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Nickel cobalt and their alloys pdf

This book is a comprehensive guide to the compositions, properties, processing, performance and applications of nickel, cobalt and their alloys. It includes all the essential information contained in the 20-volume ASM manual series. Includes new or updated coverage in the following areas: Increased corrosion coverage, including guidelines for choosing the best alloy for specific environments or applications Data sheets covering compositions, specifications, applications and properties for dozens of the most commercially important nickel and cobalt alloys and wear-resistant recent progress in the development of superalloys, including coatings to extend the high-temperature lifespan Unique features of nickel and cobalt that allow them to be used in special applications, e.g., magnets, controlled expansion devices, electronics and implants for human body engineering applications for nickel and cobalt coatings produced by electroplate, electroforming, electroless coating, thermal spray and welding coating. Content includes: Nickel and Its Alloys: The Nickel industry, occurrence, recovery and consumption Use of corrosion-resistant nickel and casted alloys Cast Heat Resistant Ni-Cr and Ni-Cr-Fe alloys Superalloys Special alloys Nickel coatings Corrosion behavior, including performance in specific environments, stress-corrosion cracking and hydrogen embrittlement, and manufacturing and corrosion at high temperature, including training, forge, powder metallurgy, thermal processing, machining, welding and brazing, cleaning and finishing, and high-temperature coatings for superalloys Metallurgy, microstructures and cobalt phase diagrams and its alloys: The cobalt industry, occurrence, recovery and consumption Uses of cobalt-base cobalt-base alloys This book is a comprehensive guide to the compositions, properties, processing, performance and applications of nickel, cobalt and their alloys. It includes all the essential information contained in the ASM Handbook multi-volume series, as well as new or updated coverage in the following areas: Expanded corrosion coverage, including guidelines for choosing the best alloy for specific environments or applications Data sheets covering compositions, specifications, applications and properties for dozens of the most commercially important heat, corrosion-, and wear resistant to nickel and cobalt alloys Progress in the development of superalloy, including coatings to extend the life of high-temperature service Characteristics unique nickel and cobalt that allow them to be used in special applications, for example, magnets, controlled expansion devices, electronics and implants for human body engineering applications for nickel and cobalt coatings produced by electroplate, electroforming, electroless coating, thermal spray and welding Publisher: ASM International Published: 2000 Pages: 442 ISBN: 978-0-87170-685-0 Electronic download Many of our products are available via electronic download. 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Returns must be intact and in good condition. Returns made after the specified time limit will be charged a 15% replenishment fee. The replenishment fee will be deducted from your total refund amount. Returns are made at the customer's expense. Please use a sender that allows you to trace the package. Shipping costs are non-refundable. Metals and alloys Superalloys, Nickel and Cobalt © 1996-2015, Amazon.com, Inc. or its affiliates This is a comprehensive guide to the compositions, properties, processing, performance and applications of nickel, cobalt and their alloys. It includes all the essential information contained in the ASM manual series, as well as new or updated coverage in many areas in the nickel, cobalt and related industries. View 1-30 Start your Nickel, Cobalt and Their Alloys exam (ASM ASM SPECIALTY Lihuyihui noted that it was amazing March 19, 2016 Jose Silva marked it as to read June 03, 2009 Hassan marked it as to read November 12, 2013 Hassan marked it as to read the 05 September 2014 Luk marked it as to read October 31, 2014 Eliane marked it as to read March 02, 2015 Marc Jp marked it as to read October 09, 2015 Eduardo marked it as to read Jan 12, 2016 Eric Bonga marked it as to read February 27, 2016 Renan Dias marked it