5.0 Summary

This chapter explains about the industrial applications of permalloy materials having different compositions. The materials used in the present investigations were characterised for usage in devices such as watch components and audio recording applications. Their performance was compared with the existing one. The effect of annealing temperature on the electro-mechanical characteristics of watch movement and audio recording characteristics of the audio head has been studied and reported.

5.1 Introduction

In chapter 1, we explained that the Fe-Ni alloys with about 40-80% Ni are novel class of magnetic materials for bulk applications. Two major subclasses with 40-50% and 77-80% Ni, find extensive usage because of the high versatility and attractiveness of their properties. The 40-50% alloys find applications in transformers and cores. The 77-80% Ni alloys have been the subjects of intensive development for many years. At the same time, high nickel alloys are also used quite extensively in thin-film form in memory elements (including magnetic bubble devices) and magnetic recording heads. High permeability of Ni-Fe alloys makes these alloys useful in low magnetic field applications that are typically found in high frequency applications devices e.g. audio and wide-band transformers. They have found many engineering uses in sensitive relays, pulse and wide band transformers, current transformers, magnetic recording heads, magnetic shielding. LF power transducers, rotor and stator Laminations, chokes, integrating current transformers for earth – leakage circuit breakers, stepping motors and magnetic valves.

5.2 Ni-Fe alloys in watch movement

Watch is an electromechanical device, which contains some mechanical, electrical and magnetic components. The heart of the movement is a bipolar stepper motor that converts electrical energy to magnetic energy and then to mechanical motion. The stepper motor consists of rotor, a stator and a coil. The rotor is formed by a permanent magnet whereas core and stator are made up of Ni-Fe alloy. Fig. 5.1 shows photograph of the core and stator of a watch movement. The coil is wound on the core such that core and stator are then mechanically joined to complete the magnetic circuit of the stepper motor.

Electronic circuit board supplies the necessary d-c voltage pulses to the coil in such a manner that the current flows in one direction when the first pulse is applied and vice-versa after one second. This process keeps on repeating every second, thereby producing an alternate polarity magnetic field in the stator. When the current flows in the coil it becomes magnetized and temporary north and south poles are created and rotor is moved by 180°. When current is flown in reverse direction, the north pole becomes south and south changes to north. The rotor moves further by 180° and this process keeps on repeating [1-2]. Since the bipolar stepping motor has a stator with two poles which keep alternating in polarity, it is important to ensure that the rotor keeps rotating in one direction. This is done by giving a slight offset in the two poles.

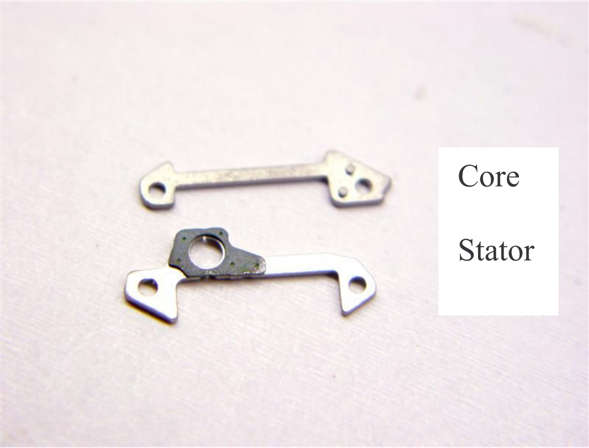


Fig. 5.1: Photograph of core and stator

5.2.1 Electro-mechanical characteristics

The samples of core and stator punched out from sample B and sample C were annealed in H_2 atmosphere with varied annealing profiles as mentioned in table 2.3. The above annealed samples were tested in the watch movement (Fig. 5.2) at different annealing temperature. The current consumption of the movement was measured at 1.5V by increasing the resistance of the coil core from 2.30 kΩ to 3.50 kΩ and simultaneously the torque of the movement was measured using torque meter (Witchi, China). The standard battery SR 626 having battery life of 24 mAh was used in the movement for the measurement of current consumption. The formula used for calculating the battery life is:

$$\text{Battery life of movement (h)} = \frac{\text{Standard life of battery}}{\text{Current consumption of the movement}}$$

