magnetic material into the three dimensional pattern results in a superconformal deposition of the ferromagnetic material within the three dimensional pattern.

[0023] These and other features, aspects and advantages of the present invention will become better understood with reference to the following drawings, description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] FIGS. **1**(*a*)-**1**(*f*) are schematic representations of different plating structures at various stages of different electrodeposition processes;

[0025] FIG. **2** is a series of field-emission scanning electron microscopy (FESEM) images of 3-D structures showing the effect of electrodeposition of Ni with an electrolytic solution containing MBIS at different concentrations within different patterns;

[0026] FIG. **3** is a series of FESEM images of 3-D structures showing the effect of electrodeposition of Ni with an electrolytic solution containing MBIS at different time intervals within different patterns;

[0027] FIG. **4** is a series FESEM images of 3-D structures showing the effect of electrodeposition of Ni at different overpotentials with an electrolytic solution containing MBIS within different patterns;

[0028] FIG. **5** is a FIB-TEM image of 3-D structure showing the morphology of Ni from the electrodeposition of Ni with an electrolytic solution containing MBIS;

[0029] FIGS. **6**(*a*)-**6**(*f*) are a series of FESEM images of 3-D structures showing the effect of electrodeposition of Ni—Fe with an electrolytic solution containing MBIS within different patterns;

[0030] FIG. **7** is a series of FESEM images of 3-D structures showing the effect of electrodeposition of Co with an electrolytic solution containing MBIS within different patterns;

[0031] FIG. **8** is a series of FESEM images of 3-D structures showing the effect of electrodeposition of Co with an electrolytic solution containing MBIS at different time intervals within different patterns;

[0032] FIG. **9** is a FIB-TEM image of 3-D structure showing the morphology of Co from the electrodeposition of Co with an electrolytic solution containing MBIS;

[0033] FIGS. **10**(*a*)-**10**(*f*) are a series of FESEM images of 3-D structures showing the effect of electrodeposition of Co—Fe with an electrolytic solution containing MBIS within different patterns;

[0034] FIGS. **11**(*a*)-**11**(*d*) are a series of FESEM images of 3-D structures showing the effect of electrodeposition of Ni with an electrolytic solution containing no additive within different patterns;

[0035] FIGS. **12**(*a*)-**12**(*c*) are a series of FESEM images of 3-D structures showing the effect of electrodeposition of Ni with an electrolytic solution containing PEI within non-uniform patterns;

[0036] FIGS. **13**(*a*)-**13**(*f*) are a series of FESEM images of 3-D structures showing the effect of electrodeposition of Ni with an electrolytic solution containing PEI within different and non-uniform patterns;

[0037] FIGS. **14**(*a*)-**14**(*d*) are a series of FESEM images of 3-D structures showing the inhomogeneity of Ni growth with the electrodeposition of Ni with an electrolytic solution containing PEI within non-uniform patterns;

DETAILED DESCRIPTION

[0038] The following detailed description is of the best currently contemplated modes of carrying out the invention. The description is not to be taken in a limiting sense, but is made merely for the purpose of illustrating the general principles of the invention, since the scope of the invention is best defined by the appended claims.

[0039] Various inventive features are described below that can each be used independently of one another or in combination with other features. However, any single inventive feature may not address any of the problems discussed above or may only address a subset of the problems discussed above. Further, one or more of the problems discussed above may not be fully addressed by any of the features described below.

[0040] In at least one embodiment provided herein, a process for bottom-up void-free filling of ferromagnetic materials within a 3-D pattern in a substrate is provided. In at least one embodiment provided herein, a process may provide void-free filling of submicrometer 3-D patterns with at least one ferromagnetic material. The products formed by the process may be suitable to form products that may be useful as active device elements in ultralarge-scale integration (ULSI) and micro-electromechanical systems (MEMS). For example, 3-D structures associated with ULSI, MEMS, 3-D packaging, actuators, ferromagnetic materials in magnetoresistive random access memory, biomedical systems, magnetic race track memories, contacts for semiconductors and related devices, new semiconductor materials, electronic and spintronic device architectures, active devices within other electronic circuitry, and other devices as known in the art that may have an application for the incorporation of ferromagnetic materials by processes disclosed herein. Other products that may be produced by the processes disclosed herein may include three-dimensional batteries which represent a new approach for miniaturized power sources that are purposely designed to maintain small footprint areas and yet provide sufficient power and energy density to operate autonomous devices. Such products are disclosed in "Rethinking Multifunction in Three Dimensions for Miniaturizing Electrical Energy Storage" by Bruce Dunn, Jeffrey W. Long, and Debra R. Rolison, published in The Electrochemical Society Interface, Fall 2008, incorporated herein in its entirety. It is anticipated that other and additional applications of the processes disclosed herein will become apparent to those skilled in the art and the present disclosure shall not be limited to these examples of products that may have applications for the presently disclosed processes.

[0041] In addition to products benefitting from the magnetic properties of materials deposited onto a substrate, aspects of the invention may provide products with materials having desired thermal expansion properties. For example, Fe—Ni INVAR alloys may be deposited onto a patterned substrate in a void free manner which may be beneficial for building micro-sensors, actuators, precision instruments such as clocks, seismic creep gauges, television shadow masks frames, valves in motors, antimagnetic watches, etc. Aspects of the present disclosure may provide methods of building such devices or other devices which may utilize the thermal expansion properties of materials deposited onto a substrate. Methods of aspects of the present disclosure may be incorporated into a Damascene process with minimal cost.