as to read March 04, 2016 Faith Uzun marked it as to read March 20, 2016 MAQUEDA marked it as to read April 26, 2017 Jithesh K marked it as to read on May 30, 2018 Al marked it as to read September 15, 2018 V.M. Prida, ... In Magnetic Nano- and Microwires, 2015Co-Ni alloys are an outstanding candidate for the development of crossover nanowires because of their abnormal electroplate behavior, resulting in preferential deposition of Co atoms relative to atoms or low deposition potential (Tian et al., 2011; Gomez et al., 1998, 2005; Gahremanizhad and Dolati, 2009). This allows the composition of co-or electrodeposited alloys to be controlled from a single electrochemical bath by varying the electroplate potential (Vega et al., 2012a,b,c; Prida et al., 2013; Garcia et al., 2014). The linear dependence of the composition and growth rate of Co-Ni nanowires on cathode electrodeposition voltage is illustrated in Figure 2.33a for a Watts-type electrolyte containing 0.36 M CoSO4 - 0.04 M CoCl2 - 0.76 M NiSO4 - 0.13 M NiCl2 - 0.073 M H3BO3 with a pH of 4-4.2 to 35 degrees Celsius. By pulverizing the electrodeposition potential as schematic in Figure 2.33b, the Nanofilar tables Co54Ni46/Co85Ni15 crossover were grown in nanoporous alumina models coated iO2 and hard anodized (Prida et al., 2013; Garcia et al., 2014). In addition, by carefully adjusting the duration of each pulse, the length of the different segments was also adjusted. Figure 2.33. a Linear dependence on cobalt content (Co) and the growth rate of nanowires based on the deposition potential measured in electrodeposited homogeneous nanowires. (b) Pulsed electrodeposition used in the manufacture of crossover nanowires, where the applied potential ranges from 1.4 to 0.9 V against a reference electrode for silver/silver chloride (Ag/AgCl) (Garcia et al., 2014). The HR-TEM characterization of isolated nanowires after being released from the alumina model revealed a sequence of segments with alternating composition in Co-Ni alloy, which was confirmed by analysis of the EDX spectroscopy line, as shown in Figure 2.34a-c. In addition, the content co and neither is constant in each segment. The average length of the Co54Ni46 alloy segments estimated from these images was 290 ± 30 nm, and the average length of segments with composition Co85Ni15 alloy was 422 ± 50 nm. On the other hand, the modulation of the diameter of each Co-Ni segment could be an indication of a slight chemical engraving on the surface of the co-rich segments during the release release process. NANOWires of the NAM model. However, these engravings or oxidations were not observed in the most Ni-rich segments, due to the different corrosion resistance behaviours of the Co85Ni15 and Co54Ni46 alloys (Srivastava et al., 2006). Figure 2.34. a) Image of high-resolution transmission electron microscopy of self-permanent nanowires. Segmented regions are clearly visible. b) Marked region where the scan of the composition line (c) demonstrates the compositional modulation of the nanowires. Adapted from Prida et al. (2013). Local examination of the microstructure and composition of the different nanowire segments shown in Figure 2.35 reveals that their crystal structure changes as the Co-to-Ni ratio is modified. In particular, the high co-grade nanowire segments display SAD patterns that correspond to the unique HCP crystals observed through the plane [001], which means that the C-axis of the HCP phase develops perpendicular to the nanowires. On the other hand, nanowire segments with almost equiatomic composition have SAD patterns corresponding to a single Co-Ni alloy crystal with an FCC structure, where the direction [111] is along the nanowire axis. The appearance of the HCP structure in co-grade Co-Ni alloys is consistent with its balance phase diagram (Hansen 1958). It should be noted, however, that in some of the nanofiled segments studied, the HCP phase also appeared in the co54Ni46 segments, probably due to the nonequilibrium nature of the electrodeposition processes. Figure 2.35. Selected area diffraction spectra measured in the Co85Ni15 (1) and Co54Ni46 (2) segments where a near, face-centered hexagonal cubic phase, respectively, can be indexed. Both measures also reveal the preferred crystalline phase for each segment (Garcia et al., 2014). The aforementioned structural characterization