for every type of MS structure in Turkey increase for almost every year.

Article History:
Received: 2018/04/17
Accepted: 2019/02/04
Online: 2019/02/07

***Correspondence to**: Serhat Orkun Tan*
Karabuk University, Department of Electronics and Automation, Karabuk, Turkey
Tel: 0(370) 418 7202
Fax: 0(370) 418 7203
E-Mail:serhatorkuntan@karabuk.edu.tr

Keywords:
Metal-Semiconductor; Interfacial Layer; Schottky Structures; Academic studies; Statistical analysis

INTRODUCTION

Metal-semiconductor (MS) or Schottky structures, which form the basis of semiconductor base circuit elements, formed by the tight contact of metal and semiconductors instead of a semiconductor-semiconductor junction as in typical diodes constructed by p-type and n-type semiconductors (PN junction) in contact. In metal-semiconductor structures, typically used metals are gold (Au), silver (Ag), platinum (Pt), tungsten (W), aluminium (Al) and molybdenum (Mo) and semiconductors are gallium arsenide (GaAs), zinc selenide (ZnSe), cadmium telluride (CdTe) besides mostly used Silicon (Si). These structures can respond quickly to the transitions between conductivity and insulator states at high frequencies and become widespread in production and use in the semiconductor industry due to their significant advantages. The voltage drops across PN and Schottky junctions are approximately between 0.6 - 1.7 volts and 0.15 - 0.45 volts, respectively. The typical current - voltage (I-V) curve of Schottky structure and 3D figure of interfacial layered MS structure is given in Fig. 1.

The lower voltage drop of Schottky diode can provide fast switching and also very low switching time. Besides, low power consumption, negligible storage time, rapid response to a change in biases are the other advantages of these structures. These fast switching devices are used in various electronics applications, such as AC to DC (ADC) converters, clamping and clipping circuits, switch mode power supplies, digital computers, mixer and detectors, etc. As a result of this widespread use, many theoretical and experimental researches have been made on MS and interface-layered metal-insulator-semiconductor (MIS) structures [1-4]. Metal-polymer-semiconductors (MPS) and metal-ferroelect-

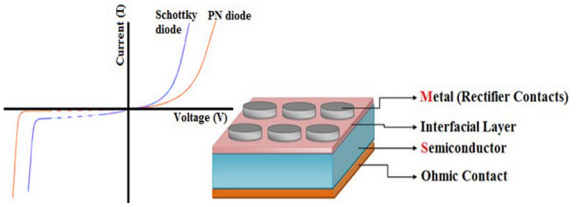


Figure 1. The I-V characteristics of Schottky structure and the structural view of the interfacial layered MS structure.

ric-semiconducting or metal-ferroelectric / insulator-semiconducting (MFS/MFIS) are obtained when a polymer and ferroelectric material is used as an interface layer between the metal and the semiconductor. A thin layer of insulator, polymer, ferro-electric grown by different methods between the metal and the semiconductor isolates the metal from the semiconductor and regulates the load transitions between them. Solid-liquid phase separation, self-assembly, template synthesis and electrospinning are the most used methods to grow the thin interlayer between metal and semiconductor.

The first rectification with MS diodes was performed by Braun in 1874 using metal point contacts on lead sulphide and ferrite sulphide semiconductors [2]. The developed shape of these contacts is Schottky barrier diodes (SBDs) which have a vacuum between the metal and the semiconductor, and the contact potential and the current distribution is homogenous in the junction region. Afterwards, the calculation of the barrier between the metal and the semiconductor has been independently proved by Schottky and Mott [1]. The behaviour of the contacts formed in relation to the character of the MS interface occurs in two forms, Schottky or rectifier contact and ohmic contact. The motion of electrons in the created contacts also determines the contact states. In both MS and MIS type structures, the "rectifier contact" state occurs, if the electron motion in one direction is quite easy at low potential barrier height (forward biases), and it becomes very difficult by increasing potential barrier height (reverse biases) at reverse direction. The ohmic contact states occurs while the electrons can move freely in both directions.

