MTJ PROPERTIES MODIFICATION

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ABSTRACT

The electrophysical properties changing of MTJ-structures Fe/MgO/Fe have been investigated. The detected changes of properties are concerned with changes occurring in insulating barrier. It can be conditioned by diffusion in insulator. The zone with the negative differential resistance, similar to a tunnel diode, is found out on a volt-ampere characteristic. It is supposed, that it can be due to formation of excitons in the modified MgO layer.

Key words: MTJ, Fe/MgO/Fe, diffusion, TMR, spin polarization, excitons.

INTRODUCTION

The MTJ-structures fabricated by various methods in the conditions of a high vacuum (~10^{-8} Torr) [1,2] are traditionally investigated. MBE and EBE-techology allow to grown up epitaxial film structures Fe/MgO/Fe on monocrystal substrates. Advantage of such structures is their crystallographic orientation set by a surface of a substrate, allowing to provide high values of spin polarisation coefficients (up to 70 % and more) and TMR more than 150 % at room temperatures [3]. Such parametres are well consistent with existing theoretical works in this area [4], but demand not only precision techniques, but also especially pure materials.

In manufacture of microelectronic elements and microchips materials with the parameters strongly differing from ideal, both on a composition, and on structure are widely used. For instance, polycrystalline corundum and glass-ceramics are used as substrates for chips. They, as is known, have polycrystalline structure, correspondingly, with large (up to 10 microns for polycrystalline corundum) and small (up to 0.5 microns for glassceramics) crystal grains. The morphology of carefully prepared surface of such substrates appears quite suitable for production of multilayer film structures Fe/MgO/Fe. Such structures will have fine-crystalline structure with corresponding orientation of a magnetic moment within grains of a film [5]. Unlike the films which have been grown up on monocrystal substrates, their total magnetic moment without a magnetic field will not have the clearly defined orientation. Depending on a relation between the typical crystal grains sizes and MTJ dimensions such situation can

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be valid within all MTJ. In such structures it is possible to expect the electrophysical properties differing from characteristic for MTJ with epitaxial films on monocrystals. For this the size of a fabricated MTJ should considerably exceed the characteristic size of domains. For fine-crystalline structures it is possible to consider, that the size of the domain of an order of magnitude of grain.

At manufacturing of MTJ-structures by traditional processing techniques presence of impurities makes the negative effect on their electrophysical properties. In [6] one of possible mechanisms of influence of impurities on a spin-dependent tunneling in a ferromagnetic-oxide-ferromagnetic systems is viewed. Presence of impurities can lead to change as quantities, and sign of TMR. Thus, by means of the insertion of impurities in MTJ structure it is possible to expect a new properties for use in spin electronic devices of new type.

METHODS OF SAMPLE MANUFACTURING AND ANALYSIS

Film evaporation of MTJ-structures was done in installation VUP-5m by means of an elektron-beam evaporation (EVE) of corresponding substances on substrates from pyroceram CT52-1. Such substrates, as is known, widely use for manufacturing of electronic microcircuits. Substrates with dimensions 20x20 mm before sputtering were subjected to chemical treatment. An evaporation mask was imposed on a substrate effective area before sputtering of each film. Typical volt-ampere characteristic of MTJ-structures Fe (30nm)/MgO (3 nm)/Fe (20 nm)/Cr (25 nm) with interlayer resistance of 1.8 kOhm has semiconductor character of conductance.

RESULTS AND DISCUSSION

After measuring degradation of electrical properties of MTJ-structures was observed. With time interlayer electroresistance of tunneling junction decreased practically to 0 (*Fig. 1*).

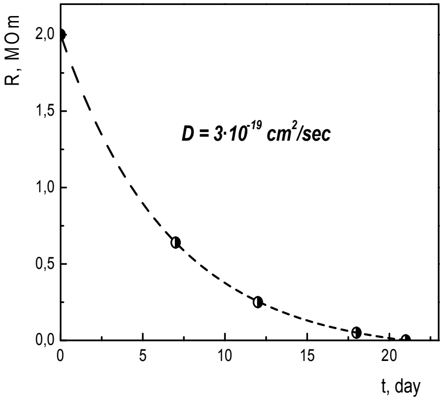

Fig. 1 – Degradation of properties MTJ with time

On the assumption of an exponential view of the curve, what is typical for diffusion dependence, it is possible to suggest, that degradation occurred as a result of conductive impurities diffusion. The estimation of an average diffusion coefficient through layer MgO with thickness $d = 3\cdot10^{-9}$ m gives the value $D \approx 3\cdot10^{-19}$ cm^2/s. It more than ten orders exceeds a volume diffusion coefficient of metals in MgO [7].

