Rasterkraftmikroskopie

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0 Expose

The III-V semiconductor system based on GaSb is commonly used for optical semiconductor devices with wavelengths beyond 2.3 µm [1]. In Würzburg especially the interband cascade lasers, which are grown by MBE on GaSb substrate, made significant progress during the last years [2]. In order to grow devices with high performance it is inevitable to use high quality substrates with a minimum of defects. Despite the use of 'epiready' substrates the wafers suffer from native oxide like Ga_2O_3 and Sb_2O_3 [3]. The growth of devices on top of this oxide would lead to non-monocrystal layers. To remove this oxide a commonly used technique in Würzburg is to heat the substrate to about 580° for short time. At this temperature the most of the oxide desorbes from the surface but leaving holes in the surface with about 10 nm in size [4]. Hereupon a 200 nm GaSb buffer layer is grown at 485° to flatten the surface. This method has been established during the last years although it has never been investigated whether a different technique would lead to smoother surfaces. Therefore one of the goals of this experiment is to determine a method of reducing the roughness on the wafer we want to grow on optical structures. This is important on the behalf of the optical quality the device can operate at.

From an intuitive point of view it is clear what roughness is. Trying to quantify in in a mathematical way however is not obvious. While common definitions use the standard deviation of the surface's mean height as $S_a = \frac{1}{A} \iint\limits_A |z(x,y)| \mathrm{d}x\mathrm{d}y$

For this purpose we need to define roughness as a way to quantify the properties of the surface of interest. We think that the concept of a surface energy is a good approach to address those optical qualities. One of the simplest models of surface energy or surface tension is to assign an atom an energy depending on how many sides it has a neighbouring atom. The neighbour positions are those of the nearest neighbours in the lattice of the material. In a simple cubic lattice the energy of a free atom would be six, the energy of a surface atom would be one. Large fluctuations have a small effect, already represented by the surface energy. On the other hand very small fluctuations, much smaller than the wavelength of the light, also have a small effect on the optical properties. Since they would have a big, but also unwanted contribution to the surface energy, we need to define the size of the 'atoms' with a parameter λ. A natural choice is to set λ to the wavelength of the light which the device will interact with. All smaller fluctiations are then neglected and averaged to a mean height with the quantization of the axis in x and y direction to the length scale of λ.

$$\Upsilon = \sum_i \epsilon_i \tag{0.1}$$

$$\text{where} \quad \epsilon_i = \sum_{r=x,y,z} \Big(r_{i-1} + r_{i+1} \Big) \tag{0.2}$$

$$\text{and} \quad r_j = \begin{cases} 1 & \text{if site contains an atom} \\ 0 & \text{else} \end{cases} \tag{0.3}$$

The Atomic Force Microscope (AFM) is the perfect instrument to characterize this roughness of the wafers as it determines the height of the surface very precisely. The expected differences in height on the surface is about 10 nm which is within the resolution of the AFM. As the AFM doesn't work in situ we have to produce and investigate the surface at each step of the growth process to understand the mechanisms of oxide desorbtion and flattening of the surface. We going to characterize the single steps of the standard process which are: an untreated GaSb Wafer, the Wafer after the oxide desortion and after 200 nm GaSb buffer. To vary this process we want to test two aspects: first the increase of the GaSb buffer's growth temperature up to 500° and 515° and second the growth of a 30 nm GaSb/AlAsSb superlattice directly after oxide desorbtion. Recent research showed that the growth of AlAsSb shutting down the step-flow growth mode. This step-flow growth mode is dominant during the growth of GaSb layers and is not very successful in flattening bigger defects like defects in pyramidal shape [4]. The growth of a superlattice is nevertheless necessary to maintain the electrical conductivity of the sample.

It would be helpful to understand how these defects can be removed from the surface and how the process can be improved. If the smoothing is not successful theses pyramidal defects tend to grow bigger as the growth progresses. After the growth of structures with a thickness of several microns these defects can even be observed by a optical microscope with a magnification of 50.

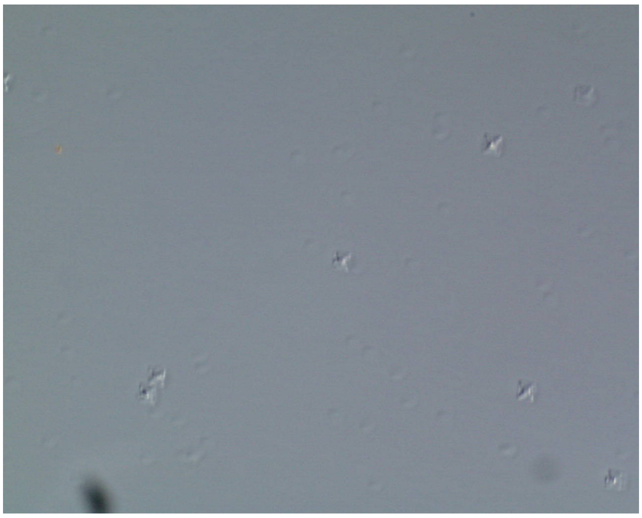

Abb. 1: At the samples' surface after several micrometer growth small pyramidal defects are visible. The image was taken by an optical microscope at a magnification of 50.

After producing the samples we can't avoid a expose them to the atmosphere. Nevertheless we are going to produce the samples promptly before the AFM experiment and store them in a cabinet flooded by pure nitrogen in order to reduce surface corrosion.

Literatur

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