Metal-Insulator-Semiconductor (MIS) structures are obtained by using natural methods or by forming an insulating layer between metal and semiconductor layers by artificial oxidation method. If the thickness of this insulating layer is about 100-200 Å, it is called as MIS structures and above these values it is called as metal oxide semiconductors (MOS) structures or capacitors. Unlike MIS structures, MOS structures usually exhibit capacitor properties due to the thickness of the interface layer. In other words, instead of transmitting loads MOS structures store loads and this means they store huge amount of energy. Generally, compounds such as silicon dioxide (SiO2) and tin-dioxide (SnO2) utilize as insulators between metal and semiconductors, isolating metal and semiconductors from each other and also regulating charge transitions [5-7].

The electrical properties of MPS and MFS / MFIS structures are similar to those of MIS structures in case of the interfacial characteristics between the metal semiconductors, the formation of the insulator / polymer interface layer, the homogeneity at the Schottky barrier height and the series resistance [4]. The quality of the insulating / organic / ferroelectric layer between the semiconductor surface and the metal semiconductors also significantly affects the diode performance. Attention should be paid to the choice of materials with a high dielectric constant, a surface passivation, controlled current conduction mechanism, and the least leakage current as the interface layer [8,9]. The materials with these properties are SiO2, TiO2, SnO2 and Si3N4 for insulating materials, and poly-indole, poly-aniline and polyvinyl alcohol (PVA) for organic materials which has been subjected to many studies in chemistry [10-12]. Organic semiconductors have been preferred as interface materials in many recent studies to modify the electrical properties of MS structures [13-16]. The most important reasons for choosing organic semiconductors are high cost, flexible and twistable structure, high loss ratio and high nonlinearity. Beside MS structures, with these important properties organic semiconductors are widely used in electronic and optoelectronic applications such as organic field effect transistors (OFET), organic light emitting diodes (OLED), solar cells, etc., [16].

MFS and MFIS structures have been extensively investigated towards the end of the 1950s in order to acquire field-effect transistors (FETs) by directly growing a variety of ferroelectric materials on Si or by adding a dielectric layer [17-19]. Due to their remarkable physical properties, researches on ferroelectric materials have been increased in the last decade. FeRAM (ferroelectric random-access memories) developed with ferroelectric thin films can store information without needing a stable memory unit [20]. A typical ferroelectric material, bismuth titanite (Bi4Ti3O12), is preferred over piezoelectric, optical memories, FeRAMs and electro-optical devices [21,22]. Due to the incompatibility in the formation of MFI structures, which are types of MOS structures, thin insulating layers are added to BTO / Si interfaces by natural or artificial oxidation method to form MFIS structures. It is known that the ferroelectric layer in the MFIS structure gains memory property to the MOS capacitor [23,24].

There are many reasons for researchers to make new researches on MS structures. For instance, it is possible to use a wide range of interlayers and doping materials, such as many metals with different percentages, which are able to increase the conductivity of interlayers. Thanks to this characteristic diversity, it is possible to develop a structure that

emerges to the ideal case and improves its performance. On the other side, new methods can be developed to control the growth and assembly of nanostructures to further improve the development of metal and semiconductor nanostructures. At the same time, in addition to isolated metal or semiconductor nanostructures, they can also be combined with super or hetero structures, resulting in many new features that differ from the characteristics of the main components through interactions such as charge and energy transfer. Considering these significant properties, the area of metal-semiconductor structures is open for improvement and the academic studies on these structures in Turkey are increasing every year. Especially in recent years, many academic studies have been added to the literature on MS, MOS, MPS and MFS / MFIS structures with both MS and interface layers [25-29]. The aim of this study is to examine the MS structures and the statistical distribution of the data obtained from the academic studies on MS structures in Turkey for finding out the increasing rate of the studies, their publication years and the most focusing area of MS structures. Automatic data collection methods were used to obtain data from the Web of Science database and statistical analyses were performed with the SQL server management studio program. The increment of the academic studies on distinct types of MS structures every year indicates the interests of the researchers in Turkey to this area.

