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(54) Title: PACKAGED COMBINATION MEMORY FOR ELECTRONIC DEVICES

(57) Abstract: A variety of different types of memory (16, 18, 20, 22), providing a complete memory solution, may be packaged together with a processor (14). As a result, a variety of different memory needs may be available in one package (10), particularly for portable applications. The packaged integrated circuit (10) may include a cross-point memory (16), and a volatile memory (22).

Packaged Combination Memory For Electronic Devices

Background

This invention relates generally to memories or storage for electronic devices.

A wide variety of memory is available for a variety of specialized applications. For example, volatile memories, such as dynamic random access memory (DRAM) and static random access memory (SRAM), may be utilized for fast access to data. However, DRAM memory is difficult to integrate and SRAM memory is relatively high in cost.

Another type of memory is flash memory. However, flash memory is slower in write mode and has a limited number of write and erase cycles. Because it is non-volatile memory, flash memory may be applicable to both code and data storage applications.

In a wide variety of electronic devices, there is a need for relatively low cost memory that performs a variety of different functions. Examples of such devices include portable devices, such as cellular telephones, personal digital assistants (PDAs), notebook computers, wearable computers, in-car computing devices, web tablets, pagers, digital imaging devices, and wireless communication devices, to mention a few examples.

Currently, the storage on processor-based systems is largely handled by semiconductor memories, such as SRAMs and DRAMs, and by mechanical devices, such as optical and magnetic disk drives. Disk drives are relatively inexpensive but have relatively slower read and write access times. Semiconductor memories are more expensive, but have relatively fast access times. Thus, electronic devices using a combination of disk drive and semiconductor memories for storage may place the bulk of the data and code in the disk drive and store frequently used or cache data on semiconductor memories.

However, none of the existing technologies adequately provide the needed attributes for a truly portable device including lower cost, lower power consumption, non-volatile memory compactness and easy integration. Thus, there is a need for new types of memory.

One new memory type is the polymer memory. The polymer memory involves polymer chains with dipole moments. Data may be stored by changing the polarization of a polymer between conductive lines. For example, a polymeric film may be coated with a large number of conductive lines. A memory location at a cross-point of two lines is

selected when the two transverse lines are both charged. Because of this characteristic, polymer memories are one type of cross-point memory. Another cross-point memory being developed by Nantero, Inc. (Woburn, MA) uses crossed carbon nanotubules.

Cross-point memories are advantageous since no transistors are need to store each bit of data and the polymer layers can be stacked to a large number of layers, increasing the memory capacity. In addition, the polymer memories are non-volatile and have relatively fast read and write speeds. They also have relatively low costs per bit and lower power consumption. Thus, the polymer memory has a combination of low cost and high capacity that fits well in handheld data storage applications.

Phase-change materials may also be utilized to create memories. In phase-change memories, a phase-change material may be exposed to temperature to change the phase of the phase-change material. Each phase is characterized by a detectable electrical resistivity. To determine the phase of the memory during a read cycle, current may be passed through the phase-change material to detect its resistivity.

The phase-change memories are non-volatile and high density. They use relatively low power and are easy to integrate with logic. The phase-change memory may be suitable for many code and data storage applications. However, some high-speed volatile memory may still be needed for cache and other frequent write operations.

Thus, there is still a need for a memory solution for low cost, portable applications.

Brief Description of the Drawings

Figure 1 is a block diagram of one embodiment of the present invention;

Figure 2 is a schematic depiction of a package in accordance with one embodiment of the present invention;

Figure 3 is a schematic depiction of a package in accordance with another embodiment of the present invention;

Figure 4 is a schematic depiction of a package in accordance with still another embodiment of the present invention;

Figure 5 is a schematic depiction of a package in accordance with yet another embodiment of the present invention;

Figure 6 is a cross-sectional view of a package in accordance with one embodiment of the present invention; and

Figure 7 is a cross-sectional view of a package according to another embodiment of the present invention.

