Also a deep scanning read operation DSR may be performed sequentially with respect to the candidate fail row addresses included in the accumulated error table more frequently than the full scanning read operation FSR. In other words, the deep scanning read operation DSR is performed two or more times while the full scanning read operation FSR is performed once. As such, monitoring through the patrol read operation may be enforced with respect to the candidate fail row addresses that have the errors or higher probability of future errors, and the failure of the volatile memory device may be further prevented.

[102] FIG. 12 illustrates, as an example, one patrol read operation PROPRi including one full scanning read operation FSR and a plurality of deep scanning read operations DSR1~DSRn. The one full scanning read operation FSR may be divided into a plurality of part scanning read operations PFSR1~PFSRn). Each of the deep scanning read operations DSR1~DSRn may start whenever the full scanning read operation arrives at an intermediate row address among row addresses PADD1~PADDn-1. According to an example embodiment, FIG. 12 illustrates that the candidate fail row addresses PFRADD for the scanning read operation are adjacent in one address region for convenience of illustration, the candidate fail row addresses PFRADD may be distributed irregularly over the entire row addressed between the start row address STADD to the end row address EDADD.

[103] As a result, the deep scanning read operation may be performed multiple times corresponding to the candidate fail row addresses PFRADD (n+1) while the full scanning read operation is performed once with respect to the other row addresses.

[104] FIG. 13 is a diagram illustrating an example layout of a memory cell array included in a volatile memory device according to example embodiments.

[105] FIG. 13 illustrates a memory cell array region MCA, a column decoder CDEC, and a row decoder XDEC and other components of the volatile memory device are omitted for convenience of illustration. The memory cell array region MCA includes a dual

the error attribute ATT1. Accordingly, according to an embodiment, the accumulated error table may be generated or modified based on the error attribute determination.

[115] In one or more example embodiments, main address error attribute may be determined with respect to the address group including row addresses of a plurality of sub wordlines corresponding to a main wordline of the volatile memory device when a number of the candidate fail row addresses included in the address group is greater than a reference number. In the example of FIGS. 14 and 15, the number of the candidate fail row addresses corresponds to three and the reference number is assumed to be two.

[116] In one or more example embodiments, the main address error attribute may be determined with respect to the address group including row addresses of a plurality of sub wordlines corresponding to a main wordline of the volatile memory device when a sum of the correctable error numbers corresponding to all of the row addresses included in the address group is greater than a reference number. In the example of FIGS. 14 and 15, the sum of the correctable error number corresponds to eight and the reference error number is assumed to be seven.

[117] FIG. 16 is a diagram illustrating an example embodiment of an accumulated error table for a method of controlling repair of a volatile memory device according to example embodiments.

[118] In one or more example embodiments, the repair manager RMNG may store, in the accumulated error table AET, candidate fail column addresses having the correctable errors with respect to each of the candidate fail row addresses.

[119] In comparison with the accumulated error table AET1 of FIG. 7, the accumulated error table AET of FIG. 16 may further include the candidate fail column addresses CAa~CAk with respect to each of the candidate fail row addresses RAa~ARf.

What is Claimed is:

1. A method of controlling repair of a volatile memory device, the method comprising:

performing a patrol read operation repeatedly to identify error position information of one or more errors included in read data from the volatile memory device;

obtaining accumulated error information by accumulating the error position information based on the patrol read operation performed repeatedly;

identifying error attribute information based on the accumulated error information, the error attribute information indicating correlation between the one or more errors included in the read data and a structure of the volatile memory device; and

performing a runtime repair operation with respect to the volatile memory device based on the accumulated error information and the error attribute information,

wherein generating the accumulated error information comprises:

storing, in an accumulated error table, one or more candidate fail row addresses having correctable errors among entire row addresses of the volatile memory device and correctable error numbers respectively corresponding to each of the one or more candidate fail row addresses, each of the correctable error numbers indicating a number of errors in the respective candidate fail row address.

~~2. The method of claim 1, wherein generating the accumulated error information comprises:~~

~~storing, in an accumulated error table, one or more candidate fail row addresses having correctable errors among entire row addresses of the volatile memory device and correctable error numbers respectively corresponding to each of the one or more candidate~~

~~fail row addresses, each of the correctable error numbers indicating a number of errors in the respective candidate fail row address.~~

~~3~~2. The method of claim ~~2~~1, wherein performing the runtime repair operation comprises:

performing a post package repair operation with respect to a candidate fail row address, among the one or more candidate fail row addresses, having a correctable error number greater than a reference error number.

~~4~~3. The method of claim ~~2~~ 1 or claim ~~3~~2, wherein performing the patrol read operation comprises:

performing a full scanning read operation sequentially with respect to the entire row addresses of the volatile memory device; and

performing a deep scanning read operation sequentially with respect to the one or more candidate fail row addresses.

~~5~~4. The method of claim ~~4~~3, wherein the deep scanning read operation is performed two or more times while the full scanning read operation is performed once.

~~6~~5. The method of ~~any one of~~ claim~~s~~ ~~2~~ 1~~to 5~~, wherein the obtaining the accumulated error information comprises:

storing, in the accumulated error table, an address group including row addresses having a same correlation as ~~the~~ a candidate fail row address among the one or more candidate fail row addresses, based on the error attribute information.

~~7~~6. The method of claim ~~6~~5, wherein performing the runtime repair operation comprises:

performing a post package repair operation with respect to all of row addresses included in the address group when a sum of the correctable error numbers of the address group is greater than a risk error number.