Carbon presence is the non-prescribable factor of processing technique of film evaporation in installation VUP-5m. Therefore further for inhibition of degradation processes of MTJ special attention devote to flattening of interfaces and magnification of a MgO film thickness from 2 nanometers to 7-8 nanometers. *Fig. 2* show VA-characteristics of MTJ Fe (30 nm)/MgO (7 nm) / Fe (80 nm) against a junction voltage within 0 – 3 – 0 V.

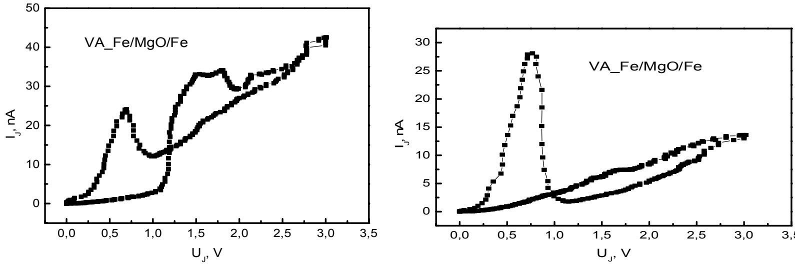

Fig. 2 – VA-characteristics of MTJ

On an initial section of a direct branch 0 – 3 V a curve has nonlinearity (*Fig. 2a*). It is typical for semiconductors. At voltage rise electrodiffusion processes can become more active. Impurity atoms, in particular, carbon, move from one interface metal - dielectric to other dielectric-metal. Impurity presence forms in a dielectric additional energy levels which provide occurrence of excitons in band-gap: couple of an electron-hole. Thus, as a result of impurity exhaustion at one interface and concentration at another the structure with energy bands as in a tunnel p-n junction is formed. It is exhibited by occurrence of a section with the negative differential resistance on a decaying section of Volt-ampere characteristic at voltage reduction (*fig. 2a*). At repeated measuring of Volt-ampere characteristic of the same MTJ the negative differential resistance is already observed both at voltage increasing and at reduction (*Fig. 2b*).

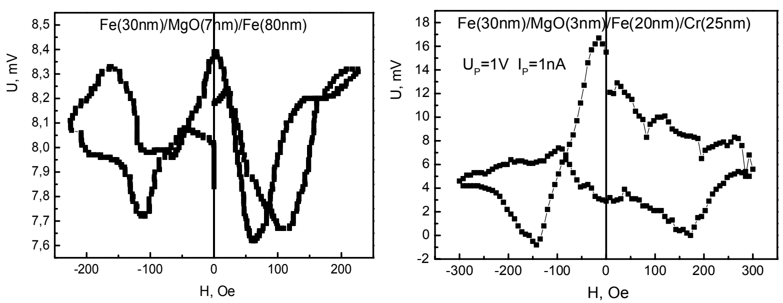

Fig. 3 – Dependence of signal amplitude U (mV) on MTJ versus magnitude of a magnetic field at a various mode of magnetic fixing of the ferromagnetic layer and a thickness MgO: a)7 nanometers b) 3 nanometers.

Magnitude of a magnetic field influence on properties of the obtained structures. Results of investigations of MTJ properties in linearly changing magnetic field are presented on *Fig. 3*.

Regarding, that voltage drop on MTJ is proportional to change to its resistance in variable magnetic field, the tunnel magnetoresistance TMR for a curve at fig.4a can be defined as

$$TMR = \frac{U_{ap} - U_p}{U_p} \cdot 100\% = 10.5\%, \qquad (1)$$

An average coefficient of spin polarization for this system it will be defined as

$$P \cong 1/\sqrt{\frac{2}{TMR} + 1} \cong 31\% \qquad (2)$$

CONCLUSIONS

It is shown possibility of MTJ obtaining at sputtering of thin-film structure on fine-crystalline substrates. Stability of MTJ properties achieved by increasing of a thickness of an insulating barrier and interface smoothing between Fe and MgO layers. The increasing of a thickness of a insulating barrier and change of its electrophysical properties leads to decreasing TMR of MTJ. Control of a transmittance and conductance of potential barrier of MTJ can be carried out by means of amount and type of an implanted impurity. In MTJ-structure with impurities in a barrier layer at potential supply is possibility of energy structure formation as in a *p-n* junction with Volt-ampere characteristic, similar to a tunnel diode. It can be due to formation of excitons in the modified MgO barrier. The results will be useful at making spintronic oscillator devices of new type.

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