NEW TECHNOLOGY OF PREPARATION OF INDIUM ANTIMONIDE THIN FILMS ONTO DIELECTRICAL SUBSTRATES AND ONTO OXIDE SILICON SUBSTRATES

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The technology of preparation of the indium antimonide thin films of n-type conductivity is an actual problem at the present time. The preparation of thin semiconductor films by different methods is described in scientific literature widely and multilaterally. These methods are described for elementary, binary and multicomponent semiconductor materials, which are still widely used in practice for preparation of the new semiconductor integral schemes, devices and constructions successfully working in different spheres of human activity. These methods are applied to the vacuum evaporation of initial crystal and crystalline powder, gas-transport method, Vecshinsky method, three temperatures method, discrete evaporation, thermal recrystallisation and etc., which were improved by the process of preparation thin semiconductor layers as elementary, binary as well as multicomponent semiconductor materials.

The condensation of different materials in vacuum is one of main methods of the preparation of thin films applied in the physics investigations, electronic technique, construction of apparatus, microelectronic and other spheres of science and technique. The lawfulness of transition of substance from the condensering phase in gas one, transformation of its vapors in vacuum from the evaporator to substrate and condensation of steam onto the substrate were studied very well. The theories of vacuum evaporation, condensation processes, germination, crystallization and stature of films applicable to elementary semiconductors and binary semiconductor compounds and also to multicomponent systems were described in detail in monographies [1, 2].

Last time the methods of molecular-ray epitaxion (MRE) have spread in thin film technology. This method in used for preparation indium antimonide films, for instance, for growing of heteroepitaxial films onto [100] surface of substrates from semiisolate of GaAs alloyed by Cr [3]. The velocity of growth was about 1 μm/h. In spite of the very big disaccording in lattice parameters the single crystalline films were prepared with the polished surface at substrate temperature 330...420°C. The electrical parameters equal \( n=(2...4)\times10^{16}\) cm\(^{-3}\) & \( \mu_n=(4...5)\times10^{4}\) cm\(^2\)/V·s at \( T=300K \) that it close to values of parameters for massive material.

The method of temperature source programme was used for preparation of \( \text{In}_{1-x}\text{Ga}_x\text{Sb} \) and \( \text{InAs}_x\text{Sb}_{1-x} \) films [4]. The cleave plates of mica served as the substrates. After condensation the films inflict to recrystalization. The electron mobility on InSb films was \( (5.0+6.5)\times10^{4}\) cm\(^2\)/V·s and it was decreasing quickly at increasing of GaSb content.

Among the ways of the epitaxial layers growing the epitaxy from the vapor phase and also the liquid-phase epitaxy received wide use.

The important factors technology methods of the thin semiconductor films obtaining are the simplicity of method, its reproduction, the possibility of the layer preparation with parameters and properties close to properties of single crystal or initial material. All above
named methods as a rule didn’t give possibility to obtain the layers with properties close to properties of initial material.

We suggested the new method of the preparation of thin semiconductor layers n-InSb, which permits significantly to approach layers on parameters and properties to those of initial single crystal InSb of n-type conductivity.

The earlier indium antimonide thin films of n-type conductivity were received by the different above – mentioned methods onto the dielectrical substrates from mica, quartz, sapphire, silicon oxide and also onto different crystallographical planes, received by cleaving of single crystals of semiconductor materials Ge, Si, also A\textsuperscript{II}B\textsuperscript{IV} and A\textsuperscript{III}B\textsuperscript{V} semiconductors – so as ZnTe, CdTe, ZnSe, CdSe, InSb, GaAs, InAs and entire row of the other two, three and multicomponent semiconductors.

The essence of new method consists in its essential difference from all the listed above methods and it will practically effectively solve all technological problems of the thin film semiconductor material preparation at its improvement. It needs to take a piece of n-InSb semiconductor single crystal by volume \(\sim 8\text{mm}^3 = 2\times2\times2\text{mm}\), that is easy to make by cleaving it from the single crystal block and of course it is not exactly at the appointed dimension. After that put it onto substrate made of the material on which it is needed to get this layer (for instance, mica, quartz, sapphire, silicon oxide and etc.) and to heat this substrate till the temperature of the material melting in vacuum \(\sim 10^{-4}\text{torr}\). The simple calculations show that for getting thin film of this cube with thickness 20 ÷ 30 μm the layer square must be \(\sim 400\text{mm}^2\), i.e. 20×20 mm or 300 mm\(^2\), i.e.17.5×17.5 mm.