Detailed Description

Referring to Figure 1, a packaged integrated circuit device 10 may include a bus 12 that couples a plurality of memories of different memory types to a processor 14. By combining a plurality of different types of memory within the same package with a processor 14, a solution may be provided to the varying memory needs of a wide variety of portable device equipment manufacturers.

A cross-point memory 16 may be a polymer memory and may primarily be utilized for mass storage of data. A volatile memory 22 may be provided for cache and frequent write functions. A phase-change memory 18 may be utilized for both data and code storage needs and a non-volatile memory 20 may also be provided for code storage purposes.

The memories 16, 18, 20 and 22 may be integrated within the same integrated circuit package as separate dice in one embodiment of the present invention. In one embodiment of the present invention, the bus 12 may be integrated in the same die with the processor 14. Thus, each of the dice containing the memories 16, 18, 20 and 22 may be electrically coupled to a die including the processor 14 and the bus 12 in accordance with one embodiment of the present invention. For example, the dice containing the memories 16, 18, 20 and 22 may simply be stacked over a die containing the processor 14 and bus 12 and then the dice may be encapsulated within the same package 10.

By encapsulating the various memory types within a single package 10 with the processor 14, a solution may be provided to virtually any memory need of any portable device. Thus, portable device manufacturers may simply use the package 10 and may be assured that a complete solution is available for all their memory needs. This may improve the standardization of portable devices and, as a result, may reduce costs.

Referring to Figure 2, the package 10a may include a stack of four separate dice in accordance with one embodiment of the present invention. The lowermost die may include the processor 14. Moving upwardly, the next die above the processor 14 die may contain the non-volatile storage 20 and the next die above the non-volatile storage 20 die

may include the cross-point memory 16. The uppermost die may include a volatile memory 22. Each of the dice may be electrically coupled to one another.

Referring next to Figure 3, the processor 14, bus 12, and non-volatile memory 20 may be integrated into the same die in the package 10b. In such an embodiment, a stack may include the die for the processor 14 and non-volatile memories 14 and 20 at the bottom, followed by the dice for the cross-point memory 16 and volatile memory 22, if needed.

Referring to Figure 4, in still another embodiment, a package 10c may include a die integrating the processor 14, volatile memory 20 and non-volatile memory 22 and a separate die may include the cross-point memory 16 in accordance with one embodiment of the present invention. Of course, a wide variety of other integrated combinations of memory types may be included as well.

Referring to Figure 5, a package 10d may include a processor 14 and non-volatile memories 16 and 20, integrated into the same die. Another die may include the phase-change memory 18, still another die may include the cross-point memory 16 and yet another die may include the volatile memory 22. In various embodiments, one or more of the memory types may be omitted.

Finally, referring to Figure 6, a specific package architecture is illustrated for the package 10e in accordance with one embodiment of the present invention. In this case, a substrate 30 may provide electrical connections as well as the bus 12. A separate die 42 may be provided, for example, for the processor 14, and one or more of the other memories 16, 18, 20 or 22. Still another die 40 may contain another one of the memories 16, 18, 20 or 22 and a third die 38 in the stack may contain still another memory type, such as one of the memories 16, 18, 20 or 22.

Electrical connections 34 may be provided from each die 38, 40 or 42 to the substrate 30 to provide electrical connections between the processor 14 and the memories 16, 18, 20 and 22 (as well as the bus 12). Any type of electrical connection to the external world may be provided on the package 10e including solder balls 32, in accordance with one embodiment of the present invention.

Referring to Figure 7, still another embodiment of the present invention may use a folded stacked package 10f. In this case, the package 10f may be formed by providing the dice 54 connected by flexible foldable tape 50. The tape 50 may be divided into sections,

one section including the solder balls 32 and the die 52c, another section including the die 54a and still another section including the die 54b. The sections may be wing folded towards the center. As a result, surface mount interconnections 56 can be made between the various dice 54. Solder ball connections 58 may also be provided. Thus, in some embodiments, the dice 54 may include the processor 14, and one or more of the memories 16, 18, 20 or 22. Folded stacked packaging technology is available, from Tessera Technologies, Inc., San Jose, California, 95134.

