Research on the High Permeability Permalloy and Its Application to the Hydrogen Maser

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Hydrogen maser operates on the transitions between two hydrogen atomic energy levels. and energy levels of hydrogen atom are very sensitive to the change of magnetic field. Frequency of the microwave emitted by atoms as shown in Formula (1) changes with the magnetic field. Therefore, magnetic shielding is required to achieve the desired working magnetic field, which is critical to the frequency instability performance of the maser. Our research on increasing the magnetic permeability of the materials[1] will apparently contribute to the magnetic shielding performance, and to the improvement of frequency instability performance of hydrogen maser.

$$v = v_{hf} + 1399.08 \times 10^7 \, B_0^2 \quad \text{----------(1)}$$

By adding an appropriate amount of silicon (Si) to the domestic 1J85 ($Fe_{15}Ni_{80}Mo_5$) permalloy, the grain size can be increased and made more uniform, as shown in figures (a), (b), and (c). And promotion of the $FeNi_3$ phase formation has been observed too, as shown in figure (d). Therefore, the $Fe_{15}Ni_{80}Mo_{5-x}Si_x$(x=0,1,2,3) system was prepared. Out of which, the relative magnetic permeability of $Fe_{15}Ni_{80}Mo_4Si_1$ is 407,600, a 221 % promotion compared to domestic 1J85.

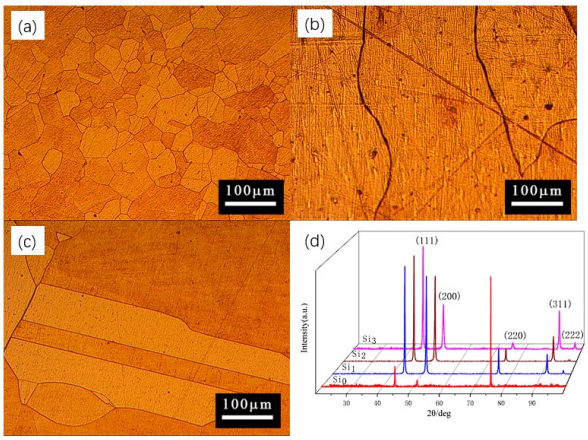

Fig. 1: Phase of $Fe_{15}Ni_{80}Mo_{5-x}Si_x$ by optical microscope, of mag.100×,(a) x=0, annealed (b) x=1, as-cast (c) x=1, annealed (d) x=0,1, 2, 3, XRD

Compared to Si, thulium (Tm) has an advantage of lower magnetic anisotropy coefficient, which making it possible to ensure that the alloy still has a low magnetic anisotropy coefficient. Relevant data of Experimental research will be presented soon.

The magnetic shielding system in the condition of the environmental magnetic field of 5×10^{-5} T has been simulated. The central magnetic field within the four-layer shielding shell of the $Fe_{15}Ni_{80}Mo_4Si_1$ material was reduced to 4.58×10^{-7} T, a 90 % decrease of the original value compared to the same geometric design of 1J85. Theoretically, improvement of the magnetic shielding effectiveness has been achieved. Based on this, a three-layer magnetic shielding system was designed, with the central magnetic field of 5.33×10^{-7} T. The mass of the magnetic shielding system was reduced by 320 g, and volume by 4332 cm^3.

[1] Wolf, S. A, Gubser, D. U, Cox, J. E, Shielding of longitudinal magnetic fields with thin, closely, spaced concentric cylindrical shells with applications to atomic clocks[C], Precise Time and Time Interval (PTTI) Appl. and Planning Meeting, 79N24738.