indicates that the crystalline structure of Co-Ni alloys depends heavily on its composition. The Hl magnetic panels of Co85Ni15/Co54Ni46 multi-layered nanowire arrays measured along parallel and perpendicular directions in relation to the long axis of the nanowire are shown in Figure 2.36. HLS corresponding to the homogeneous nanowires Co85Ni15 and Co54Ni46 of similar length and diameter are shown for comparison purposes. All samples show low coerciveness and reduced residual values, and none of the samples show a clear easy magnetization axis along the measurement directions. This fact suggests strong competition between the form and anisotropies of magnetocrystalline; this is what happens more in the case of nanowires with a major HCP phase (Vivas et al., 2012c). In the Co-Ni alloy nanowires crossover composed of segments with two different compositions of Co-Ni alloy, its overall magnetic behavior is strongly influenced by the magnetocrystalline anisotropy of its segments because of their different crystal structures. In the case of magnetic measurements made along the long Parallel direction, the crossover system mainly follows the behavior exposed by the nanofil table Co54Ni46, where the major cubic phase involves a reduction in magnetocrystalline anisotropy and thus a switching process dominated by form anisotropy. On the other hand, the perpendicular HL of crossover nanowires exhibits essentially the same magnetic characteristics as those exposed by co-rich nanowires tables, where the contribution of the major HCP phase to magnetocrystalline anisotropy plays an important role in the magnetization reversal process. Given this, the magnetic behavior resulting from the crossover nanowires does not appear to be just an overlay of the contributions corresponding to the different segment compositions, but rather a predominant process of magnetization reversal conducted by the Co54Ni46 and Co85Ni15 phases along the parallel and perpendicular directions, respectively. Figure 2.36. Co85Ni15, Co54Ni46 and cobalt (Co)/nickel (Ni) nanofil (nanow) ambient temperature hysteresis loops measured along parallel directions (a) and perpendicular (b) to the nanowir axis (Garcia et al., 2014).J.K. Dennis, T.E. Such, in Nickel and Chrome Placage (Third Edition), 1993 For nearly two decades, electrodeposited nickel/cobalt alloys containing approximately 18% of cobalt provided one of the most important shiny nickel coatings of this period. Developed almost simultaneously in the United States by Weisberg and Stoddard10 and in Germany by Hinrichsen, this process was used industrially from 1936. The composition of a typical bath is given in Table 13.1., from which it can be seen that it contained formated ions and formaldehyde to complete the lightening effect of cobalt. It produced light deposits, but had no leveling properties so that the final finish depended on that of the substrate, but since its only competitors were the first organically bright nickel veneer processes, which were similar in not providing leveling, this alloy process was of major importance until the invention of the niant shiny nickels. The favorable economy provided by these processes to avoid the need for the substrate to be polished to as high a degree as before - and the elimination of the need for expensive nickel/cobalt alloy anodes - resulted in the total volume of this alloy bath in use decreasing considerably during the 1950-60s. Only a small, ever-decreasing amount has continued to be used since then. Table 13.1. Typical electrolyte composition and operating conditions for the electrodeposition of nickel/cobalt sulfate gloss coatings (NiSO4-6H2O):240 g/l Chloride denickel (NiCl2-6H2O):50 g/lCobalt sulphate (CoSO4-7H2O):15 g/lacid 30 g/lSodium formate0.9 g/lAmmonium sulfate2.5 g/lFormaldehyde2 g/lpH3.5 to 4.0Temperature45 to 55oC Current density4 to 6 A/dm2Note. The electroplate solution is based on that patented by Weisberg and and and (U.S. Patent 2026718 (1936). Hinrichsen also patented a similar solution (British Patent 461126 (1937) which differed slightly in that it did not contain formaldehyde and less (c.1 g/l) or zero ammonium sulphate. In 1969 and 1969-1911-1913, the use of electrodeposited nickel/cobalt alloy coatings was almost entirely resumed, when nickel was scarce due to miners' strikes. At that time, cobalt was used as