It is typical, that the layers of this thickness have already physical properties approximating to properties of massive materials, because the influence of layer thickness, e.g. the dimension effect already does not influence the electrophysical properties of layers for film of InSb of n-type conductivity. The experimental investigations of heating process of substrate presuppose two types of heating: graphite furnace in which quartz tubes are fitted with nihrome spiral and simple heater from tungsten plate which possesses notable least inert ion that permits quickly to change temperature of heating process and of course easier to control melting process and layer crystallization.

In our experiment the temperature of furnace was about 550ºC at which n-InSb crystal was melting onto mica. Under action of gravitation of the plane-parallel load hung under this furnace the drop was spread equally onto the substrate, forming the layer of indium antimonide of n-type conductivity and 20-30 micron thickness. The action of this load onto drop performs during 5 seconds and then the furnace swiches off and the layer crystallizes onto the substrate. Of course in the result of the melting the crystalline structure of n-InSb binary compound destroys but in new aggregate state it is for a little time and appearance of any admixtures and considerable deviations from the initial crystalline structure in the crystallization process of layer under the influence of gravity at a drop in temperature is scarcely probable.

The presence of covalent chemical cohesion in A\textsuperscript{III}B\textsuperscript{V} components, which has property of direction leads to placing some limits to the mutual arrangement of atoms that prevents them from being diffused. Because of the difficulties of the diffusion there is the disturbing in the crystallization process. However in the components with covalent cohesion the diffusion coefficient increases exponentially at temperature rise according to the equilibrium that may be reached quickly enough.

After the drop spreads and the layer is subjected to the process of crystallization the form of the sample onto substrate under the influence of gravity may be diffuse.
The measurement of electrophysical parameters and properties of the preparing layer can lead to cutting of it a rectangular part by the ordinary method or by Van-der-Paw method [5].

The leading estimate of electrophisical parameters is preparing by this method of n-InSb thin film onto mica substrate at room temperature displayed that its electroconductivity is close to value in the initial single crystal and consists $\sim 10^{-3}$Ohm$^{-1}$cm$^{-1}$ and the concentration of charge carriers equal $10^{15}\div10^{16}$cm$^{-3}$. It is characteristic that these data are close to parameters of the initial single crystal.

The given method permits to prepare also heterostructure if the semiconductor substrate is on the silicon base. So for preparation of n-InSb-SiO$_2$-p-Si heterostructure the appointed method can considerably change it parameters, because at the present time it is known [2], that n-InSb layers are being prepared by the above – mentioned method at room temperature in concentration interval $(0,5\div1,0)\cdot10^{17}$cm$^{-3}$ and conductivity $\sim 10^2$ Ohm$^{-1}$cm$^{-1}$. It is significant that SiO$_2$-p-Si substrate heating in vacuum $10^{-4}$ torr till $550^\circ$C temperature doesn't cause any changes of its electrical properties and heterostructure prepared with the above-named n-InSb layer will possess large integral sensibility in infra-red region of spectrum.

To the given advantages of new technology preparation of n-InSb semiconductor layers and n-InSb-SiO$_2$-p-Si heterostructures we can relate the time reducing of realization of technological process, consequential economy of initial crystal. So, for instance, at discrete method of preparation the initial crystal breaks into pieces with dimension $\leq 150$ μm and the remainder in volume – 30-40% of material isn't used in this process. Besides at the evaporation onto the substrate in best case it falls 50 per cent of initial material. Therefore the reduction of material expenditure is directly connected with economizing on initial stuff and on time of the layer preparation process. In the process of layer recrystallization prepared by discrete evaporation oxide layer influences its electrophysical parameters and in the first place its purity. All above listed methods of the preparation of the indium antimonide films of n-type conductivity and alloys on its base in this or another measure reduce electrical parameters of layers in comparison with single crystal of this material if the dimension effect is discounted.

Of course the further investigations of n-InSb films prepared by the described method intend attentive investigation of the structure by electronographic, x-ray, metallographic and other methods with aim of further explanation of influence of the structure particular films onto its electrophysical, galvano-magnetic, optical, photoelectrical and other properties.

The suggested method to the important degree is applicable for materials with melting temperature lower than $600^\circ$C. At higher temperatures the determining influence on the formed layer can render a surface of gravity acting onto layers and also time of its action. Notwithstanding we suppose that the suggested method will find successful application in technology of preparation of thin semiconductor layers.

References