~~8~~7. The method of claim ~~6~~ 5 or claim ~~7~~6, wherein identifying the error attribute information comprises:

obtaining main address error attribute information with respect to the address group including row addresses of a plurality of sub wordlines corresponding to a main wordline of the volatile memory device when a number of the one or more candidate fail row addresses included in the address group is greater than a reference number.

~~9~~8. The method of claim ~~6~~ 5 or claim ~~7~~6, wherein identifying the error attribute information comprises:

obtaining main address error attribute information with respect to the address group including row addresses of a plurality of sub wordlines corresponding to a main wordline of the volatile memory device when a sum of the correctable error numbers corresponding to all of the row addresses included in the address group is greater than a reference number.

~~10~~9. The method of any one of claims ~~2~~ 1 to ~~6~~5, wherein generating the accumulated error information further comprises:

storing, in the accumulated error table, one or more candidate fail column addresses having the correctable errors with respect to each of the one or more candidate fail row addresses.

~~11~~10. The method of claim ~~10~~9, wherein identifying the error attribute information includes:

obtaining column error attribute information with respect to each of the candidate fail column addresses when a number of the one or more candidate fail row addresses including the each of the candidate fail column addresses is greater than a reference number.

~~12~~11. The method of claim ~~11~~10, wherein performing the runtime repair operation comprises:

performing a post package repair operation with respect to the each of the candidate fail column addresses that is identified as the column error attribute information.

~~13~~12. The method of ~~any one of~~ claim~~s 2 to 6~~1, further comprising:

when an access write operation is performed to store write data to ~~the~~ a candidate fail row address among the one or more candidate fail row addresses, performing a replica write operation to additionally store the write data to a replica row address corresponding to the candidate fail row address; and

when the data read from the candidate fail row address among the one or more candidate fail row addresses, includes uncorrectable errors, providing data that is read from the replica row address instead of the data read from the candidate fail row address among the one or more candidate fail row addresses.

~~14~~13. The method of claim ~~13~~12, wherein performing the runtime repair operation comprises:

performing a post package repair operation with respect to the candidate fail row address among the one or more candidate fail row addresses, including the uncorrectable errors; and

storing data read from the replica row address to a redundancy wordline that is identified to replace a wordline corresponding to the candidate fail row address among the one or more candidate fail row addresses, by the post package repair operation.

~~15~~14. The method of any one of claims 1 to ~~14~~13, further comprising:

storing the accumulated error information and the error attribute information in a nonvolatile memory device when the volatile memory device is powered off; and

loading the accumulated error information and the error attribute information from the nonvolatile memory device to the volatile memory device when the volatile memory device is powered on.

~~16. The method of claim 1, wherein generating the accumulated error information comprises:~~

~~storing, in an accumulated error table, previous accumulated error information including one or more previous candidate fail row addresses having correctable errors among entire row addresses of the volatile memory device and one or more previous candidate fail column addresses having the correctable errors with respect to each of the one or more previous candidate fail row addresses based on a previous patrol read operation; and~~

~~storing, in the accumulated error table, present accumulated error information including the one or more candidate fail row addresses and the one or more candidate fail column addresses based on a present patrol read operation.~~

~~17. The method of claim 16, further comprising:~~

~~comparing the previous accumulated error information and the present accumulated error information;~~

~~obtaining an address of a candidate fail cell that is included in the previous accumulated error information and is not included in the present accumulated error information; and~~

~~identifying whether the candidate fail cell is a fail cell by writing to and reading from the candidate fail cell using a data bit and an inversion bit of the data bit.~~

~~18~~15. A method of controlling repair of a volatile memory device included in a storage device, the method comprising:

performing a patrol read operation repeatedly to identify error position information of one or more errors included in read data from the volatile memory device while the storage device is in an idle mode;

storing as accumulated error information, in an accumulated error table, one or more candidate fail row addresses having correctable errors, among entire row addresses of the volatile memory device, and correctable error numbers respectively corresponding to each of the one or more candidate fail row addresses by accumulating the error position information based on the patrol read operation performed repeatedly, each of the correctable error numbers indicating a number of errors in the respective candidate fail row address;

identifying error attribute information based on the accumulated error information, the error attribute information indicating correlation between the one or more errors and a structure of the volatile memory device; and

performing a post package repair operation with respect to the volatile memory device based on the accumulated error information and the error attribute information.

~~19~~16. A storage device comprising:

a nonvolatile memory device; and

a storage controller configured to control an access to the nonvolatile memory device, the storage controller comprising a volatile memory device and a memory controller configured to control an access to the volatile memory device,

wherein the memory controller or the volatile memory device includes an error check and correction (ECC) engine configured to perform error detection and correction with respect to access data of the volatile memory device, and

wherein the memory controller is configured to:

perform a patrol read operation repeatedly to provide error position information of one or more errors included in read data from ~~a~~ the volatile memory device regardless of an access read operation to provide data read from the volatile memory device,

obtain accumulated error information by accumulating the error position information based on the patrol read operation performed repeatedly, wherein the accumulated error information is generated by storing, in an accumulated error table, one or more candidate fail row addresses having correctable errors among entire row addresses of the volatile memory device and correctable error numbers respectively corresponding to each of the one or more candidate fail row addresses, each of the correctable error numbers indicating a number of errors in the respective candidate fail row address,

identify error attribute information based on the accumulated error information, the error attribute information indicating correlation between the one or more errors included in the read data and a structure of the volatile memory device, and

perform a runtime repair operation with respect to the volatile memory device based on the accumulated error information and the error attribute information.

~~20~~17. The storage device of claim ~~19~~16, wherein the patrol read operation is performed during an idle mode of the storage device.