a rather expensive but useful metal to replace nickel in electroplate coatings by up to 50%. Cobalt was then only used as a substitute for nickel, with the thinning and leveling effects still provided by organic chemicals. Some variations in the types of thinners and operating conditions had to be made in some cases if the amount of cobalt greater than 40% was desired. In general, it was considered technically quite feasible to operate such baths under the same conditions as for pure shiny nickel, but their cost was so high that their use ceased as soon as nickel was readily available again. The industrial use of cobalt or nickel/cobalt alloys during this nickel shortage provided the necessary impetus for the study of corrosion behaviour of the decorative systems made up of these deposits as well as chromium overlays. A number of authors have shown that nickel/cobalt alloys are less noble than nickel12-15. However, it should be noted that the electrochemical nature of the deposits will be governed by the particular organic addition agents used and the internal stress levels developed. Major corrosion testing programs were conducted and most showed that as the cobalt content of the alloy increased, the diameter of the corrosion pits also increased. Carter14 observed that crowfoot punctures and macro-cracks occur when a regular chromium overlay is used. When microdiscontinuous chromium is used, the degree of surface dullness is increased by substituting cobalt for nickel13,14. Although appearance may be negatively affected by nickel substitution of cobalt, the protection of the base metal is not significantly affected11,14. When using multi-layer coating systems, it is essential to consider the effect of using nickel/cobalt alloys rather than pure nickel as electrodeposits. For example, semi-shiny alloy layers are less noble than semi-brilliant nickels, but shiny layers containing a relatively large proportion of cobalt can result in sacrificial protection of an underlying layer15. All detailed results of accelerated corrosion tests and fundamental polarization studies indicate that there is no benefit in replacing cobalt with nickel in decorative coating systems. However, it has now been proven that these alloy baths can be operated satisfactorily on a commercial basis, if it wishes.T.J. NIIDAM, ... W.G. SLOOF, in Novel Approaches to Improving High Temperature Corrosion Resistance, 2008The protection offered by MCrAlY alloys (M-Ni,Co) against high-temperature oxidation is based on alloy's ability to develop and maintain a continuous, dense and slow-growing α -Al2O3 scale on its surface [1]. In general, the formation of such a continuous layer of alumina is preceded by a first period of rapid oxidation, associated with simultaneous formation of α -Al2O3 and the fast-growing non-protective oxide phases Cr2O3, NiO, NiCr2O4 and/or NiAl2O4 [1]. The formation of these oxides usually has harmful effects. For example, the development of the NiAl2O4 spinel on MCrAlY binding coatings at the interface with a ceramic topcoat in the barrier thermal coating systems (TBC) promotes the spalling of the ceramic topcoat on the thermal cycle [2]. Therefore, ideally, the formation of an oxide scale consisting only of α -Al2O3 is desired. Recently, a coupled thermodynamic-kinetic oxidation (CTK) model has been developed for thermal oxidation of ternary alloys [3]. Calculations with this model revealed a close relationship between non-protected, non-protective oxide formation and compositional changes in the underlying alloy [3]. It has also been demonstrated by model calculations and experiments that the total amount of non-protective oxides (i.e. all oxide phases excluding α -Al2O3) are suppressed by maintaining a sufficiently high concentration of Al in the alloy at the oxide/metal interface (OM) during the early stages of oxidation as achieved by, for example, a low partial oxygen pressure (pO2) during oxidation or a small size of alloy grain [4]. In this study, it is shown that the amount of each phase of individual oxide developed is also determined by the composition of the alloy at the O/M interface. The formation of α -Al2O3, Cr2O3, NiO, NiCr2O4 and NiAl2O4 were determined based on oxidation time for thermal oxidation of γ -Ni-27Cr-9Al (at.