Perminvar Ferrites

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Perminvar ferrites are essentially nickel-zinc ferrites having the following manufacturing characteristics :

(a) Cobalt is added in small amounts.

(b) The basic composition contains an excess of Fe_2O_3. I.e. they are over-stoichiometric.

(c) Annealing is essential to obtain the specified electrical properties.

Magnetically perminvar ferrites are characterized by very low losses at relatively high frequencies, and they can be used to obtain high values of Q at the high frequency end of the spectrum of application. When perminvar ferrites are compared with non-perminvar nickel-zinc ferrites of similar permeability it becomes apparent that a higher value of Q is obtainable for the same permeability. The very low losses of perminvar ferrites are due to the fact that cobalt ferrite has an anisotropy constant of opposite sign to nickel and zinc ferrites and of much greater magnitude. There is therefore a possibility of mutual cancellation and the resultant anisotropy; energy can be greatly reduced by a small addition of cobalt.

The significance of anisotropy is that it gives a preferred crystallographic orientation which impedes the rotation of domains in certain directions and results in energy being spent on making the magnetic orientation follow the direction of the applied field. If the anisotropy can be reduced, less energy needs to be spent during each cycle and the losses are consequently lower.

In extremely weak fields, the magnetization of ferrite is carried out by the domains which are favored directionally, i.e., that they are in full or partial alignment with the field vector. These domains expand at the expense of their less-favored neighbors which results in movement of the domain walls and expenditure of energy to make them move.

In perminvar ferrite, individual domains can be imagined as being surrounded by low-energy trenches in which domain walls can move very easily with minimum expenditure of energy; however, when the field becomes too strong, the walls are ejected from the trenches and the perminvar structure is destroyed.

The structure of a perminvar ferrite consists of the usual spinel lattice with cobalt ions in some of the unoccupied octahedral sites to form an orderly independent sub-lattice. The ions of cobalt are brought into these sites by the internal forces of the main lattice very slowly and gradually and there is no known way of accelerating this process of migration except by elevated temperatures. This leads to the requirement for annealing. When ferrite is heated beyond its Curie point, the whole magnetic structure is disorganized and when the temperature drops below the Curie point, the magnetic structure is reformed and its internal forces begin to move the cobalt ions to their ultimate sites in a regular pattern, i.e., cobalt sub-lattice. This must happen because it corresponds to the least-energy state of ferrite and all matter tends towards this state of minimum energy. As the temperature is below the Curie point and relatively low, the mobility of ions is also low and the process of migration requires a long time.

To facilitate the migration of cobalt ions to their ultimate stations, the ferrite must have a large number of empty sites (vacancies) thus enabling cobalt ions to jump from stage to stage towards their goal. Empty sites exist if the oxygen content in the sintering atmosphere is high, i.e., firing of perminvar ferrites must be in air. This also leads to a relatively small number of divalent ions in the ferrite resulting in high resistivity. As the properties of perminvar ferrites depend upon the existence of their regular structure, anything which can possibly disturb this structure is disruptive to the electrical properties.

An adverse influence may be exerted by the application of a strong magnetic field (proximity of permanent magnets or excessive current through the winding), heating without slow cooling or a strong mechanical pressure which causes dislocations of the crystalline structure (grinding is one example of such a pressure and ultrasonic cleaning may be another). Under such influences the permeability increases and Q is lowered, especially at the higher frequencies, although the changes in Q at the lower frequencies may be very small.