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[2] Influence of Ni addition on magnetic and electro-mechanical behaviour of permalloys, **Kiran Gupta**, K. K. Raina and S. K. Sinha, Bulletin of Materials Science, **29** (2006) 391-396.

[3] Influence of process parameters and alloy composition on structural, magnetic and electrical characteristics of Ni – Fe permalloys, **Kiran Gupta**, K. K. Raina and S. K. Sinha, Journal of alloys and compounds **429** (2007) 357-364.

[4] On the structural and magnetic behaviour of Ni-Fe permalloys, **Kiran Gupta**, K. K. Raina and S. K. Sinha, Indian Journal of Engineering and Materials Science (under revision)

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[5] Study of permalloy materials under H_2-annealing for optimisation of the magnetic properties, **Kiran Gupta**, S. K. Sinha and K. K. Raina, Proc. of National Conference on Materials and Related Technologies, TIET, Patiala, Sept. 19-20 (2003) 226-231.

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Magnetic Applications : Characterisation & Measurements, DMRL, Hyderabad, Sept. 2-3 (2005) 6B.5.

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SYNOPSIS

The Ni-Fe alloys are based on the face-centered cubic structure of Ni-Fe system. They contain about 40 to 90 % Ni, few percent each of other alloying elements (like Cu, Mo, Cr, Co, Mn etc. and rest is Fe. Their remarkable magnetic properties have made them the subject of intensive study over the last about half a century. Three ranges of nickel content are usually used as soft magnetic alloys: about 36% Ni for maximum resistivity, 50% Ni for maximum saturation magnetization and 80% Ni for optimum initial and maximum permeabilities. Out of above, 50% Ni and 80% Ni alloys are most widely used in rotor and stator laminations, stepping motors, shieldings, relay parts, audio head etc.

The objectives of the present research work were:

- To optimise the processing conditions for the preparation of permalloys.
- To study and characterize the prepared permalloys for industrial applications and other magnetic properties.
- To compare the performance of the material / device developed, through the proposed route with the existing one.

Chapter 1 reviews the various soft magnetic metallic materials, in general and nickel-iron alloys in particular. A detailed account of the magnetic properties of the Ni-Fe alloy systems is described. The fundamentals of the soft magnetic materials are discussed with a focus on their industrial applications. The aim and scope of the work has been given in this chapter.

Chapter 2 describes the experimental methods for materials preparation. It highlights various techniques for characterizing and analysing the permalloy samples. The three samples adopted for the investigation includes 82.13 % Ni (sample A), 79.90 % Ni (sample B) and 47.01 % Ni (sample C). The materials were characterized for their chemical composition by wet chemical analysis and atomic absorption spectrometer. The first step involved is the preparation of ring samples. The samples were annealed under different processing conditions in the temperature range of 1100-1180°C, cooling rate was varied from 2 to 7°C/min. and holding time was varied from 1 to 3 hrs. The samples were analysed with optical microscope (Nikon, Japan) and X-ray diffractograph (Rigaku, D-max IIIC). The data of XRD was matched with the standard database compiled in software PCPDFWIN provided by the International Centre for Diffraction Data –ICDD (formerly known as JCPDS). The magnetic properties were studied with B-H analyzer (AMH-401, Walker Scientific, USA). The samples were tested for industrial applications (like watch movement and audio recording head). Results were compared with the performance of the existing one.

Chapter 3 explains experimental results of the study of the influence of various process parameters such as annealing temperature, holding time and cooling rate under hydrogen atmosphere on the magnetic properties of the permalloys. The phase analysis, microstructural characterization and magnetic measurements were carried out by XRD, optical microscope and B-H analyser respectively. The AC magnetic properties such as induction, remanence, coercivity, peak permeability and core loss were studied as a function of frequency, field strength, temperature and cooling rate. The salient features and role of each process parameter on the magnetic properties of Ni-Fe alloys have been discussed. From this study, we conclude that the magnetic properties of permalloys are better at lower frequency i.e. 100 Hz then at higher frequency i.e. 300 Hz. Also, variation in magnetic properties was observed with changed process conditions. Another heat treatment process was carried out in an atmosphere of cracked ammonia and we found that there was not any significant change in the magnetic properties of permalloys annealed under two different environment conditions.

In **Chapter 4,** the influence of different alloying elements on the magnetic properties of the permalloys have been discussed. The scaling of different compositions by varying the annealing temperature, cooling rate and holding time in the presence of hydrogen atmosphere have been investigated. The results have been discussed in terms of correlation between microstructures, X-ray diffractographs and their magnetic properties. The material properties of the permalloys show strong dependence on their crystal structure and annealing conditions. We found that grain diameter has a significant effect on the magnetic properties of the alloys. We observed that the sample A (82.13 % Ni) is found to show better magnetic properties over the other two samples, due to relatively larger grain size (320 μm) in sample A over others two samples. The higher values of permeability and other magnetic parameters have strong correlation to the grain structure.

The use of such materials in audio recording head and watch movement has been discussed in **Chapter 5.** All indigenously developed materials were tested for industrial applications and compared the performance of the device developed through the proposed route with the existing one. The watch movement was tested for its electro-mechanical characteristics such as current consumption and torque. We found that for sample B, the resistance of the coil core can be increased from 2.30 kΩ (existing) to 3.20 kΩ by maintaining the acceptable limit of torque but in sample C, the resistance of coil core can be increased only upto 2.80 kΩ and the battery life of the watch movement has been improved by 38% using sample B. M/s Purewal & Associates Ltd., Jubbar (manufacturer of Maxima watches) have tested such materials in their watch movement. Similarly, the permalloys in the audio head was tested for its audio recording characteristics such as hum noise, sensitivity and frequency response. We found that sample A was having better audio recording characteristics over the sample B due to the better magnetic properties of sample A [M/s Magtronics Devices Pvt. Ltd., Parwanoo also tested these materials for their audio head devices].

Chapter 6 concludes the work done and summarizes the important features and results obtained from varying different process parameters and alloy composition on magnetic properties as discussed in chapter 3-4. It also highlights the performance of the material developed for industrial applications.

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