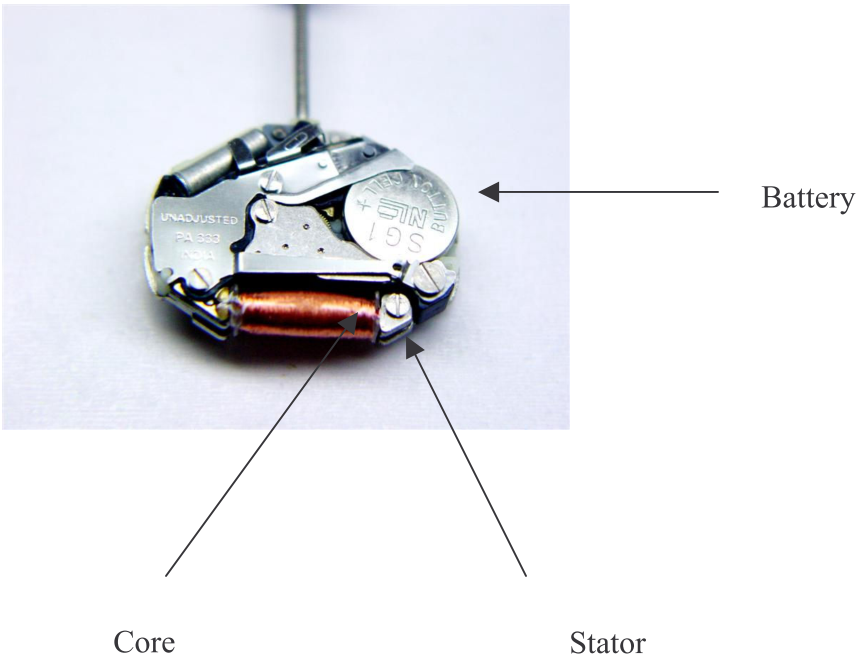


Fig. 5.2: Photograph of the watch movement

The torque of the sample B and sample C is given in Fig. 5.3. The acceptable limit of torque is 4.55 μNm. We observed that in sample B, 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 up to 2.80 kΩ (Fig. 5.3). The battery life of the movement with sample B has been improved by 38 % with the existing sample C as given in Fig. 5.4 [3].