%) at 1353 K and 1443 K and a partial oxygen pressure of 20 kPa using high-temperature X-ray in situ diffractometry (XRD) [5-7]. The intensities recorded in the XRD experiment can be used to quantitatively assess the oxidation kinetics because virtually no spallation of the oxide scale occurs at the oxidation temperature [5]. The results obtained by XRD are compared to microstructural observations from images of backscattered electron scanner scan (ESB) (SEM), and calculations of models using the CTK oxidation model [3, 4].P. Ripka, M.M. Arafat, in Reference Module in Materials Science and Materials Engineering, 2019Crystalline, nanocrystalline and amorphous flexible magnetic alloys such as nickel-iron and nickel-cobalt alloys are used for ferromagnetic magnetoresistors. These include sensors based on the anisotropic magnetoresistance (AMR) effect, Giant magnetoresistism (GMR), spin-dependent tunneling effect (SDT), fluxgate effect and giant magnetoimpedance effect (GMI) (Jiles and Lu, 2003). Flexible magnetic alloys are also used in flow concentrators, which are used to enhance the sensitivity of some hall and magnetoresistor sensors. Flexible magnetic shields are used in GMR sensors. Gmr. The application is yokes for position sensors based on the change of reluctance. Most of the flexible magnetic materials used in sensors are crystalline. Nanocrystalline soft magnetic alloys are rarely used because of their fragility. One of the few exceptions is the nanocrystalline nucleus used in today's transformers. Amorphous alloys are used less often. All the materials mentioned are used in bulk form and thin layers made by different deposition techniques such as spraying, electroplate or laser deposition. Bulk materials are produced not only as thin ribbons, but also as yarns. The most common sensors based on flexible magnetic alloys are AMR sensors and they are usually based on the pulverized permalloy that can be used up to 225 C.J.L. Sullivan, in Encyclopedia of Materials: Science and Technology, 2020In order to meet the high requirements for areal recording density, thin metal films such as Ni-Co alloys have evaporated vacuum on a flexible polymer substrate. This medium has potentially more efficient magnetization than particles due to the increase in grain density. The support consists of a single, or perhaps multilayered, of metal magnetic layers evaporated on a polymer substrate, covered with a protective carbon overcoat that is in turn lubricated topically. Tribologically the system is inherently simpler than the particulate media, but presents its own unique problems. One is that, unlike particles, the surface coverage of the lubricant must be complete, must remain complete for the expected life of the media, must allow full protection against corrosion and must not be more than 5 nm thick so that the spacing losses are not excessive. The evaporated metal (ME) of the flexible thin-film supports presents the advantages of particle porosity and surface chemistry, so the requirements on the lubricant present a daunting challenge. Lubricants are perfluoropolyethers, often with final group changes. It should also be kept in mind that these thin metal films are much less compliant than particle-filled polymer films and should not be subjected to excessive pressure if cracking and catastrophic failure are to be avoided.D. Sobha Jayakrishnan, in Corrosion Protection and Controlling Control Nanomaterials, 2012To obtain a hardness value comparable to hard chrome coatings, n (15 to 20 nm grain size) ni-co-electroplated alloys were considered, as they exhibit microhardness values from the age of 820 to 900 VHN (Hui and Richardson, 2004; Brooman, 2005). these were treated with heat, precipitation hardening occurred and microhardness values as high as 1000 to 1150 VHN were obtained. The electrodeposition of NC cobalt alloy coatings (Prado et al., 2009), as an environmental alternative to hard chrome deposits as part of the U.S. Department of Defense's Strategic Environmental Research and Development Program, reveals that nano CoP has equivalent properties (and in many ways better than) than) high hardness, increased ductility, lower wear rate, higher corrosion resistance and no problem with hydrogen embritting after cooking. The Nano CoP process differs, however, in that it uses pulse veneer technology to control and build fully dense deposits and nano grain size (5 to 15 nm) leading