OPTOELECTRONIC MODULES THAT HAVE SHIELDING TO REDUCE LIGHT LEAKAGE OR STRAY LIGHT, AND FABRICATION METHODS FOR SUCH MODULES

FIELD OF THE DISCLOSURE

This disclosure relates to optoelectronic modules have shielding to help reduce light leakage or stray light, and fabrication methods for such modules.

BACKGROUND

Smartphones and other devices sometimes include miniaturized optoelectronic modules such as light modules, sensors or cameras. Light modules can include a light emitting element such as a light emitting diode (LED), an infra-red (IR) LED, an organic LED (OLED), an infra-red (IR) laser or a vertical cavity surface emitting laser (VCSEL) that emits light through a lens to outside the device. Other modules can include a light detecting element. For example, CMOS and CCD image sensors can be used in primary or front facing cameras. Likewise, proximity sensors and ambient light sensors can include a light sensing element such as a photodiode. The light emitting and light detecting modules as well as cameras can be used in various combinations. Thus, for example, a light module such as a flash module can be used in combination with a camera that has an imaging sensor. Light emitting modules in combination with light detecting modules also can be used for other applications such as gesture recognition or IR illumination.

As illustrated in FIG. **1**, one challenge when integrating an optoelectronic module **10** into a device such as a smartphone is how to reduce light leakage **14** from the light source **16** in the light module, or how to prevent incoming stray light from impinging, for example, in the case of sensors or cameras. Preferably, light emitted from light source **16** (or light to be detected by a sensor in the module) should pass through lens **12** and exit (or enter) directly through the transparent cover **18** of the module **10**. However, in some cases, some of the light **14** exits (or enters) the sides of transparent cover **18**, which can be undesirable.

SUMMARY

The present disclosure describes various optoelectronic modules that include an optoelectronic device (e.g., a light emitting or light detecting element) and a transparent cover. Non-transparent material is provided on the exterior sidewalls of the transparent cover, which, in some implementations, can help reduce light leakage from the sides of the transparent cover or can help prevent stray light from entering the module.

In addition, various techniques are described for fabricating the modules. In some implementations, the modules can be fabricated in a wafer-scale process. Such processes allow many modules to be manufactured at the same time. In some implementations, various elements (e.g., an optical element such as a lens, an optical filter, or a focal length correction layer; or a spacer) can be formed directly on one side or both sides of the transparent wafer using one or more vacuum injection and/or replication tools.

For example, in one aspect, an optoelectronic module includes an optoelectronic device mounted on a substrate, and a transparent cover held at a distance from the substrate by a spacer. The spacer is composed of a material that is non-transparent to light emitted by or detectable by the optoelectronic device. Sidewalls of the transparent cover are covered by a material that is non-transparent to light emitted by or detectable by the optoelectronic device.

Some implementations include one or more of the following features. For example, the module also can include an optical element (e.g., a lens, an optical filter (e.g., a dielectric band-pass filter) and/or a focal length correction layer on a surface of the transparent cover). The non-transparent material covering the sidewalls of the transparent cover can be, for example, the same material of which the spacer is composed. In some cases, the non-transparent material covering the sidewalls of the transparent cover is a polymer material (e.g., epoxy, acrylate, polyurethane, or silicone) containing a non-transparent filler (e.g., carbon black, pigment, or dye). The transparent cover may be substantially parallel to the plane of the substrate or tilted at an angle with respect to the plane of the substrate.

In another aspect, a method of fabricating optoelectronic modules includes providing, on a support surface, a plurality of singulated transparent substrates separated laterally from one another. A vacuum injection technique is used to cover sidewalls of each of the singulated transparent substrates with a non-transparent material, and spacer elements are formed that project away from the support surface. In some cases, the method also includes forming or applying a respective optical element (e.g., a lens, an optical filter (e.g., a dielectric band-pass filter) and/or a focal length correction layer on a surface of the transparent cover) on a surface of each of the singulated transparent substrates.

Some implementations include one or more of the following features. For example, the spacer elements can be formed as part of the same vacuum injection technique used to cover the sidewalls of the singulated transparent substrates with a non-transparent material. In some cases, the same combined replication and vacuum injection tool(s) is used for the replication technique and for the vacuum injection technique.

In some implementations, the method includes using a first vacuum injection tool to cover the sidewalls of the transparent substrates with a non-transparent material and to form the spacer elements on a first side of a plane in which the transparent substrates are located during a first vacuum injection process, and using a second combined replication and vacuum injection tool to form the optical elements on a second side of the plane during a replication process and to form projections on the second side of the plane during a second vacuum injection process. The projections can serve, for example, as non-transparent baffles and/or alignment features for the optoelectronic modules.

According to another aspect, a method of fabricating optoelectronic modules includes providing a plurality of singulated transparent substrates within openings of a non-transparent wafer disposed on a support surface. The transparent substrates and the non-transparent wafer are in a plane, and the support surface has openings adjacent a first side of the plane. The method includes forming a respective optical element on each of the transparent substrates on a second side of the plane using a replication technique, filling the openings in the support surface with a first non-transparent material using a first vacuum injection process, and forming non-transparent spacer elements on the second side of the plane using a second vacuum injection process.

According to yet a further aspect, a method of fabricating optoelectronic modules includes providing a wafer that has a plurality of transparent portions laterally spaced from one another. Each of the transparent portions is surrounded laterally by non-transparent material, and the wafer is in a