The magnetism was measured by radiating continuous wave laser on the grain-oriented electrical steel sheet having a thickness of 0.23 mm under the condition as disclosed in Table 1. A radiation line is illustrated as a line divided into three to six sections in the width direction as illustrated in FIG. 2. A laser radiation interval was 2.50 mm, and the beam length d_t in the width direction of the electrical steel sheet at the time of radiating the laser was 50 μm and had a spherical shape. In this case, the movement speed of the electrical steel sheet was 0.9 m/s.

Table 1

E_d J/m m^2	D_H μm	T_L/T_B	Average thickness of scattering alloy layer μm	Pa Kgf /cm^2	Vs m/s	Before radiating laser $W_{17/50}$	Before heat treatment $W_{17/50}$	After heat treatment $W_{17/50}$	Comparison
1.0	10.0	0.3	1.2	0.2	51.8	0.82	0.78	0.78	Example
	11.0	0.4	1.1	5.0	51.8	0.82	0.75	0.74	Example
	6.4	0.2	0.768	5.0	200	0.82	0.79	0.79	Example
5.0	21.0	0.7	1.26	0.2	51.8	0.82	0.70	0.69	Example
	22.2	0.8	0.9	5.0	51.8	0.82	0.71	0.71	Example
	15.3	0.5	1.224	5.0	200	0.82	0.69	0.69	Example
1.2	15	0.5	0.6	61.0	51.8	0.83	0.68	0.68	Example
	20	0.6	1.6		51.8	0.82	0.67	0.67	Example
	25	0.7	3		200	0.83	0.68	0.67	Example
5.3	25.5	0.85	1.5	5.0	51.8	0.82	0.86	0.82	Comparative Example
			1.8	5.0	51.8	0.82	0.87	0.83	Comparative Example
			0.5	5.0	200	0.82	0.85	0.83	Comparative Example

In the laser radiation condition range according to the present invention, it is possible to provide the grain-oriented electrical steel sheet, which may obtain stable core loss characteristics even at a high movement speed of the steel sheet.

Example 2

The magnetism was measured by setting the energy density to 1.2 J/mm^2

[CLAIMS]

1. A grain-oriented electrical steel sheet, which has a surface which is formed with grooves for a magnetic domain refinement treatment,

wherein a scattering alloy layer in the groove is eroded in a Goss texture during a recrystallization annealing process; and

wherein when a thickness of the scattering alloy layer on a bottom surface of the groove is defined as T_B, and a thickness of the scattering alloy layer at a point that is one-half the distance between any one end of the groove and the bottom surface of the groove is defined as T_L, T_B/T_L is 0.2 to 0.8.

2. The grain-oriented electrical steel sheet of claim 1, wherein:

a thickness of the scattering alloy layer is 4% to 12% of a depth of the groove.

3. The grain-oriented electrical steel sheet of claim 2, wherein:

the depth of the groove is 4% to 11% of a thickness of the electrical steel sheet.

4. The grain-oriented electrical steel sheet of claim 3, wherein:

the groove is formed diagonally with respect to a width direction of the electrical steel sheet.

5. The grain-oriented electrical steel sheet of claim 4, wherein:

the groove is formed at an angle greater than 0° and equal to or smaller than

5° with respect to the width direction of the electrical steel sheet.

6. The grain-oriented electrical steel sheet of claim 5, wherein:

three to six grooves are intermittently formed in the width direction of the electrical steel sheet.

7. A method of manufacturing a grain-oriented electrical steel sheet, the method comprising:

providing electrical steel sheet before forming primary recrystallization or after forming the primary recrystallization; and

forming a groove in a surface of the electrical steel sheet by radiating laser and simultaneously spraying gas onto the electrical steel sheet,

wherein energy density E_d and a laser scanning speed V_s of the radiated laser satisfy the following conditions,

$1.0\ J/mm^2 \leq E_d \leq 5.0\ J/mm^2$,

$0.0518\ mm/\mu sec \leq V_s \leq 0.2\ mm/\mu sec$;

wherein pressure of the sprayed gas is 0.2 kg/cm^2 to 5.0 kg/cm^2; and

wherein an angle formed between the spray direction of the gas and the laser radiation direction is 0° to 50° (here, a state in which the angle formed between the spray direction of the gas and the laser radiation direction is 0° means that the spray direction of the gas and the laser radiation direction are parallel to each other).

8. The method of claim 7, wherein:

in the radiating of the laser, a laser beam is radiated on the surface of the electrical steel sheet at an angle greater than 0° and equal to or smaller than 5° with respect to a width direction of the electrical steel sheet.

9. The method of claim 8, wherein:

in the radiating of the laser, a movement speed V_L of the electrical steel sheet is at least 0.9 m/s.

10. The method of claim 9, wherein:

in the radiating of the laser,

when a beam length in the width direction of the electrical steel sheet is d_t, and a beam length in a rolling direction of the electrical steel sheet is L, a light collecting shape of the laser satisfies the following condition,

$$0.20 \leq L/d_t \leq 1.0$$

11. The method of claim 10, wherein:

d_t is 50 μm or smaller.

12. The method of claim 11, wherein:

in the radiating of the laser,

a scattering alloy layer in which a melted portion of the electrical steel sheet

by the radiation of the laser scatters and is resolidified is generated, and when a thickness of the scattering alloy layer on a bottom surface of the groove is defined as T_B, and a thickness of the scattering alloy layer at a point that is one-half the distance between any one end of the groove and the bottom surface of the groove is defined as T_L, T_B/T_L is 0.2 to 0.8.

13. The method of claim 12, wherein:

a thickness of the scattering alloy layer is 4% to 12% of a depth of the groove.

14. The method of claim 13, wherein:

in the radiating of the laser,

the laser is radiated diagonally with respect to a width direction of the electrical steel sheet.

15. The method of claim 14, wherein:

in the radiating of the laser,

the laser is radiated at an angle greater than 0° and equal to or smaller than 5° with respect to the width direction of the electrical steel sheet.

16. The method of claim 15, wherein:

in the radiating of the laser,

three to six grooves are intermittently formed in the width direction of the electrical steel sheet.