to improved material properties. Thanks to Hall-Petch reinforcement, NC alloys such as nano CoP show significant increases in hardness and strength. The nCoP shows hardness in the range of 530-600 VHN as deposited. A further increase in hardness can be achieved by ringing the material deposited by a precipitation hardening mechanism, in order to induce the precipitation of phosphides co of solid oversaturated solution at high temperatures. Fasol and Runge (1997) deposited permalloy magnetic nanowires (Ni-Fe) on the edge of a quantum inAs well. Carrey et al. (2002) used Al2O3/Al nanoinerted aluminum foil to preferentially electrodeposit Ni-Fe nano-shared arrays from an electrodeposition bath containing a nickel and iron sulphate solution. Ni-Cu alloys had previously been used primarily for decorative purposes; in recent times, there has been a renewed interest in the electrodeposition of NC Ni-Cu alloys (Quang et al., 1985; Chassaing et al., 1987; Cherkaoui et al., 1988; Ying, 1988; Roy et al., 1994). This alloy is a component in Cu Ni/Cu multilayers that show giant magnetoresistance properties (GMR) and find application in magnetoresistive devices (Kazeminezhad et al., 2004). Natter et al. (1998) reported pulse electrodeposition of Cu-Ni nano alloys. NC Ni-Cu alloys with an average grain size of 2 to 30 nm were synthesized under the pulse as well as under DC veneer conditions (Ghosh et al., 2006). High-resolution electronic microscopic examination (HREM) indicated that the NC alloys deposited were dense in nature. The Fe-Ni alloy repository is of industrial interest because these materials find applications in electronic devices (e.g. PC hard drive). The most popular alloys are Permalloy (soft magnetic properties) and Invar (very low thermal expansion). The magnetic and mechanical properties of the Fe-Ni alloy can be designed by nanostructuring. Natter and Hempelmann (2003) used an electrolyte containing 40 g/l NiSO4, 20 g/l (NH4)Cl, 20 g/l citrate na, 5 g/l citric acid, 1 g/l saccharine, 45 g/l boric acid and a variable iron content (10) ammonium sulphate. (soft parameters used were ton 2 ms, toff 48 ms and pulse 250 mA/cm2. For different concentrations of iron salts, alloys (crystallite size, 16-19 nm) with a between 0 and 71 mol% could be obtained. Rajiv Kohli, in Developments in Surface Contamination and Cleaning: Methods of Cleaning and Cleanliness Verification, 2013A wide variety of metal substrates, such as stainless steels, molybdenum and titanium alloys, aluminum and nickel-cobalt alloys, can be electroplated in IT and EN to produce a clean, shiny and smooth surface (Fig. 1.19) [320,345-347]. Lia Lia the solubility of oxides in IT and DES allows the intensification of processes [297 348]. The operating parameters are comparable to those of existing acid-based electrolytes, but significantly higher current efficiency can be achieved. Typical operating parameters include a process temperature of 303-323 K and 3-5 V for 10 minutes. The polishing process can be significantly improved by additives such as oxalic acid, allowing the process to be extended to other systems. The main benefits of the process include the use of a noncorrosive electrolyte solution, improved surface finish, reduced and simplified waste management, recycling and reuse of the electrolyte, and safer operating conditions. FIGURE 1.19. Surface finish of an electroplated titanium alloy part in choline chloride-based ion liquid (right image) relative to the original surface (left image). [345,347] Rajiv Kohli, in Developments in Surface Contamination and Cleaning: Applications of Cleaning Techniques, 2019A wide variety of metal substrates, such as stainless steels, molybdenum and titanium alloys, silver, aluminum and nickel-cobalt alloys, can be electroplated in IL and ENS to give a clean, shiny and smooth surface (Fig. 16.8) [240 257-265]. In the case of nickel-based super-softening, the removal of the scale of as-cast components facilitates critical quality checks and evaluations to identify defective components before costly and time-consuming heat treatment. The high solubility of oxides in IT and DES allows the intensification of processes [207 265]. The operating parameters are comparable to those of existing acid-based electrolytes, but significantly higher current efficiency can be achieved. Typical operating