MATERIALS AND METHODS

Depending on the data in the Web of Science database, automatic retrieval of information is done by a data retrieval method that uses a data collection program to periodically read the table when any new data is placed. Through the program, each new data search is checked whether predetermined criteria are met. Here, the predetermined criterion is the existence of word sequences which are included in publications at Web of Science database such as "Metal Semiconductor" or "MS Structure", "MIS Structure" OR "Metal Insulator Semiconductor". In addition, if the program meets the criteria, it starts a data retrieval by performing a web-based search based on the data. If the criteria are not met, the program will not perform data retrieval [30]. Data retrieval from the Web of Science database and statistical analysis with the SQL server management studio are done through the logic of the study of Automatic Data Collection Method. The statistical distributions of the studies on the MS structures and the analysis values of the data were transferred to Excel Power Pivot and the analysis results were displayed.

Keywords focused on the study are entered in the Web of Science database as all possible word sequences for MS, interface layered MIS, MPS, MOS and MFS/MFIS structures in order to avoid bypass any publication in this area.

RESULTS AND DISCUSSION

Many electronic circuits and devices use the MS interface as Schottky contacts or as ohmic contacts. MS structures, which have been developed in the past as microwave diodes and radar and radar detectors, are now widely used in many areas, such as solar cells, varactors and switching circuits, metal-semiconductor field effect transistors (MESFETs). The factors that lead the researchers to study on MS structures can be explained as it is an open for improvement area by forming different materials and structures and the expansion of its application field is consistently increasing.

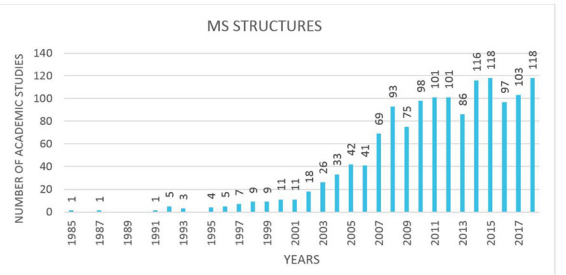
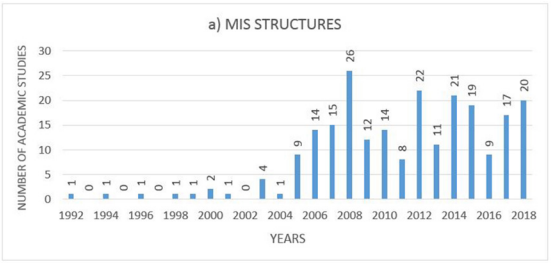


Figure 2. Distribution of the number of Web of Science database indexed academic studies on MS structures in Turkey by years.

Many scientific researches and academic studies have been made in Turkey over the past decade. The distribution of the number of academic studies scanned in Web of Science database on MS structures in Turkey by years is presented in Fig. 2.

Especially in the last decade, the increment rate of the number academic studies on MS structures in Turkey can clearly be seen in Fig. 2. The academic studies on MS structures in Turkey reaches the highest level in 2014 and 2015 and it is expected to increase in the future as well when considering the interest given to this area. It can be predicted that, the increase in the number of researchers and their co-operations and the examinations of different types metal and semiconductor structures due to various parameters, such as temperature, frequency and radiation, are the reasons of this increment between 2014-2015. When an insulating layer is added between the metal semiconductors, MIS structures are formed, and it is known as MPS and MFS / MFIS structures when organic polymers and ferroelectric materials are used as an interface layer. The distribution of the number of Web of Science database indexed academic studies in Turkey on MIS, MPS and MFS/MFIS structures by years is given in Fig. 3.