In addition, the folded stacked packages may in turn be stacked to form a stack of folded stacked packages.

As still another alternative, a larger die such as a processor may have multiple stacks of other dice stacked on top of the processor. For example, a processor may have two sets of stacked dice on top of the processor die.

While the present invention has been described with respect to a limited number of embodiments, those skilled in the art will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of this present invention.

What is claimed is:

1. A packaged integrated circuit comprising:
a processor;
a volatile memory; and
a cross-point memory.

2. The circuit of claim 1 including a first die and a second die, wherein said processor is on said first die and said cross-point memory is on said second die.

3. The circuit of claim 2 wherein said first die includes a processor and a bus that couples said processor to the volatile memory and the cross-point memory.

4. The circuit of claim 1 also including a phase-change memory.

5. The circuit of claim 1 including a package containing stacked dice.

6. The circuit of claim 1 wherein said package is a folded stacked package.

7. The circuit of claim 2 wherein said first die includes a processor and a non-volatile memory.

8. The circuit of claim 1 including a non-volatile memory.

9. The circuit of claim 1 including a ball grid array package.

10. A method comprising:
providing a processor and a cross-point memory on separate dice; and
packaging said cross-point memory and said processor in the same package.

11. The method of claim 10 including packaging a volatile memory on a separate die in said package.

12. The method of claim 10 including packaging said processor and said cross-point memory in a folded stacked package.

13. The method of claim 10 including packaging a phase-change memory in said package.

14. The method of claim 10 including providing a bus on said die with said processor and coupling said processor to said cross-point memory through said bus.

15. The method of claim 10 including stacking said dice on top of one another.

16. The method of claim 10 including packaging a volatile memory in the same package with said processor and said cross-point memory.

17. The method of claim 10 including providing a ball grid array on said package.

18. A packaged integrated circuit comprising:
a first die including a processor; and
a second die including a cross-point memory.

19. The circuit of claim 18 including a third die with a volatile memory.

20. The circuit of claim 18 including a bus on said first die coupling said processor to said cross-point memory.

21. The circuit of claim 18 including a phase-change memory.

22. The circuit of claim 18 including a plurality of stacked dice.

23. The circuit of claim 18 including a folded stacked package.

24. The circuit of claim 18 including a ball grid array package.

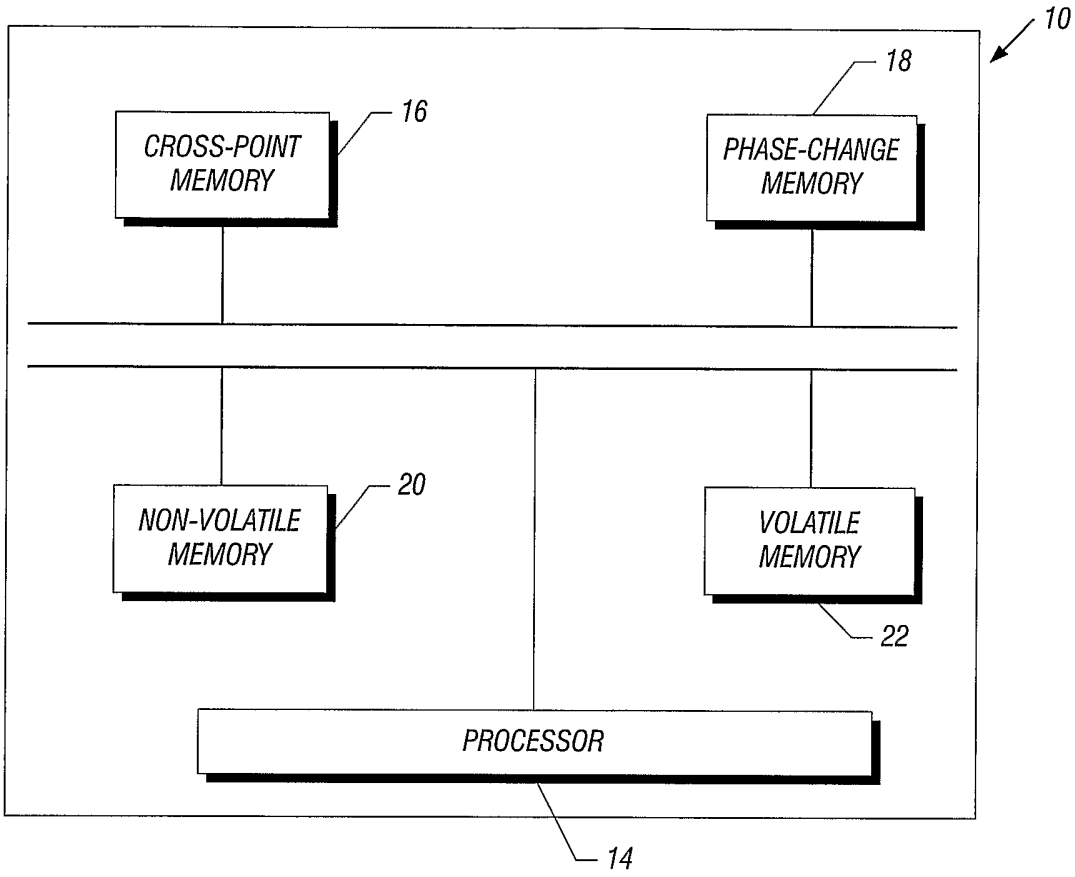
10
18
16
CROSS-POINT MEMORY
PHASE-CHANGE MEMORY
20
NON-VOLATILE MEMORY
VOLATILE MEMORY
22
PROCESSOR
14