parameters include process temperature 303 to 323 K and anode voltage below 5 V for 10 minutes. In fact, the dissolution of metallic titanium occurs at an anode voltage as low as 1.5 V [260]. The polishing process can be significantly improved by additives such as oxalic acid, allowing the process to be extended to other systems. The main benefits of the process include the use of a noncorrosive electrolyte solution, improved surface finish, reduced and simplified waste management, recycling and reuse of the electrolyte, and safer operating conditions. Figure 16.8. Surface finish of an electroplated titanium alloy part in choline chloride-based ion liquid (right image) relative to the original surface (left image) [257 259]. Mohammad S. Hussain, in Nanomaterials in Chromatography, 2018Jet technique, i.e. high-speed selective electrodeposition (HSJE). Jet has successfully used to prepare high-speed cobalt-nickel alloys [99]. HSSJE is a process in which an unsured electrolyte jet is made to encroach at high speed on a cathode surface from an anodine source [40]. A metal nozzle is used as an anode and the work piece as a cathode during this electrodeposition process. Electrolyte jet emerges from nozzle and encroaches on work room four distinct regions of flux. These regions are schematically represented in Figure 16.9. Near the imping point, the flow changes speed and direction from that of the free jet to region D, known as the wall jet. The metal is deposited just under the jet and its immediate surrounding area. As the diameter of the jet is generally very small (usually 1 mm), the electrodeposition surface becomes tiny [41]. Therefore, it can be complicated to use HSSJE in case of large or irregularly shaped work parts. It is important to carefully note the difference between jet electrodeposition and turbulent electrodeposition of the flow. Qiao et al. [39] used jet electrodeposition to electroplate Ni-Co on copper substrates. It is well known that structural steel mills must be coated for corrosion protection. The jet electrodeposition technique (i.e. HSSJE) has been successfully used to prepare high-speed cobalt-nickel alloys. Figure 16.9. A diagram of the electrolytic jet, where ro, L, and Vz are the inner radius of the nozzle, the distance between the electrodes, and the speed of the electrolyte, respectively. (A) Central Zone, (B) Free Movement Zone, (C) stagnation zone, and (D) radial flow zone.H. Lee, ... B. Kim, in Magnetic Nano- and Microwires, 2015Because CoCl2 (anhydrous) and NiCl2 (anhydrous) decompose at similar temperatures, the CVT method using their mixed precursor allows the epitaxial growth of Ni-Co alloy NWs on a substrate. Various Ni-Co alloy structures have been reported because neither co or are not only messy, but also stable when they become alloys (Huang et al., 1994). In addition, ni-co alloy NWs can combine the good magnetic property of Co and the good corrosion resistance of Ni: Co has a Curie temperature (TC) of 1100 degrees Celsius and a saturation magnetization of 24,000 G, while Ni has a TC of 370 degrees Celsius and saturation magnetization (S) of 6200 G (CDI, 2006). Although one-dimensional Ni-Co alloy structures have a high magnetic anisotropy based on form anisotropy, most of those prepared using an anodic aluminum oxide (AAO) model do not meet surface morphology and crystallinity for effective spin transport applications (e.g., electronic devices). To synthesize well-aligned, single-crystalline Ni-Co alloy NWs with optimal surface morphology, a robust synthetic strategy alternating the typical electrochemical reduction method or wet chemical synthesis is required. As Ni NWs synthesizes, vertically aligned single-crystalline Ni3Co NWs can be epitaxially grown on a C-cut sapphire substrate from a mixed precursor NiCl2 (anhydrous) and CoCl2 (anhydrous) (Figure 6.9; et al., 2010). The Ni3Co NWs mono crystals have a flawless, flawless crystalline structure and a well-faceted morphology thanks to a solid and solid synthetic steam mechanism. Interestingly, a precursor change under the same conditions for epitaxial growth of Ni NWs induces a new NWs Ni3Co preparation, implying that various magnetic NWs can be creative combinations of transition metal halide. (Figure 6.9, a) Chemical steam transport facility using a NiCl2 and CoCl2 mixed precursor. b) Temperature grading