As clearly seen in Fig. 3, until the last five years there has not been any academic studies made in Turkey on MPS type structures. However, even if a small number of academic studies has been made in this area it was later uncovered that the polymer interface layer enhanced the quality



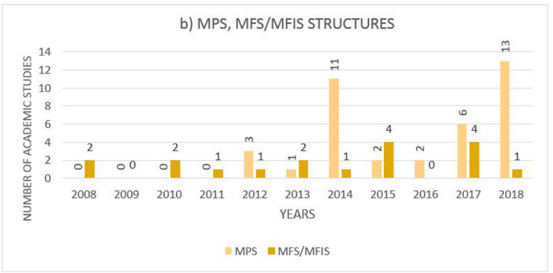


Figure 3. Distribution of the number of Web of Science database indexed academic studies in Turkey on a) MIS b) MPS and MFS/MFIS structures by years.

and performance of the MS structures. The increment of the polymer materials usage at semiconductor technology in recent years indicates that the academic studies on these structures will increase in the following period. On the other hand, although ferroelectric materials are used as interfaces at MS structures earlier than polymer materials, it is observed that ferroelectric materials are less preferred than polymer materials as an interlayer. As mentioned earlier, the addition of an insulator interface layer between the metal and the semiconductors, such as natural or thermal oxidation, forms MIS and MOS type structures. If the thickness of the insulator layer which isolates the metal and semiconductor layers is less than 100 Å, MIS type structure are formed otherwise it will be MOS type structure. The statistical analyses of the academic studies in Turkey scanned at Web of Science database on MOS type structures is presented in Fig. 4.

The number of academic studies made on MOS structures has lagged behind the number of academic studies made on the MIS structures in Turkey. This situation may be explained by the availability of compounds such as silicon dioxide (SiO_2), tin-dioxide (SnO_2) as an interface insulating layer and by the fact that diode production capable of fast switching is more preferred than capacitor production. In order to see and compare clearly, the total number of academic studies indexed in Web of Science database for every type of MS structure are presented in Table 1. On the other hand, the number of academic studies on MS structures were comparatively analysed in the world and in Turkey in previous article [31]. According to this research, approximately 5% of the total publications in the world indexed in Web of Science database on MS structures are from Turkey. This rate was 4% for MIS structures, 29.4% for MPS structures, 3% for MFS / MFIS structures and 1% for MOS structures [31]. The rates here indicate that MPS type structures have been considerably attracted in Turkey in recent years. This information is supported by the results which included some leading countries such as USA, China, Russia, India and Germany in addition to Turkey. The total number of academic studies on with and without interlayer MS structures by these leading countries and Turkey are given in Fig.5.

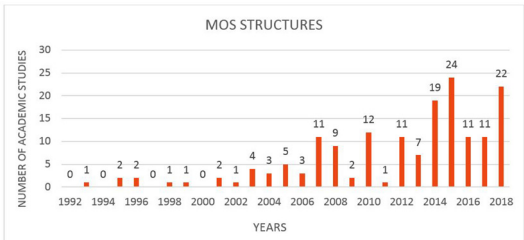


Figure 4. Distribution of academic studies by years on MOS structures and indexed in Web of Science database in Turkey.

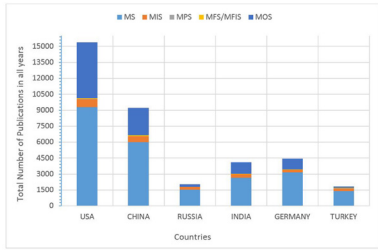


Figure 5. Distribution of the total number of academic studies indexed in Web of Science database in all years on with and without interlayer MS structures by countries.

Referring to Fig.5 and Table 1, Turkey seems to be lagging behind in almost all areas except the MPS structures between leading countries of the world. However, when we look at the studies on MS, MIS and MFS / MFIS structures, it is seen that it has almost the same number of studies with the countries except USA and China. The number of publications on the MPS structures in Turkey appears to be greater than the number of total publications in all other leading countries. This shows that MPS structures are attracted too

Table 1. The number of academic studies indexed in Web of Science database on MS and interlayered MS structures in Turkey and some leading countries.

SOME LEADING COUNTRIES ON WITH AND WITHOUT INTERFACIAL LAYER MS STRUCTURES						
TYPES OF MS STRUCTURES	*USA*	*CHINA*	*RUSSIA*	*INDIA*	*GERMANY*	*TURKEY*
MS	9305	6003	1537	2661	3153	1402
MIS	744	530	252	324	242	230
MPS	16	12	1	1	6	38
MFS/MFIS	67	100	6	37	23	18
MOS	5256	2563	255	1094	1026	165

much interest in Turkey. Contrary to this, the studies on the MOS structures in Turkey left behind the other leading countries.

