As Heyen and Balk [1] have shown, the free electron mobility measured on VPE layers occurs lower, in general, than the theoretically calculated mobility values. This fact, seemingly, cannot be explained simply supposing elevated compensation ratios or a worse crystal quality. In the present work it is shown that one of the most important reasons, or possibly the most important one, is due to the depth inhomogeneity of the layer. This is the result of the conditions of growth and can be avoided in many cases. Some concentration profiles and their interpretation are discussed.

When growing epitaxial layers, the process of primary importance is the characterization of the layer or the layered structure. The characterization includes first of all the electrophysical properties of the material, among others the mobility of the free carriers. For the measurement of the mobility the most important and the most frequently used method is based on the Hall effect, and is technically performed by van der Pauw’s method.

Very often the electron mobility values obtained in such a way are smaller than the theoretically predicted ones for many possible reasons (e.g. compensation, defects etc.). This paper deals with this question in GaAs, but concerning the inhomogeneity of the layer.

Measurement of Hall mobility

Experimental mobility data on GaAs epitaxial layers were collected by Heyen and Balk [1]. Fig. 1 shows this mobility vs concentration distribution at 77 K, the theoretical maximum mobilities (K=0, K is the compensation ratio) and, also, some of our own results. From Fig. 1 one could conclude that the smaller mobility values are regular and this is an inherent feature of the epitaxial layers [1].

The Hall mobility can be measured in the way described above only if the epitaxial structure has only one layer (the layer under question) on a semi-insulating substrate. In MESFET type structures the mobility in the active layer can be measured directly. In the case of devices requiring heavily doped substrates, like Gunn diodes, the mobility cannot be measured directly in the active layer but one has to grow a special one-layer structure on a semi-insulating substrate, supposing that the measured mobility in this wafer will be identical (or nearly identical) to the mobility in the active layer of the real device structure. This special structure for mobility measurements can be grown mainly in a special run with semi-insulating substrate and reproducing only one layer, the active layer, when also buffer and contact layers are desired for devices.

Because of the requirements for van der Pauw measurements, the measured and calculated mobility value is an integrated value, i.e. the mobility inhomogeneity along the wafer and also in depth is included. In this paper, however, only the question of the inhomogeneity of electrical properties in depth is dealt with, since it is supposed that this is the main reason for the lowered mobility in the epitaxial layer and all the other possible reasons might be excluded or neglected.
Fig. 1. Carrier concentration dependence of the electron mobility in GaAs at 300 K and 77 K. Continuous line is a summarized mobility for GaAs VPE layers in [1], dotted line is the highest theoretical mobility, dots are our VPE layers.

Experimental

Epitaxial structures of GaAs were prepared by the chloride VPE system [2] under the usual technological conditions in the diffusion limited regime [3]. For mobility measurements one epitaxial layer was obtained on either a Cr doped or a nondoped semi-insulating substrate. These structures were prepared in similar technological conditions, except the presence of another substrate. In this sense there are two types of structures, viz: type B: in the same deposition zone of the reactor there is a heavily doped, n type substrate, too, and the semi-insulating substrate is placed behind the conducting substrate, along the gas flow direction; type W: there is only one semi-insulating substrate in the deposition zone, without a conducting substrate.

The integrated mobility values were obtained as above, by DC technics. Some mobility data are shown Fig. 1.

Also the carrier concentration depth profiles were measured by electrochemical etching, using a Post Office Profile Plotter system.

Layer thickness

If one considers Fig. 1, it can be seen that the "lowered" mobility is a relative notion: the mobility is lower relative to the carrier concentration. The same mobility would be relatively higher at a higher concentration value, respectively. So the first question is the layer thickness since for the determination of the carrier concentration the exact value of the layer thickness is necessary. In possession of bulk samples the thickness obviously can be measured but this is not true for epilayers [4].

Figure 2 shows two concentration profiles: the active layer is grown (i.) on a highly doped substrate (curve 1) and (ii.) on a semi-insulating substrate (curve 2).

Let us suppose that the carrier concentration in the depth of the layer is homogeneous (as shown in Fig.2). Curve 1 of this figure clearly shows that there is no absolutely abrupt junction between the heavily and lightly doped regions. In view of this, the question arises as to how we can define the layer thickness. Because of the continuously decreasing concentration, it is not evident. But it has to be the same situation for the semi-insulating substrates, with opposite sign concentration gradient. On MESFET type structures the concentration profile shows this phenomenon more clearly.

With the usual decoration technique (angle lapped or cleaved structures) the thickness values obtained by us agree with the metallurgical interface and these are in the region