EPITAXIAL GROWTH OF AlIII BV SEMICONDUCTORS FROM VAPOUR PHASE

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The growth of AlIII BV semiconductor epitaxial layers by chemical vapour deposition (CVD) has a great importance in producing materials for microwave and optoelectronical devices. In this paper the basic considerations of vapour phase epitaxy and the used growth systems are discussed. The main emphasis is on the open-tube flow technique using halides as transport materials. Examples of different source materials for group III element (Ga) as liquid Ga and solid AlIII BV ingots are described for materials and structures of GaP, GaAs and GaAs$_{1-x}$P$_x$ grown on GaAs and GaP substrates. Different homo-, and heteroepitaxial growth systems are also discussed. The epitaxial reactors used are single- and double-tube growth systems. A general description of the regulation temperature and the flow system is given as well as some properties of the grown layers.

1. Introduction

Ever since the early days of semiconductors, vapour phase processes have been employed in their preparation and often as an essential part of their fabrication into devices. This is particularly true in the case of AlIII BV compounds and structures involving the growth of epitaxial layers on substrates of the same material (homoepitaxy) or on substrates of different materials (heteroepitaxy).

A wide variety of different technics utilizing the vapour phase for epitaxy has been described [1—3]. Besides the physical methods (evaporation, sputtering, etc.), a great number of chemical vapour transport (CVT) or deposition (CVD) including the different closed tube and open-tube flow methods have been employed. (We distinguish between CVT and CVD methods on the basis of conditions over the growing crystal. If equilibrium is achieved fairly closely, the system is CVT, otherwise it is CVD.) Because of its capability, flexibility, reproducibility and the degree of control that can be achieved over the growth conditions using e.g. mass flow controllers determining and regulating the gas phase composition and dopant concentrations — up to a mass scale production — the open-tube flow methods are the most popular epitaxial methods.

In this paper the vapour phase epitaxial (VPE) technology used for the production of different, homo- and heteroepitaxial AlIII BV layer structures, which consist of GaP, GaAs and GaAs$_{1-x}$P$_x$ (0 < x < 1.0) materials, is discussed. All of these materials have been or might be prepared by different methods.
AIIIIV compound vapour growth by halogen transport using MX₃ halide or HX type (e.g. AsCl₃, PCl₃, etc. or HCl) has widely been used to produce various microwave and optical devices. The earliest effort to deposit AIIIIV compound from the vapour was the sealed-tube chemical transport of bulk GaAs using GaCl₃ [4]. This type of reaction was extended to an open-tube flow system by Newman and Goldsmith [5] and it was improved later by many authors. In the simplest form HCl gas is passed over AIIIIV bulk material to form GaCl and Mn (e.g. As₄). Epitaxy occurs downstream at a lower temperature. Metallic P or As and Ga can also be used as source materials. In the most generally used method the AIIIIV compound is synthetized in the reactor itself, and this so-called epitaxial synthesis has continued to be useful in the deposition of materials such as GaP, GaAs and GaAs₁₋ₓPₓ. The first high quality GaAs epitaxial layer with a very low impurity contamination was grown by Knight and coworkers [6] using also AsCl₃ to supply both the arsenic and the HCl in a H₂ carrier gas. Gallium arsenide phosphide (GaAs₁₋ₓPₓ) was also grown as epitaxial layer on GaAs substrate by methods derived from those devised by Tietjen and Amich [7] with PH₃ as well as methods using AsCl₃ and PCl₃ [8, 9]. For GaP VPE growth with PCl₃ transport was described by Oldham [10].

2. Basic considerations

2.1 Stephan flow

The theory of gas phase chemical transport is given in detail in [11, 12]. Using the simple, one dimensional model along the X-axis if one supposes that all species diffuse with the same diffusion coefficient D, the flux of each species can be written as

\[ J_i = \frac{V}{RT} p_i - \frac{D}{RT} \frac{dp_i}{dx}, \]

where \( V \) is the so called Stephan velocity. According to Stephan’s early observations, evaporating material in a tube or pipe the whole of the gas moves away from the source surface with this velocity \( V \). The process involves not only the diffusion, but both the interdiffusion of the evaporated material and the surroundings (e.g. air) and the generation of vapour, as the latter process needs volume. Summing Eq. (1) for all components we obtain

\[ \sum_i' J_i = \frac{V}{RT} p, \]