TRANSDUCERS AND INDICATORS HAVING PRINTED DISPLAYS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Ser. No. 08/504,896 filed Jul. 20, 1995, pending, U.S. Ser. No. 08/983,404 filed Jul. 19, 1997, abandoned, and U.S. Ser. No. 08/935,800 filed Sep. 23, 1997, allowed, the contents of all of which are incorporated herein by reference. This application claims priority to U.S. Ser. No. 60/057,133 filed Aug. 28, 1997, U.S. Ser. No. 60/057,716, filed Aug. 28, 1997, U.S. Ser. No. 60/057,122, filed Aug. 28, 1997, U.S. Ser. No. 60/057,798, filed Aug. 28, 1997, U.S. Ser. No. 60/057,799 filed Aug. 28, 1997, U.S. Ser. No. 60/057,163 filed Aug. 28, 1997, U.S. Ser. No. 60/057,118, filed Aug. 28, 1997, U.S. Ser. No. 60/059,358, filed Sep. 19, 1997, U.S. Ser. No. 60/059,543 filed Sep. 19, 1997, U.S. Ser. No. 60/065,629, filed Nov. 18, 1997, U.S. Ser. No. 60/065,630 filed Nov. 18, 1997, U.S. Ser. No. 60/065,605 filed Nov. 18, 1997, U.S. Ser. No. 60/066,147, filed Nov. 19, 1997, U.S. Ser. No. 60/066,245, filed Nov. 20, 1997, U.S. Ser. No. 60/066,246, filed Nov. 20, 1997, U.S. Ser. No. 60/066,115 filed Nov. 21, 1997, U.S. Ser. No. 60/066,334 filed Nov. 21, 1997, U.S. Ser. No. 60/066,418 filed Nov. 24, 1997, U.S. Ser. No. 60/070,940 filed Jan. 9, 1998, U.S. Ser. No. 60/071,371 filed Jan. 15, 1998, U.S. Ser. No. 60/072,390 filed Jan. 9, 1998, U.S. Ser. No. 60/070,939 filed Jan. 9, 1998, U.S. Ser. No. 60/070,935 filed Jan. 9, 1998, U.S. Ser. No. 60/074,454, filed Feb. 12, 1998, U.S. Ser. No. 60/076,955 filed Mar. 5, 1998, U.S. Ser. No. 60/076,959 filed Mar. 5, 1998, U.S. Ser. No. 60/076,957 filed Mar. 5, 1998, U.S. Ser. No. 60/076,978 filed Mar. 5, 1998, U.S. Ser. No. 60/078,363 filed Mar. 18, 1998, U.S. Ser. No. 60/083,252 filed Apr. 27, 1998, U.S. Ser. No. 60/085,096 filed May 12, 1998, U.S. Ser. No. 60/090,223 filed Jun. 22, 1998, U.S. Ser. No. 60/090,232 filed Jun. 22, 1998, U.S. Ser. No. 60/092,046 filed Jul. 8, 1998, U.S. Ser. No. 60/092,050 filed Jul. 8, 1998, and U.S. Ser. No. 60/093,689 filed Jul. 22, 1998, the contents of all of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to display applications, and in particular, to transducers and indicators having printed displays, including printed encapsulated electrophoretic displays.

BACKGROUND OF THE INVENTION

Many applications can benefit from inclusion of a display. For example, projection devices, sketching apparatuses, telephones, pocketbooks, and battery indicators are only a few applications that display transient information. To date, widespread incorporation of displays has been hindered because such applications generally require flexible displays that consume very little power.

Despite much effort directed to developing highly-flexible, reflective display media, there are relatively few examples of displays formed on semi-flexible substrates, and these examples have found only moderate success. For example, plastic-based liquid crystal displays, including twisted nematic (TN), supertwisted nematic (STN), polymer dispersed liquid crystal (PDLC), and bistable cholesteric liquid crystals have been developed. Nevertheless, problems remain with liquid crystal alignment in TN and STN displays, cholesteric displays are sensitive to changes in their cell gap, and local stress can cause changes in the

scattering or absorbance of PDLC and cholesteric films. As such, only moderate flexibility can be achieved with these displays.

Emissive electroluminescent films and organic light emitting diode films can be deposited on flexible substrates to create flexible displays. However, these devices require continuous power consumption for operation, and thus are not practical for many applications.

Another problem with developing highly flexible displays is the lack of an appropriate conductor for addressing the display elements. Typically, an indium tin oxide (ITO) layer vacuum sputtered onto a plastic substrate is used as a top conductor for displays. An ITO layer, however, can be damaged when the display is flexed. If the local curvature of the plastic substrate becomes too great, the ITO layer tends to crack, damaging the display.

SUMMARY OF THE INVENTION

An object of the invention is to provide a highly-flexible, reflective display which can be manufactured easily, consumes little (or no in the case of bistable displays) power, and can, therefore, be incorporated into a variety of applications. The invention features a printable display comprising an encapsulated electrophoretic display medium. The resulting display is flexible. Since the display media can be printed, the display itself can be made inexpensively.

An encapsulated electrophoretic display can be constructed so that the optical state of the display is stable for some length of time. When the display has two states which are stable in this manner, the display is said to be bistable. If more than two states of the display are stable, then the display can be said to be multistable. For the purpose of this invention, the term bistable will be used to indicate a display in which any optical state remains fixed once the addressing voltage is removed. The definition of a bistable state depends on the application for the display. A slowly-decaying optical state can be effectively bistable if the optical state is substantially unchanged over the required viewing time. For example, in a display which is updated every few minutes, a display image which is stable for hours or days is effectively bistable for that application. In this invention, the term bistable also indicates a display with an optical state sufficiently long-lived as to be effectively bistable for the application in mind. Alternatively, it is possible to construct encapsulated electrophoretic displays in which the image decays quickly once the addressing voltage to the display is removed (i.e., the display is not bistable or multistable). As will be described, in some applications it is advantageous to use an encapsulated electrophoretic display which is not bistable. Whether or not an encapsulated electrophoretic display is bistable, and its degree of bistability, can be controlled through appropriate chemical modification of the electrophoretic particles, the suspending fluid, the capsule, and binder materials.

An encapsulated electrophoretic display may take many forms. The display may comprise capsules dispersed in a binder. The capsules may be of any size or shape. The capsules may, for example, be spherical and may have diameters in the millimeter range or the micron range, but is preferably from ten to a few hundred microns. The capsules may be formed by an encapsulation technique, as described below. Particles may be encapsulated in the capsules. The particles may be two or more different types of particles. The particles may be colored, luminescent, light-absorbing or transparent, for example. The particles may include neat pigments, dyed (laked) pigments or pigment/polymer