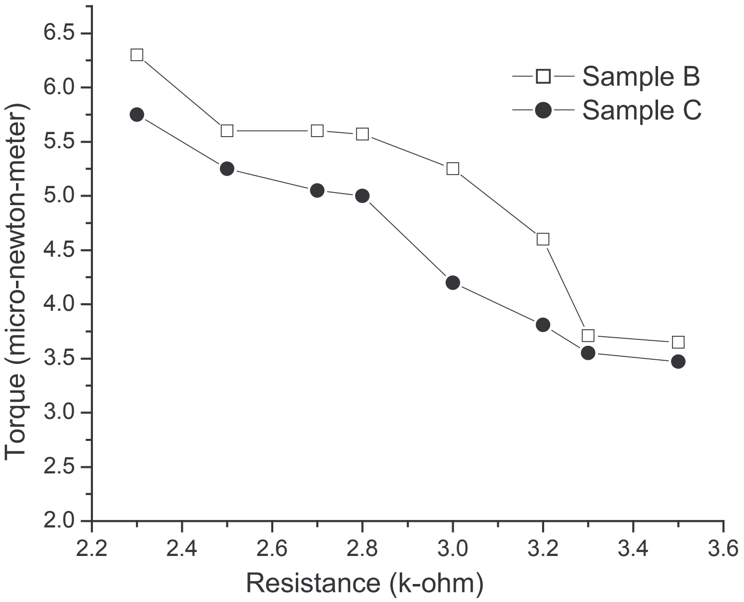


Fig. 5.3: Torque of watch movement as a function of resistance

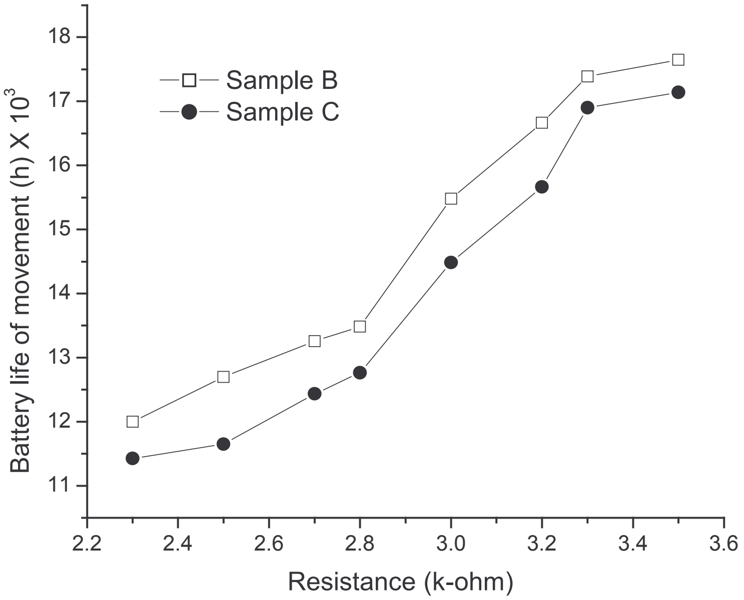


Fig. 5.4: Battery life of watch movement as a function of resistance at 1.5 V bias

The torque of the sample B and sample C as a function of annealing temperature is given in Fig. 5.5. We observed that the torque of sample B increased from 5.5 μNm to 6.3 μNm with increase in the annealing temperature from 1100 to 1150°C and after that decreased to 6.25 μNm with further increase in the temperature to 1180°C. Similar behaviour has been seen for sample C. However, the torque of sample B observed, is more as compared to sample C, this is well related with the magnetic properties as mentioned in chapter 4.

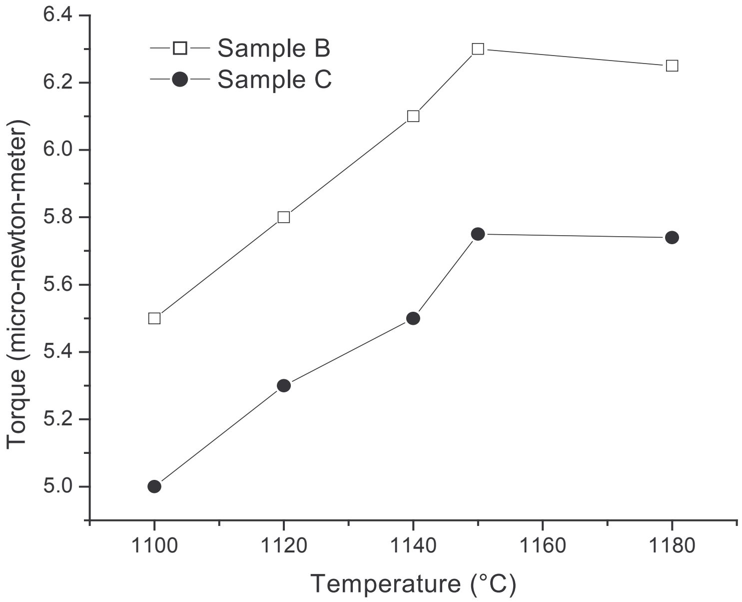


Fig. 5.5: Torque of watch movement as a function of annealing temperature

The comparison of battery life and peak permeability of the watch movement as a function of annealing temperature for sample B and sample C is given in Fig. 5.6. From the graph, it is clear that the performance of the sample B is better in the watch movement as compared to sample C due to the better permeability and better life achieved in the sample B.