for Ni3Co nanowire synthesis. Reprinted with the permission of Barkar et al. (2010), Copyright American Chemical Society.Figure 6.10 shows SEM images of epitaxial growth of vertical Ni3Co TN on a c-cut sapphire substrate (Al2O3 (0001)). Some slanted Ni3Co NWs are also observed on the same substrate. Well-faced ni3Co NWs have a diameter of 100-120 nm and a length of 10 μ m, and there is a 50-nm Ni3Co2 NP on their advanced structure. The results of the energy dispersive X-ray spectroscopy (EDS) presented in Figures 6.11d and 6.12d indicate a uniform distribution of ni3Co composition throughout the NW structure and the Ni3Co composition of the PN placed on the tip. In addition, a thin layer of oxide 10 nm thick completely envelops the Ni3Co NW (Figure 6.11a). The regular saed models measured from multiple zone axes are a good proof of the unique crystalline structure of the Ni NWs as-synthesized without any defects. Figure 6.10. (a) and (b) Scanning electronic microscopy images of Ni3Co (NWs) nanowires vertically aligned on a sapphire substrate cut into c.c A Ni3Co2 alloy nanoparticle on the tip of a Ni3Co NW. Reprinted with permission of Barkar et al. (2010), Copyright American Chemical Society.Figure 6.11. a) Electronic transmission microscopy (TEM) image of a Ni3Co (NW) nanowire showing the coating of the oxide shell. (b) High-resolution TEM image showing a distance of 0.25 nm between adjacent arc/cobalt corresponding to the (110) aircraft. The insert shows the rapid furnace transformation model that can be indexed to a cubic crystal structure centered on the nickel face. (c) The zone diffraction model selected in the zone axis [101] showing the unique crystalline nature of Ni3Co TN. d) Energy dispersive X-ray spectroscopy (EDS) spectrum of a Ni3Co NW showing nickel and cobalt composition in a 3:1 ratio. e Scanning the TEM image of a Ni3Co NW with corresponding EDS elemental mapping. Reprinted with permission of Barkar et al. (2010), Copyright American Chemical Society.Figure 6.12. a) Transmission electron microscopy (TEM) image solved by mesh of the interface of a Ni3Co nanowire (NW) and a Ni3Co2 (NP) nanoparticle. The insert shows some zone diffraction models of Ni3Co NW and Ni3Co2 NP, respectively. b) Low-resolution TEM image of Ni3Co NWs showing the presence of a PN at the tip of individual ED. c) An enlarged TEM image of an NP-sided Ni3Co2 alloy from the rectangular region in panel b). d) Spectre of X-ray spectroscopy dispersive in energy from a single PN showing nickel and cobalt are present in an atomic report of about 3:2. Reprinted with permission of Barkar et al. (2010), Copyright American Chemical Society.La epitaxial relationship between Ni3Co NWs and Ni3Co2 NPs demonstrate that ni3Co2 NPs can serve as seed seed to trigger the epitaxial growth of Ni3Co NDS. Figure 6.12a is an enlarged image of an NP Ni3Co2 and shows an internal angle of 130 degrees surrounded by [111] facets. The SAED models of Ni3Co NWs and ni3Co2 NPs also show a similar growth orientation [110] and a cubic crystal structure centered on the face. However, although additional metal catalysts such as gold or Ni have not been used on the substrate, the shape of the Ni3Co NW and Ni3Co2 NP attached to the advanced structure is very similar to that of metal catalyst-assisted TNs. As in the case of a heterostructure Mn11Ge8/germanium (Ge) NW, previously formed Ni3Co2 PNs can effectively nucleate the atoms or co provided by the precursor, so that they act at the same time as seed and catalyst during the growth of Ni3Co TN. Figure 6.13 shows the high magnetic anisotropy of vertically grown Ni3Co NWs using a SQUID. When an external magnetic field of 100 or 1000 Oe is applied, the Ni3Co NW has a b value of 320 K in a temperature-dependent magnetization curve (M-T). A layer of thin oxide formed naturally on a Ni3Co NW can also be a good basis for their additional magnetic anisotropy via an exchange bias effect. Figure 6.13. a) Measure M versus T at 100 and 1000 Oe. b) Measurement M versus H ni3Co nanowires on a sapphire substrate cut c to a room temperature. The insert shows the hysteresis loop amplified between 0.3 and 0.3 kOe. FC, cooling on the ground; ZFC, zero-field cooling. Reprinted with permission of Barkar et al. (2010), Copyright American Chemical Society. Company.

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