FIG. 1

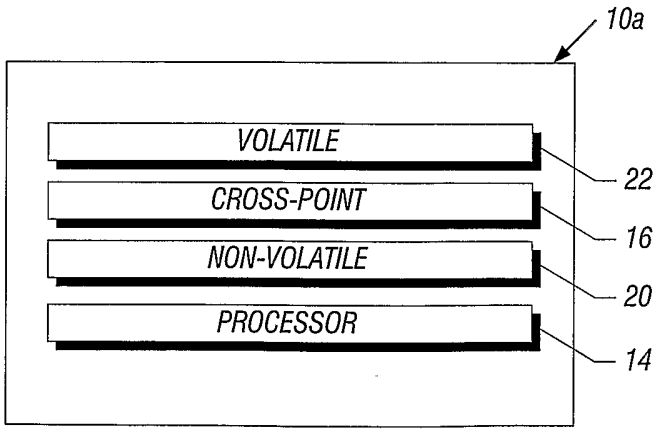
10a
VOLATILE
22
CROSS-POINT
16
NON-VOLATILE
20
PROCESSOR
14

FIG. 2

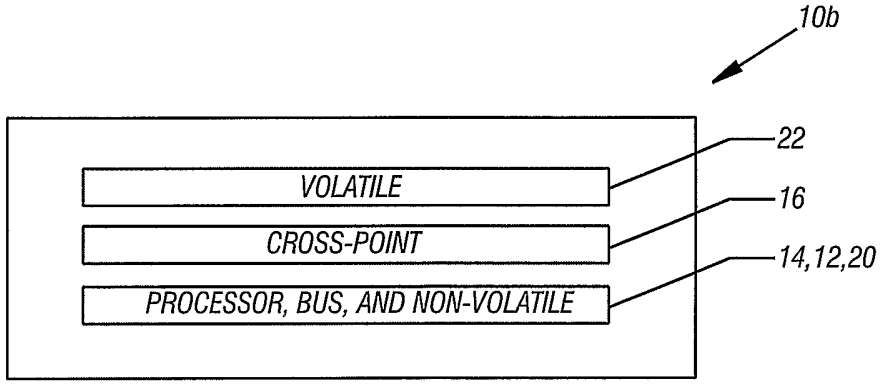

FIG. 3