CONCLUSION

In the light of the analysis results, it can obviously be seen that the academic studies on MS structures increased with the years of 2000s and the number of academic studies has increased almost every year. Comparing with the leading countries as USA, China, Russia, India and Germany, the number of publications on MS, MIS and MFS / MFIS in Turkey are very close to the number of publications made in Russia, India and Germany. Meanwhile, in comparison with the academic studies on MS structures in Turkey, the number of academic studies on MIS, MPS and MFS / MFIS structures seem to be considerably less. This can be explained by the adverse effects of the interlayer that reduces the MS structure's quality. Another reason for the smaller number of academic studies on interfacial layered MS structures is the organic polymers usage as an interlayer on MS structures is almost a new area. Although polymers have been used as an interlayer for a few years, it is also a remarkable situation that the number of publications on the MPS structures in Turkey appears to be greater than he numbers of total publications in all other leading countries. Moreover, the increase in the number of academic studies on organic polymers used as interfacial layers in MS structures over the last five years indicates that the studies on MPS structures will increase every year. On the other hand, it is certainly known that, as given for some leading countries, there are also a lot of researches and academic studies on MOS structures around the world. However, in Turkey, the number of academic studies scanned in Web of Science database on MIS structures are more than the academic studies on MOS structures.

REFERENCES

1. Sze SM, Kwok KNg. Physics of Semiconductor Devices 3rd ed., John Wiley & Sons, New Jersey, 2007.
2. Rhoderick EH, Williams RH. Metal Semicondutor Contacts, 2nd ed., Oxford Press, USA, 1988.
3. Farag AAM, Yahia IS, Fadel M. Electrical and photovoltaic characteristics of Au/n-CdS Schottky diode. International Journal of Hydrogen Energy 34 (2009) 4906-4913.
4. Sharma BL. Metal-Semiconductor Schottky Barrier Junctions and Their Application, Plenum Press, New York, 1984.
5. Sing A, Reinhard KC, Anderson WA. Temperature dependence of the electrical characteristics of Yb/p-InP tunnel metal-insulator-semiconductor junctions. Journal of Applied Physics 68 (1990) 3475-3479.
6. Depas MR, Van Meirhaegh L, Laflere WH, Cardon F. Electrical characteristics of Al/SiO2/n-Si tunnel diodes with an oxide layer grown by rapid thermal oxidation. Solid State Electronics 37 (1994) 433-441.
7. Goetzberger A, Klausmann E, Schulz MJ. Interface states on semiconductor/insulator surfaces. CRC Critical Reviews in Solid State Sciences 6 (1976) 226-233.
8. Ichenko VV, Marin VV, Lin SD, Panarn KY, Buyanin AA, Tretyak OV. Room temperature negative differential capacitance in self-assembled quantum dots. Journal of Physics D: Applied Physics 41 (2008) 235107.
9. Werner J, Guttler H. Barrier inhomogeneities at Schottky contacts. Journal of Applied Physics, 69 (1991) 1522-1533.
10. Boran F, Akti F. Synthesis and characterization of Poly(HEMA-co-AAc)/Diatomite hydrogel composites: Their application for heavy metal removal from the aqueous solution. Hittite Journal of Science & Engineering 2:2 (2015) 173-180.
11. Tamahkar E, Özkahraman B. Potential evaluation of PVA-based hydrogels for biomedical applications. Hittite Journal of Science & Engineering 2:2 (2015) 165-171.
