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Research Article

ANALYSIS OF STUDYING THE STRUCTURE OF EPITAXIAL IRON FILMS ON GALLIUM ARSENIDE Fe/GaAs

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ABSTRACT

The anisotropy in thin films coincides with the crystallographic direction of an increase in the thickness of the iron layer. The value of the cubic anisotropy constant decreases. In this case, the value of the uniaxial anisotropy constant, on the contrary, increases. The dilution of the semiconductor matrix with iron atoms is also noted, and the formation of Fe-Ga or Fe-As compounds is assumed. An analysis of the surface sensitivity of the spectra of As and Ga shows that As is more easily mixed with Fe than with Ga.

KEYWORDS

Thin films, electron beam epitaxial, uniaxial and cubic anisotropy, ferromagnetic resonance.

INTRODUCTION

At present, much attention is paid to the development of technology for creating devices based on controlling the orientation of electron spins in a semiconductor material. In such devices, it is necessary to pump, transfer, control the state, and switch the magnetic moments of electrons at temperatures above room temperature. In order to obtain high spin polarization, materials with a high Curie temperature should be used, such as iron on a semiconductor substrate.

Thin films are solid or liquid (rarely gaseous) layers between macroscopic phases, the thickness of which is commensurate with the distance of action of surface forces. They have special (in comparison with the bulk phase from which a thin film was formed) composition, structure and thermodynamic characteristics. A distinction is made between symmetrical thin films separating phases of the same composition, and asymmetric thin films formed, for example, by spreading liquid on a solid or liquid surface (wetting films). Hard thin films are oxide films on the surface of metals and artificial film coatings formed on various materials. Liquid thin films separate gaseous, dispersed phase informs and liquid phase emulsions. Liquid thin films can form spontaneously between grains in polycrystalline solids if surface energy grain boundaries exceed surface tension at the boundary of the solid and liquid phases more than twice (the Gibbs-Smith condition) [3-9].

Main Part

A large number of experimental and theoretical works are devoted to the study of interface systems, such as metal-semiconductor. The complexity of the atomic structure and morphology of such systems does not allow for completely experimental and theoretical analysis of the internal parameters. All modern models for describing the metal-semiconductor interface are based on studies of the epitaxial interface between a single-crystal semiconductor and a single-crystal metal. Thin films of iron on gallium arsenide Fe/GaAs were used as the sample under study. The films were obtained by electron beam epitaxy in an ultrahigh vacuum chamber [10-14].

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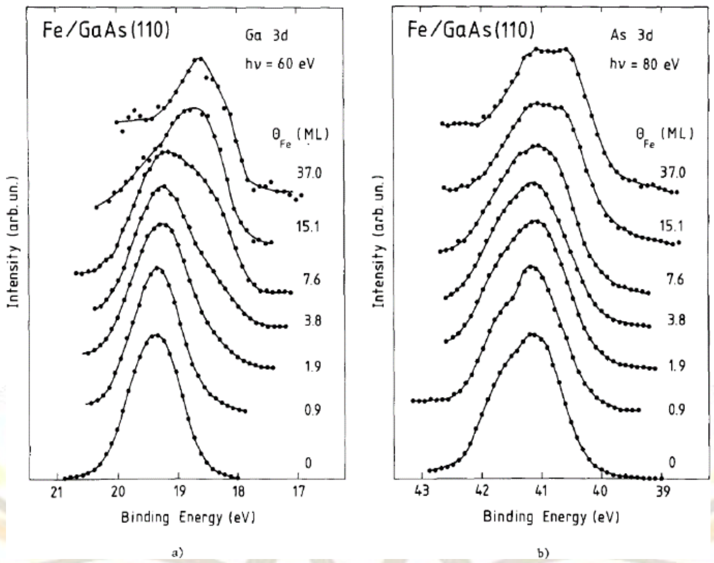

Fig. 1. Ga 3d (a) and As 3d (b) spectra of electronic levels in the iron atom in the case of successive deposition of Fe.

