Dr. Ir. J.C. Lötters

MOVPE has become the main industrial technology for the preparation of modern electronic (HEMTs for mobile communication, navigation and location) as well as optoelectronic (lasers, LEDs, detectors or solar cells). Now a new generation of digital mass flow controllers is described, claimed as ideally suitable for fast, accurate and stable precursor supply into an MOVPE reactor. The instruments are capable of handling typical precursor flow rates of the order of (gases) 5 slm AsH3, PH3 and NH3 and (liquids) 50 g/h TMA, TMG and TMI. The settling time $t_{98\%}$ of the instruments is 200µs and 2µs, respectively.

Digital mass flow control

MOVPE of III-V compound devices is commonly performed using the trimethyl- or triethyl-compounds of aluminium (eg. TMA), gallium (eg. TMG) and indium (eg. TMI) as group-III precursors and ammonia (NH_3), phosphine (PH_3) or arsine (AsH_3) as group-V precursor. For trimethyl metal precursors, the crystal growth is described by the overall reaction:

$(CH_3)_3M + VH_3 \rightarrow MV + 3CH_4$:

M = (Al, Ga, In)

V = (As, P, N): MV ≡ eg. GaAs

Crystalline or contaminate defects are extremely detrimental for semiconductor devices, so the epitaxial layergrowth should occur under very well-defined, well-controlled conditions. Therefore, accurate and stable MO precursor supply to the MOVPE reactor for the preparation of the device structure is very important. Moreover, to decrease production time per wafer, fast dosage of the (gas/ liquid) precursor is required.

Vapour delivery

A variety of bubbler configurations are used in vapour delivery systems. A classical bubbler system, consists of a liquid containing vessel, shrouded with a temperature-controlled heater jacket. The vapour flow is controlled by the carrier gas flow, possibly diluted with a dilution gas and stabilised by keeping the pressure in the bubbler at a constant level.

Although bubbler system technology is simple and mature, performance is often poor due to slow response, unstable and poorly reproducible vapour flow and dependency of the vapour pressure line of the liquid used.

Dispensing systems based on direct liquid injection differ fundamentally from bubbler systems. In direct liquid injection, such as Bronkhorst's "CEM" system (Controlled Evaporation Mixing), vapour delivery depends on control of liquid flow, as opposed to vapour control.

The precursor is controlled in its natural (liquid) state, at ambient conditions, and subsequently evaporated. The liquid, controlled by the liquid flow controller, is transported with a carrier gas into the evaporator-mixer, where vapourisation takes place. The main advantages of the CEM direct liquid injection system are fast response, high repeatability, good stability, low working temperatures and independence of the vapour pressure line.

The new generation controls

Digital versions of Bronkhorst's EL-FLOW series thermal mass flow controllers for gases are featuring flow ranges of 1ml_n/min through 1250 l_n/min (Full Scale values), high accuracy (± 0.5 % Rd + 0.1 % FS) and excellent temperature stability (± 0.1 %/°C).

The instrument can be equipped with DeviceNet, Profibus, Modbus or FLOW-BUS interface. The EL-FLOW mass flow controllers can be applied for most gas types, including AsH_3, PH_3 and NH_3. By optimising all components in the control loop, i.e. sensor, valve, electronics and control algorithm, the dynamic behaviour of the instrument has recently been dramatically improved.

Figure 1 Digital mass flow controller for liquids;

The new generation of digital EL-FLOW MFCs with very fast response shows a typical settling time $t_{98\%}$ = 200µs.

In 2003 Bronkhorst introduced a new generation of digital thermal mass flow controllers for liquids (Figure1), featuring flow ranges of 0.1up to 1000 g/h (Full Scale values) and fast response (t98% = 2µs,).

The standard accuracy for the digital Liquiflow series is ± 1 % FS and temperature stability is better than 0.1 % / °C. The instruments can be equipped with the same fieldbus interfaces as the El-Flow series. The digital mass flow controllers can be applied for most liquid types, including TMA, TMG and TMI. Since it is rather impractical to perform an actual calibration for each liquid, all calibrations are performed with a reference liquid, such as for instance isopropyl alcohol (IPA). The relation between IPA and the liquid to be calibrated, the conversion factor, can be calculated. Measurement results for a Liqui-Flow instrument can store calibration curves for up to eight different fluids.

Contact: Dr. Ir. J.C. Lötters, Manager R&D, Bronkhorst High-Tech B.V
Web: http://www.bronkhorst.com/