12. Boran F, Akti F. Synthesis of Chitosan-Based Hydrogels as a Novel Drug Release Device for Wound Healing, Hittite Journal of Science & Engineering 4:2 (2017) 137-144.
13. Aydoğan Ş, İncekara Ü, Türüt A. Determination of contact parameters of Au/Carmine/n-Si Schottky device. Thin Solid Films 518 (2010) 7156-7160.
14. Gupta RK, Singh RA. Fabrication and characteristics of Schottky diode based on composite organics semiconductor. Composites and Science and Technology 65 (2005) 677-681.
15. Yahia IS, Farag AA, Yakuphanoğlu F, Farooq WA. Temperature dependence of electronic parameters of organic Schottky diode based on fluorescein sodium salt. Synthetic Metals 161 (2011) 881-887.
16. Çiçek O, Uslu Tecimer H, Tan SO, Tecimer H, Altındal Ş, Uslu İ. Evaluation of electrical and photovoltaic behaviours as comparative of Au/n-GaAs (MS) diodes with and without pure and graphene (Gr)- doped polyvinyl alcohol (PVA) interfacial layer under dark and illuminated conditions. Composites Part B 98 (2016) 260-268.
17. Fujimori Y, Nakamura T, Kamisawa A. Properties of ferroelectric memory FET using Sr2(Ta,Nb)2O7 thin film. Journal of Applied Physics 38 (1999) 2285-2288.
18. Tokomitsu E, Fujii G, Ishivara H. Nonvolatile ferroelectric-gate field effect transistors using SrBi2Ta2O9/Pt/SrTa2O6/SiON/Si structures. Applied Physics Letter 75:4 (1999) 575-577.
19. Fujisaki Y, Iseki K, Ishiwara H. Long retention performance of a MFIS device achieved by introducing high-k Al2O3/Si3N4/Si buffer layer. Material Research Society Symposium Proceedings 786 (2004) 297.
20. Wu D, Li A, Ming N. Characteristics of metal-ferroelectric-insulator-semiconductor structure using La-modified Bi4Ti3O12 as the ferroelectric layer. Microelectronic Engineering 66 (2003) 773-778.
21. Yang Ch-H, Wang Zh, Xu HY, Sun XQ, Han JR. Samarium doped Bi4Ti3O12 thin films grown on SiO2/p-Si (111) by spin coating metalorganic solution decomposition method. Materials Chemistry and Physics 88 (2004) 67-70.
22. Joshi PC, Krupanidh SB. Structural and electrical studies on rapid thermally processed ferroelectric Bi4Ti3O12 thin films by metalloorganic solution deposition. Journal of Applied Physics 72:12 (1992) 5817-5819.
23. Lea KC, Kim WS, Park H, Jeon H, Pae YH. Thermal-stress stability of yttrium oxide as a buffer layer of metal-ferroelectric-insulator-semiconductor field effect transistor. Thin Solid Films 473 (2005) 335– 339.
24. Hill WAC, Coleman CC. A single-frequency approximation for interface-state density determination. Solid State Electronics 23

(1980) 987-993.
25. Yu J, Wang H, Dong X, Zhou W, Wang Y, Zheng Y, Zhao J. Fabrication and characteristics of Au/PZT/BIT/p-Si ferroelectric memory diode. Solid-State Electronics 45 (2001) 411-415.
26. Dakhel AA. Nanocrystalline Pr-doped ZnO insulator for metal–insulator–Si Schottky diodes. Journal of Crystal Growth 311 (2009) 4183-4187.
27. Tataroğlu A, Altındal Ş. Gamma-ray irradiation effects on the interface states of MIS structures. Sensors and Actuators A: Physical 151 (2009) 168-172.
28. Chen G, Yu J, Lai PT. A study on MIS Schottky diode-based hydrogen sensor using La2O3 as gate insulator. Microelectronics Reliability 52 (2012) 1660-1664.
29. Filip LD, Pintilie L, Stancu V, Pintilie I. Simulation of the capacitance-voltage characteristic in the case of epitaxial ferroelectric films with Schottky contacts. Thin Solid Films 592 (2015) 200-206.
30. Tan SO, Türker İ, Toku T. The scientific studies on smart grid in selected European countries. MATEC Web of Conferences 112 (2017) 10012.
31. Tan SO. Schottky Yapılar Üzerine İnceleme ve Analiz Çalışması. Journal of Polytechnic 21: 4 (2018) 977-989.