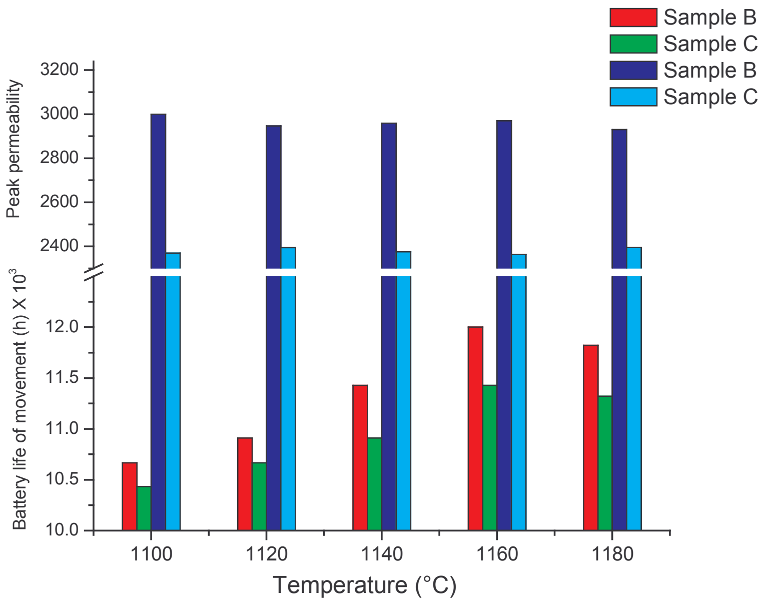


Fig. 5.6: Comparison of battery life and peak permeability of watch movement as a function of annealing temperature

5.3 Audio head

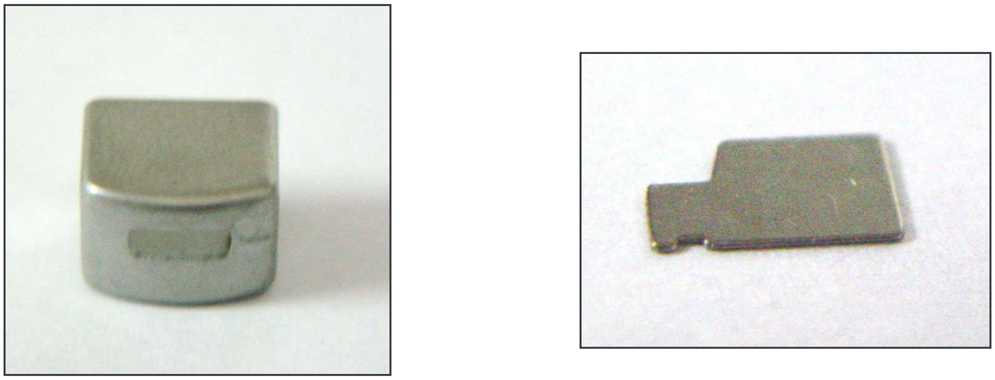
The audio head comprises of three permalloy components, each has its own valuable contribution in audio recording [4-15]. These are Case, Core and Shield Plate, where core act as a media for the magnetic flux to travel in, case is for blocking out the noise and protection of the magnetic circuit & resin and shield plate is meant for prevention of cross talking between different channels. The photograph of all three components is shown in Fig. 5.7.

5.3.1 Audio recording characteristics

The performance of the audio head was checked by incorporating the case, core and shield plate punched out of sample A and sample B and annealed as per table 2.3. Following characteristics describe the performance of audio head:

Hum noise
Sensitivity
Frequency response

Audio head



Case

Shield plate

Core

Fig. 5.7: Components of the audio recording head

5.3.1.1 Hum noise

The most important factor limiting the performance of a recorder is noise. The important sources of noise can be divided into three categories: interference, electronic noise and magnetic noise [5]. The first of these includes signals from adjacent tracks and adjacent heads as well as sources external to the recording process, such as power-line interference. These problems can be eliminated by better shielding or placement of the components. The magnetic noise sources may be divided into two general categories: barkhausen noise and particulate noise. The barkhausen noise is common in soft magnetic materials and occurs when a moving domain wall tries to move past imperfections in the material. The head is predominant source of this noise in recording. It is introduced on the recording medium during the recording process and it is also observed when the magnetization in the head changes during the playback progress. The particulate noise is due to the fact that the medium is made up of many particles that have a discrete number of magnetization states. Thus it is not possible to vary the magnetization continuously in magnitude, it is increased in steps. The larger the number of particles making up the volume being magnetized, the more steps that can be achieved between negative saturation and positive saturation, and hence the larger the signal-to-noise ratio.

