PROCESSES FOR MULTI-LAYER DEVICES UTILIZING LAYER TRANSFER

GOVERNMENT RIGHTS

[0001] This invention was made with Government support under Contract No. DE-AC04-94AL85000 awarded by the U.S. Department of Energy. The Government has certain rights in the invention.

FIELD OF THE INVENTION

[0002] The present invention relates in general to semiconductor devices having multiple functionalities, in particular integrally formed semiconductor devices having microelectronic and optoelectronic applications.

BACKGROUND

[0003] Silicon wafers are used in the fabrication of integrated circuits (ICs) and other microelectronic systems (MEMS) devices. The wafer serves as the substrate for fabrication of microelectronic devices built in and over the wafer. The wafer therefore undergoes many microfabrication process steps. Once the desired functionality is achieved, the individual devices are separated and packaged.

[0004] Silicon wafers, however, have limited functionality. For example, silicon wafers can be fabricated for the purposes of digital or analog processing but are unable to efficiently serve as light emitters and detectors. Rather light emitters and light detectors are typically fabricated from wafers made of compound semiconductor materials, such as group III-V semiconductor materials. In particular, compound semiconductor devices have stronger optical absorption, electrically driven optical emission, high and low band-gaps and higher carrier mobilities than silicon devices. Silicon devices, however, have the advantage of high performance IC processing, materials and micromachining technology.

[0005] In many microelectronic systems (MEMS) and optoelectronic applications, it is desirable to use compound semiconductor devices and silicon devices in combination. Combining the devices into one structure, however, has been challenging from a technical standpoint making it commercially unfeasible.

SUMMARY

[0006] A method for fabricating devices that are made of multiple layers of different semiconductor devices having different functionalities is disclosed. The method may include forming a release layer over a donor substrate. A plurality of devices made of a first semiconductor material can be formed over the release layer. In one embodiment, the first semiconductor material can be a compound semiconductor material such as a III-V semiconductor material that can be used to form a device having optoelectronic functionalities. A first dielectric layer is formed over the plurality of devices such that all exposed surfaces of the plurality of devices are covered by the first dielectric layer. The plurality of devices can be attached to a receiving device made of a second semiconductor material different than or same as the first semiconductor material. The resulting device can be attached to a receiving substrate. In some embodiments, the receiving substrate is a silicon semiconductor structure having devices that can be processed to have microelectronic and/or optoelectronic functionality. Once the devices are attached together, the release layer can be etched to release the donor substrate from the plurality of devices. A second dielectric layer can be applied over the plurality of devices and the receiving substrate to mechanically attach the plurality of cells to the receiving substrate. A second plurality of cells made of a compound semiconductor material may further be attached to the cells already bonded to the receiving substrate to provide further functionality to the resulting device.

[0007] In one embodiment, the resulting device may include a first plurality of devices made of a compound semiconductor material. The compound semiconductor material may be a III-V semiconductor material. A second plurality of devices made of a semiconductor material different than the first plurality of devices can be bonded to the first plurality of devices. For example, the semiconductor material of the second plurality of devices may be silicon. In addition, a dielectric layer may surround the first plurality of devices and the second plurality of devices to mechanically bond the first plurality of devices to the second plurality of devices. The resulting device is therefore an integrated device having the combined characteristics of a compound semiconductor and a silicon semiconductor.

[0008] The above summary does not include an exhaustive list of all aspects of the present invention. It is contemplated that the invention includes all systems and methods that can be practiced from all suitable combinations of the various aspects summarized above, as well as those disclosed in the Detailed Description below and particularly pointed out in the claims filed with the application. Such combinations have particular advantages not specifically recited in the above summary.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The embodiments of the invention are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings in which like references indicate similar elements. It should be noted that references to "an" or "one" embodiment of the invention in this disclosure are not necessarily to the same embodiment, and they mean at least one.

[0010] FIG. **1** schematically illustrates a cross-sectional view of one embodiment of a donor substrate having a release layer formed thereon.

[0011] FIG. **2** schematically illustrates a cross-sectional view of one embodiment of a compound semiconductor device layer formed on a release layer.

[0012] FIG. **3** schematically illustrates a cross-sectional view of one embodiment of compound semiconductor device formed from a compound semiconductor device layer.

[0013] FIG. **4** schematically illustrates a cross-sectional view of one embodiment of compound semiconductor devices covered with a dielectric layer.

[0014] FIG. **5** schematically illustrates a cross-sectional view of one embodiment of an etched dielectric layer.

[0015] FIG. **6** schematically illustrates a cross-sectional view of one embodiment of compound semiconductor devices attached to a receiving device.

[0016] FIG. **7** schematically illustrates a cross-sectional view of one embodiment in which a donor substrate is released from the compound semiconductor devices.

[0017] FIG. **8** schematically illustrates a cross-sectional view of one embodiment of compound semiconductor devices attached to a receiving substrate.