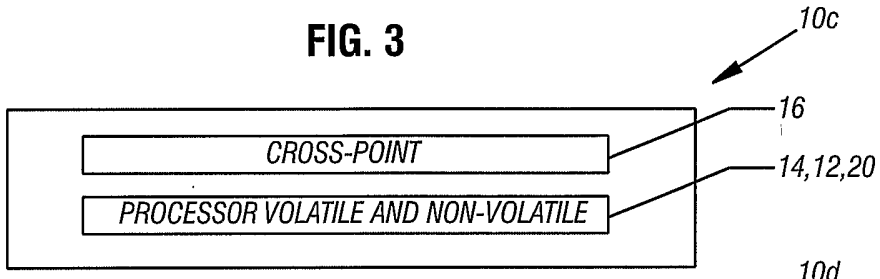

FIG. 4

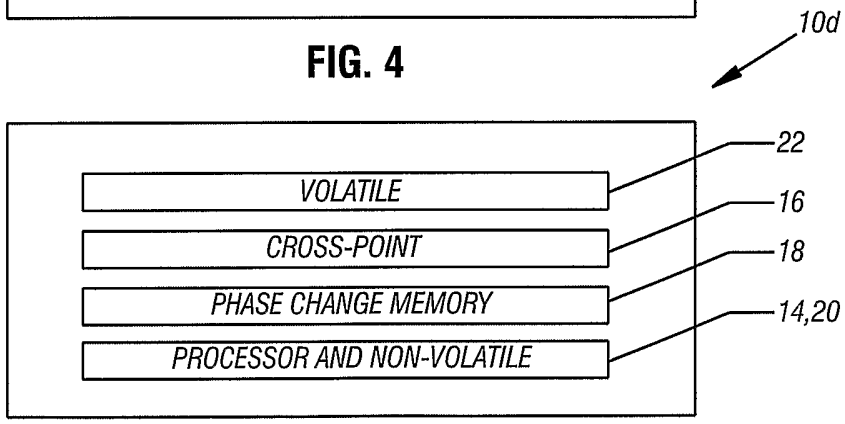

FIG. 5

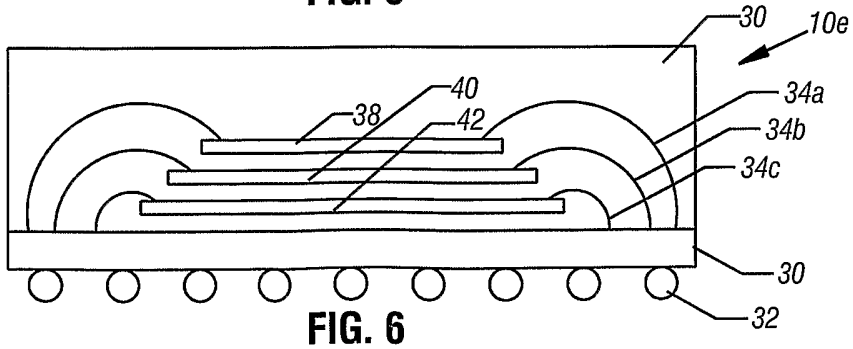

FIG. 6

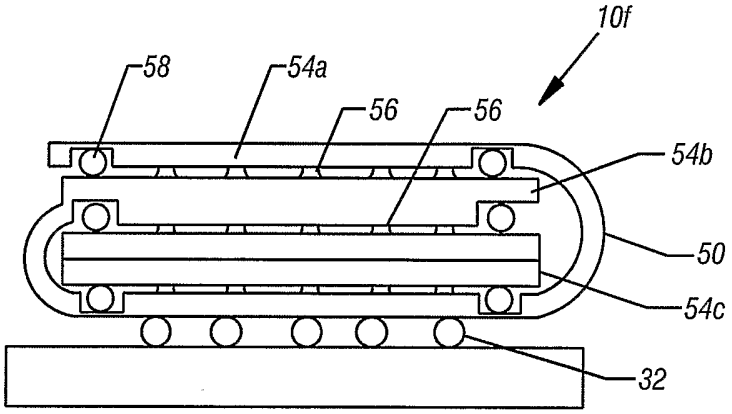

FIG. 7