When the testing head is positioned upside down in a uniform magnetic field, maximum open terminal voltage obtained is used to indicate the hum noise [16]. The audio head of sample A and sample B was tested under such conditions and found that hum noise in sample B is more as compared to sample A as shown in Fig. 5.8, this is because of the bigger grain diameter and high permeability of sample A as compared to sample B as explained in chapter 4.

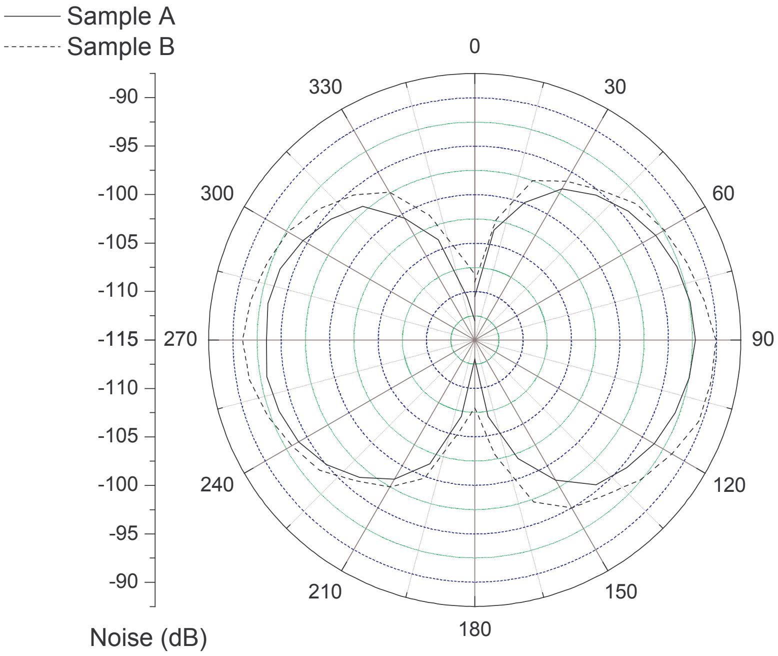


Fig. 5.8: Hum noise of sample A and sample B

5.3.1.2 Sensitivity

This is a measure of the head's ability to reproduce the signal level generated when the tape passes the head [16]. To measure the sensitivity, a standard calibrated tape is used and the testing head made out of sample A and sample B is used to measure that standard recorded tape and output values are obtained. The sensitivity of sample A and sample B as a function of annealing temperature is given in Fig. 5.9. We observed that the sensitivity of the audio head of sample A is better as compared to sample B. The sensitivity of sample A is -74.5 dBv at 1100°C, whereas for sample B -77.5 dBv, this is because of the bigger grain diameter and high permeability of sample A as compared to sample B as explained in chapter 4. Similar behaviour was noticed for other temperatures.

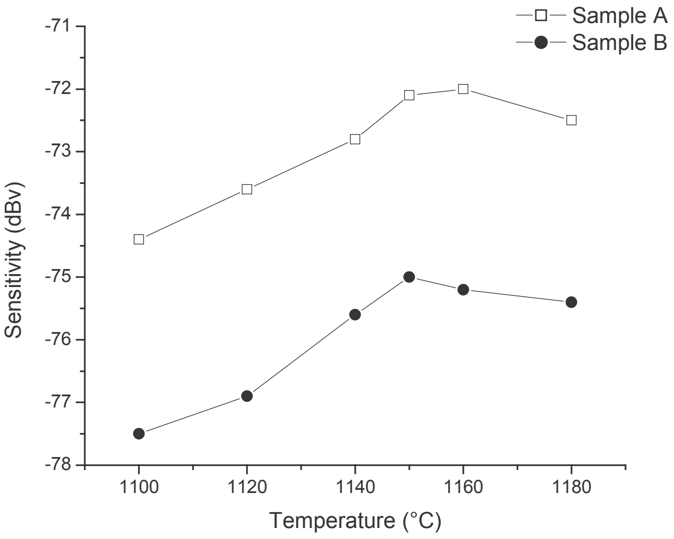


Fig. 5.9: Sensitivity of sample A and sample B as a function of annealing temperature

