or depolarizing additive may comprise 2-mercapto-5-benzimidazolesulfonic acid. Advantageously, the process may provide superconformal filling of trenches, vias, and other patterns within the dielectric substrate. It is to be understood that other and different additives may be placed into the electrolytic bath to provide void-free filling of the electromagnetic material into the trenches and vias or 3-D structure in the dielectric substrate and be within the scope of the present invention.

[0050] Advantageously, the process disclosed herein may provide for preferential deposition of the ferromagnetic material into the 3-D pattern and more advantageously the process may provide for superconformal deposition of the ferromagnetic material within the three dimensional pattern.

[0051] At least one embodiment may provide a deposition process that may allow void-free filling of recessed features with nickel and related iron group alloys as well as cobalt and other alloys and may be easily integrated with existing Damascene processes and related tool sets. Superconformal void-free deposition of nickel, cobalt, iron, and alloys thereof within a 3-D pattern with the addition of heterocyclic compounds such as benzimidazole (BI), benzotriazole (BTA), 2-mercaptobenzimidazole (MBI), a 2-mercapto-5-benzimidazolesulfonic acid (MBIS), and combinations thereof may be achieved in a modified Damascene process.

[0052] A uniform growth profile of electromagnetic materials at the pattern length scale of a given wafer may be achieved in at least one process disclosed herein. The addition of heterocyclic benzimidazole derivatives to the electrolytic bath may induce void-free feature filling of submicrometer trenches with Ni, Co, Fe, and alloys thereof for example. Superconformal filling of submicrometer trenches with electrodeposited Ni may be accomplished with an electrolytic bath comprising MBIS additions to a conventional $NiSO_4$—$NiCl_2$—$FeSO_4$ electrolytic plating bath. The process may have the ability to build 3-D magnetically active structures that may be easily integrated with the conventional Damascene process as well as other state-of-the-art metallization schemes. Although the disclosure is not restricted to a particular mechanism, MBIS may act to inhibit Ni(Fe) electrodeposition, for example, although under certain conditions rapid, autocatalytic breakdown may accompany the onset of Ni deposition. Optimal trench filling may be associated with the positive feedback process, moderated by electrolyte internal-resistance losses, and manifest as a hysteretic voltammetric response on planar electrodes for an MBIS concentration ~100 μmol/L, for example. On freshly immersed substrates, trench filling may be characterized by an initial period of uniform growth followed by the development of a v-notch geometry which may be associated with transient depletion of MBIS within the recessed feature. The finest submicrometer features may be filled with only minimal deposition on the neighboring free surface. Continued growth of the MBIS derived v-notch geometry may result in void-free filling of the larger features by geometrical leveling. Similar deposition of electromagnetic materials, such as Fe, Ni-rich Ni—Fe alloys, Co and Co—Fe alloys, for example, may be accomplished by at least one embodiment. MBIS may not significantly perturb the low coercivity of electromagnetic metals and alloys, which may be an important attribute for prospective applications of processes disclosed herein.

[0053] At least embodiment of a process disclosed herein may provide a desired effect on the rate and morphological evolution of ferromagnetic metal electrodeposition with the addition of cationic, anionic, and nonionic surfactants to the electrolytic bath. Cationic species such as polyethyleneimine (PEI) and cetyl-trimethyl-ammonium (CTA+) may provide significant inhibition of the deposition of magnetic metal, such as nickel, thereby providing void-free filling of submicrometer trenches. For a range of concentrations, single cationic surfactant systems may exhibit hysteretic voltammetric curves that, when corrected for ohmic electrolyte losses, may reveal an S-shaped negative differential resistance. Void-free bottom-up superconformal feature filling may be accomplished when operating at potentials within the hysteretic regime whereby metal deposition begins preferentially in the most densely patterned regions of the wafer followed by propagation of the growth front laterally across the wafer surface. Alternatively, at low overpotentials and concentrations, sulfur-bearing additives such as thiourea (TU) may exert a depolarizing effect on nickel deposition and negligible hysteresis. With a combination of PEI and TU in an electrolytic bath, the suppression provided by PEI may be diminished and feature filling may lead to more uniform deposition on the wafer scale. Suitable combinations of PEI and TU may enable near void-free filling of ≧230 nm wide trenches with sloping (~3.5 degree inclination from vertical) sidewalls. Initial conformal growth may be followed by geometric leveling once the deposits on the sloping sidewalls meet. Feature filling with varied morphological evolution may be provided with one or more embodiment disclosed herein.

[0054] In at least embodiment, superconformal feature filling of Ni in sub micrometer trenches with an electrolytic bath comprising cationic surfactants, such as PEI, cetyl-trimethylammonium chloride, and 4-picoline, may exert significant inhibition on Ni electrodeposition at specific ranges of concentration and overpotential. Cationic nitrogen bearing polymers that may capable of generating superconformal feature filling having lateral non-uniformities may be provided. In particular, the polyelectrolyte PEI may give rise to a superconformal growth mode whereby preferential deposition occurs at the bottom corners of the trenches with almost negligible deposition occurring on the neighboring free surface area, at least during the initial stages of trench filling. Furthermore, the deposition process may be highly heterogeneous at the pattern length scale whereby dense arrays of narrower trenches may be filled followed by lateral propagation of the growth front onto neighboring planar areas. An aspect of this embodiment may provide a means to selectively fill only the finest feature on a given level or layer while leaving the large features open and available for deposition by a different material such as Cu. In this aspect, Cu coils may be placed around a ferromagnetic inductor all on one level of metallization, e.g. in the context of Damascene processing. By appropriate patterning and design, a variety of fully consolidated 3-D shapes and geometries may be fabricated. The resulting structures may have potential use as micromagnets for microelectromechanical devices as well as active magnetic material components for use in a variety of information storage devices. The process may also be useful in the deposition of Ni and related metals as a precursor to forming silicide contacts in microelectronics. The means to selectively fill only the finest features on a given level or layer while leaving the large features open and available for deposition by a different material may provide for an array of metal structures within a single layer, e.g. in the context of Damascene processing.