The results show that in the first stage of iron film growth at thicknesses from 0 to 1 monolayer (ML), there is no strong interaction between the metal atoms and the substrate. The next stage of film formation (the thickness of the metal layer is from 1 to 40 ML) can be characterized by the appearance of a strong chemical bond between iron atoms and gallium atoms. The spectra in Figure 1. show a strongly shifted component, showing changes in the local atomic order for Ga and As. The presence of a mixed phase, in which As and Ga are present simultaneously with Fe (in the form of metallic inclusions), is retained up to an iron film thickness of 15 ML.

The dilution of the semiconductor matrix with iron atoms is also noted, and the formation of Fe-Ga or Fe-As compounds is assumed. An analysis of the surface sensitivity of the spectra of as and Ga shows that as is more easily mixed with Fe than with Ga. From the experimental results, it can be said that the reaction occurs at the interface. Thermodynamic calculations indicate that this reaction will be characterized by the formation of a Fe-As solid solution. Comparing the results for thin films of iron on gallium arsenide with the results for thin films of transition metals also on gallium arsenide, one can distinguish the formation of surface layers at the metal/GaAs interface. Such a transition layer can be characterized as a multiphase chemical system. Investigation of the dependence of the constants of uniaxial and cubic anisotropy in thin films of iron on gallium arsenide Fe/GaAs(001) on the thickness of the iron film, which varied in the range from 5 to 20 ML. The value of the anisotropy constants was estimated based on the analysis of the FMR spectra and angular dependences obtained for frequencies of 4.03 GHz and 9.24 GHz.

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RESULTS

The direction of the easy anisotropy axis in the considered thin films coincides with the crystallographic direction. It was also found that with an increase in the thickness of the iron layer, a decrease in the value of the cubic anisotropy constant occurs. In this case, the value of the uniaxial anisotropy constant, on the contrary, increases. The effect is possibly associated with surface phenomena at the Fe-InAs interface, for example, the resulting mechanical stress. Also, the appearance of uniaxial anisotropy in the samples under consideration can be affected by the peculiarity of the growth of the first iron layer on the indium arsenide substrate.

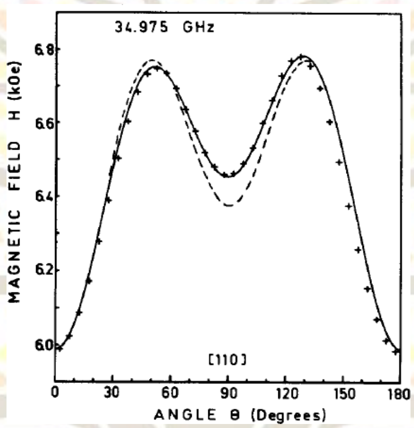

Fig. 2. Dependence of the resonant field on the orientation of the sample relative to the external magnetic field. The dashed line shows the theoretically obtained

In the study of the properties of a thin film of iron on gallium arsenide Fe/GaAs (the thickness of the iron film is d = 11 ± 0.1 nm). To characterize the magnetic properties of the system, the method of ferromagnetic resonance FMR - spectrometry, as well as the method of Brillouin scattering (BS), is used. The results of FMR - measurements of the dependence of the resonant field on the orientation of the sample are shown.

The table shows the obtained values of system parameters such as saturation magnetization, and values of uniaxial and cubic anisotropy constants.

Table 1. Obtained values of the parameters of a thin film of iron on gallium arsenide

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Method	4πM, kE	K1/M, kE	KU/M, kE
FMR	15.6	0.21	0.04
BR	15.6	0.21	0.14

Analysis of the results In the sample under consideration, there is an induced uniaxial anisotropy, the axis of which is perpendicular to the plane of the film. The saturation magnetization values obtained from the analysis of the results of each method give the same values, which correlate with the theoretical value (4πMt = 16 kE). Pa

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