5.3.1.3 Frequency response

This is a measure of the head's ability to reproduce the signal generated when the tape passes the head [16]. Similarly, to observe the frequency response, a standard calibrated recorded tape is used and the testing head made out of sample A and sample B is used to read that standard recorded tape and output values are obtained. The frequency response of sample A and sample B as a function of annealing temperature is given in Fig. 5.10. We observed that the frequency response of the audio head of sample A is better as compared to sample B. The frequency response of sample A is 11 dB at 1100°C, whereas for sample B 13.5 dB, this is because of the bigger grain diameter and high permeability of sample A as compared to sample B as explained in chapter 4. Similar behaviour was seen for other temperatures.

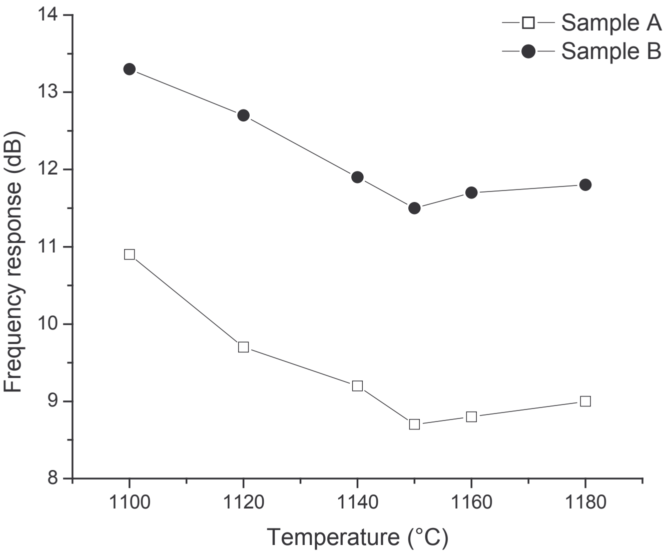


Fig. 5.10: Frequency response of sample A and sample B as a function of annealing temperature

References

1. J. Scatchard, Miller's: Wristwatches: How to compare and value, Octopus publishing group - Mitchell Beazley, London, 2004
2. M. Cutmore, David and Charles, The watch collectors handbook, London, 1976.
3. Kiran Gupta, K. K. Raina & S. K. Sinha, Bull. Mater. Sci., **29** (2006) 391
4. T. M. Jagielnski, “Recording head technology”, Eastman Kodak company, San Diego, California, USA, (1990) 1948
5. E. D. Torre, Encyclo. Phys. Sci. Tech., **7** (1987)
6. C. D. Mee, The Physics of Magnetic Recording, Amsterdam : North Holland, 1964
7. R. M. White, Physics of Magnetic Recording, New York : IEEE Press, 1985
8. R. M. White, J. Magn. Magn. Mater., **88** (1990) 165
9. M. H. Clark, J. Magn. Magn. Mater., **193** (1999) 8
10. J. M. D. Coey, J. Magn. Magn. Mater., **196 (**1999) 1
11. L. D. Stevens, Magnetic Recording: The First 100 Years, New York, NY: IEEE Press, ISBN (1997) 270
12. R. E. Jones, C. D. Mee, & E. D. Daniel, Recording Heads in Magnetic Recording, McGraw-Hill, New York, (1982) 244
13. C. Mee & E. Daniel, Magnetic Recording, McGraw Hill, New York**, 1** (1988)
14. F. Jorgensen, The Complete Handbook of Magnetic Recording, TAB, Blue Ridge Summit, PA, 1988
15. G. W. Brock, Encyclo. Mater. Sci. Engg., **4** (1986) 2679
16. Special Quality Manual, Sankyo Standards, Japan, **4 (**1998)