Magnetically Assisted Self Assembly – A New Heterogeneous Integration Technique

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Sponsorship

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We have recently proposed a radically new approach to the heterogeneous integration of compound semiconductor devices such as laser diodes with silicon integrated circuits, and have begun an experimental program to develop this technique. Our new approach, called Magnetically-Assisted Statistical Assembly (MASA), uses statistical self-assembly to locate compound semiconductor device heterostructures in shallow recesses patterned into the surface of an integrated circuit wafer, and short-range magnetic attractive forces to keep them there. When all of the recesses on the wafer are filled with heterostructures, the wafer is processed further to transform the heterostructures into devices monolithically integrated with the underlying circuitry. The process is summarized in Figure 41.

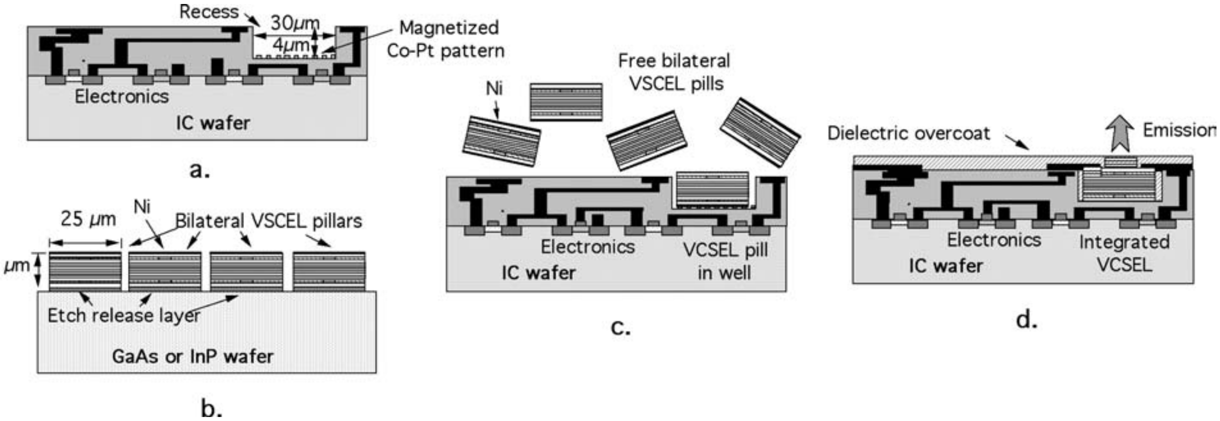

Fig. 41: The MASA process: (a) the processed IC wafer with the recesses prepared, and (b) the p-side down VCSEL wafer with pillars etched in a close-packed array; (c) statistical assemby of the freed nanopills in the recesses on the IC wafer; and (d) after completing device processing and integration.

During statistical assembly, the surface of a wafer prepared with recesses will be flooded with several orders of magnitude more nanopills than are needed to fill its recesses. The large number of pills will mean that there are many pills in the vicinity of each of the recesses, and the highly symmetric nature of the pills and recesses will result in a high probability that a pill in the vicinity of a recess will fall into it. The strong short-range magnetic attractive force which will come into play when a pill settles into a recess will keep the pill from being removed from the recess by gravity or by another nanopill or by the fluid used to flood the surface with nanopills. The process can be favorably compared to carrier trapping by deep levels in semiconductors, and the probability that a given recess is filled will be one. Once the nanopills are assembled on the circuit wafer they will be fixed in position using a polymer which will also fill in any voids on the surface surrounding the pills and planarize the surface. Processing of the heterostructures to convert them into devices and integrate them with the underlying electronics then proceeds using standard monolithic photolithographic processes.

The MASA process is an attempt to combine the best features of our Epitaxy-On-Electronics (EoE) and Aligned Pillar Bonding (APB) integration techniques, with the ability to monolithically integrate any semiconductor device on any substrate (including full 12” silicon wafers and electro-optic waveguide substrates). In MASA the device heterostructures are located in recesses in the wafer surface as in EoE and APB, and the final device patterning, processing, and integration is done after assembly at the wafer level and in a batch mode. At the same time, the device heterostructures can be grown on their optimum substrate under optimal conditions, as in APB, but the epitaxial material is much more efficiently used than in APB because the pillars are etched in a close-packed array. Finally, the relative sizes of the device and IC wafer are unimportant in MASA, unlike EoE and APB which are limited by the lack of large GaAs or InP wafers (currently 6" and 4", respectively).

With the help of Profs Zahn and Ross (MIT), we have conducted an analysis of the magnetic retention concept, and we find that a 0.5 µm thick layer of Co-Pt alloy patterned into stripes 2 µm wide and magnetized normal to the substrate surface will exert sufficient attractive force on nanopills coated with a 0.2 µm film of Ni to hold them in a well very strongly, and the attractive force is very short range, as we want. It will be negligible if the separation between the pill and the bottom of the well exceeds 2 µm, but it increases rapidly at smaller separations and far exceeds the force of gravity, for example, when the separation is under 1 µm.

Work this past year has resulted in the successful integration of a Ni soft magnetic layer with GaAs optoelectronic diode material. The Ni has been sputtered onto the diode material, patterned and wet etched. A BCl3 reactive ion etch has been used to etch the diode material vertically down 5.5 microns. A selective wet etch was used to free the diode material from the substrate using 30 % HF.

We have also initiated a collaboration with Dr. Chong Tow Chong of the Data Storage Institute in Singapore on the deposition and patterning of the hard magnetic stripe patterns. Dr. Chong and his staff are preparing substrates with a variety of hard magnetic stripe patterns for our study and use.

A practical pill collection technique needs to be refined as the next step in the program. Work will also be done on optimally depositing, patterning, and etching SiO_2 recesses on the hard magnetic stripe patterns on Si substrates for studies of the assembly process. Magnetic characterization is also planned using magnetic field microscopy to verify the MASA calculations and refine our process. With successful development of the assembly process our program will expand to encompass the use of this technology in a variety of applications.