layer **43** has a relatively simple mechanical configuration. Layers **43** are stacked together and pins **21** installed to form the completed display surface **23**. Registration of the layers can be assured by mounting all the layers **43** on shafts **44** that extend through all the layers **43** at openings **45**, or by inclusion of tongue and groove structures in some of the layers **43**, in the non-display areas of those layers. In cases where a layer **43** is required to move laterally with respect to the other layers **43** (for example, a locking layer), openings **45** that align that layer to alignment shafts **44** or tongue and groove structures can be elongated slightly, to permit just the necessary amount of lateral motion (as discussed hereinbelow) of that layer relative to the other layers (see enlarged openings **45'** relative to openings **45"** in **FIG. 5**, for example).

[**0045**] In an extended array design where each pin actuator controls multiple pins, pin retention mechanisms are preferred to hold each pin **21** in place at times when an actuator is not driving it. One approach is pressure-based device (such as a spring clip) **51** as shown in **FIG. 7**. The actuator chosen must exert sufficient force to move pin **21** against the force of the pressure-based device (e.g. spring clip) **51** exerted at ridge **33** of pin **21**, and the pressure-based device holds the pin in its new position firmly against shaft **27** and ridge **33** (enough to prevent it from being moved by the pressure of the fingers reading the display). After the displayed image has been read, pins **21** may be reset by forcing them back against the force of pressure-based device **51**.

[**0046**] Another, preferred, approach to pin retention is a two-stage pin retention system. As the pins are set, a temporary pin retention mechanism holds the pins firmly enough to keep them in the position where they were set, but not firmly enough for reading by the user. After the pins have been set to the desired configuration, a locking mechanism holds the array of pins firmly in place, permitting reading by the user. When the time comes to reset the display, the pins are first unlocked to allow free movement. (The temporary pin retention mechanism may also be released during reset, depending upon implementation, but this may not be necessary because of the relatively low forces required to move the pins against the force of the temporary pin retention mechanism).

[**0047**] Two-stage pin retention mechanisms, while more complex than the single-stage approach described above, have the following advantages: 1) less force is required to set the individual pins, 2) the pins can be held firmly while the user is reading the display, 3) less energy is required to operate the display, 4) less force is required to reset the pins (which is important when there are a large number of pins to reset in a short period of time), and 5) wear of the pins and locking mechanisms is reduced.

[**0048**] As part of the two-stage pin retention mechanism, the purpose of temporary pin retention is to hold the pins that have been set and the pins that have not been set in their correct respective positions during the process in which the selected pins are set. The temporary mechanism thus holds the pins against the influences of gravity, electrostatic attraction, light incidental contact, and acceleration (jarring or shaking) to which the display may reasonably be expected to be subjected. At the same time, it is desirable that this mechanism not require unduly high force for setting or resetting the pins, and that it have little tendency to wear or to cause wear in the pins or other display components. The mechanism may be configured to release entirely during display reset, though this capability may add unwanted complexity to the display design.

[**0049**] One example **55** of a temporary pin retention mechanism is shown in **FIG. 8** (with the pin heads cut away), and includes flexible sheet **56** (and would also comprise a layer **43** in a stacked array). A sheet of material that is strong and flexible but with low elasticity (e.g. MYLAR) is included as a component of the matrix that holds pins **21**, positioned so that a feature on each pin **21** (for example head **31** or a ridge **33** on shaft **27**) forces part (at openings **58**) of flexible sheet **56** to bend or stretch slightly to allow passage of the feature whenever a pin **21** is set or reset. Openings **58** in flexible sheet **56** through which the pins pass may be holes only slightly larger than pin shaft **27** (so that the passage through the hole of any portion of the pin with larger diameter causes the flexible sheet to stretch), or openings **58** may include cuts **60** thereat in flexible sheet **56** radial to the surface of an opening **58**, effectively forming tabs of the material of flexible sheet **56** that flex to allow passage of larger-diameter portions of pins **21**. In either event, a pin that is set or reset pops through the flexible sheet, and is held in place by the force that would be required to pop it back. When used in a multi-level display (accommodating setting of multiple pin heights), it is expected that either a separate sheets **56** in a layer **43**/**55** or multiple pin structures at each pin **21** (e.g. ridges **33**) will be required for each set level.

[**0050**] Alternatively, compressible (springy) material could be utilized for temporary pin retention. An example of this would be a thin foam plastic sheet of foam with very fine cell structure or the like. A sheet of this material can be included in a layer **43** of the matrix of layers holding the pins, and positioned so that the material contacts either the smooth shafts of the pins or a textured surface on the pins. Pin retention is accomplished by means of friction between the pins and the sheet of material. With the use of a sufficiently thin sheet of material, tendency of the pins to spring back after being set or reset can be minimized. This approach would be useful in multi-level displays, since one sheet of material can be configured to support multiple pin displacements.

[**0051**] A third approach to temporary pin retention would utilize high viscosity liquid or plastic material. The pins and a corresponding layer **43** in the pin holding matrix are made to contact a material (e.g. petroleum-based grease or silicone) that allows setting and resetting motion of the pins, but holds them lightly due to the viscosity of the material. Such an approach requires means to prevent the flow of the material to portions of the display where it is not wanted (e.g. embedding it in a fabric), and prevention of contamination of the material by abrasives (which could cause wear) or other substances (by limiting access to the environment and by selection of material for resistance to contamination).

[**0052**] An approach to temporary pin retention utilizes flexible clips **65** in a thin sheet array **67** of high strength material mounted in the pin holding matrix of layers in a way that permits a small degree of lateral movement (two different embodiments of which are shown in **FIGS. 9A and 9B**). This approach also may be utilized for pin locking