MAGNETISM AND MAGNETIC MATERIALS CONFERENCE

MMM2020 Virtual Conference

A Description of Laser Impacts on Magnetic Properties of GO Electrical Steels Under Surface Treatment With Short and Ultra-Short Pulses

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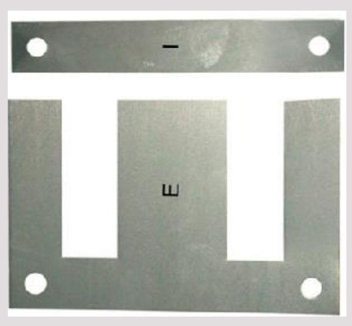
1. Aim

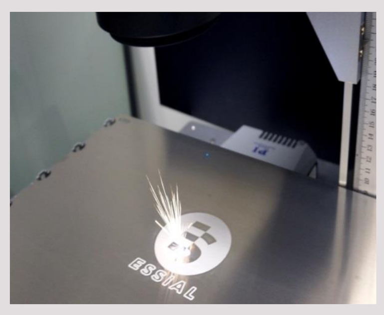
Grain-Oriented Fe-Si steels

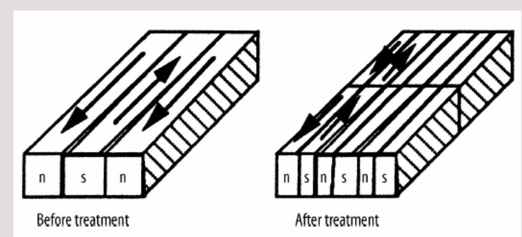


Transformer Core Laminations

Reduction of Iron Losses → **Saving Energy**

Technic: Surface Laser treatment

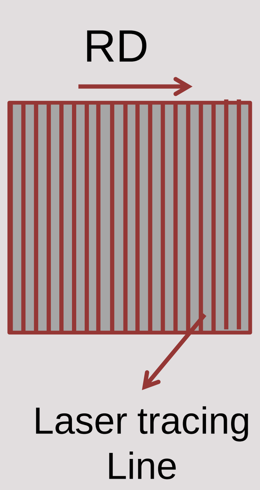




Magnetic Domain Refinement

- Loss reduction up to 20% and apparent permeability improvement
- Correlations between the laser energetic quantities, laser impact and the identified magnetic properties
- Impact of laser on microscopic magnetic structure

2. Laser Treatment and Material



IPG pulsed Ytterbium fiber:

Scribing
short pulse laser (1.064µm)

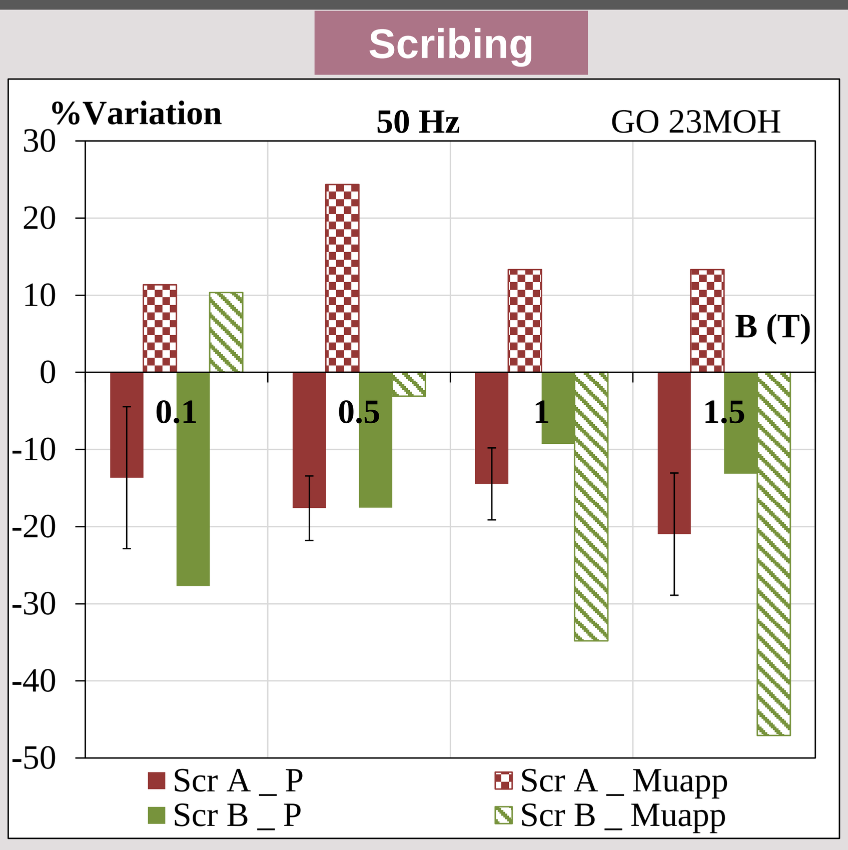
Ablation
ultra-short pulse laser(1.030µm)

Grain-Oriented Fe-(3wt%)Si	
Name	GO 23MOH
Coating	2.3 μm
Thickness	0.23mm
Size	Square(150mm)
Density	7.38 g/cm^3

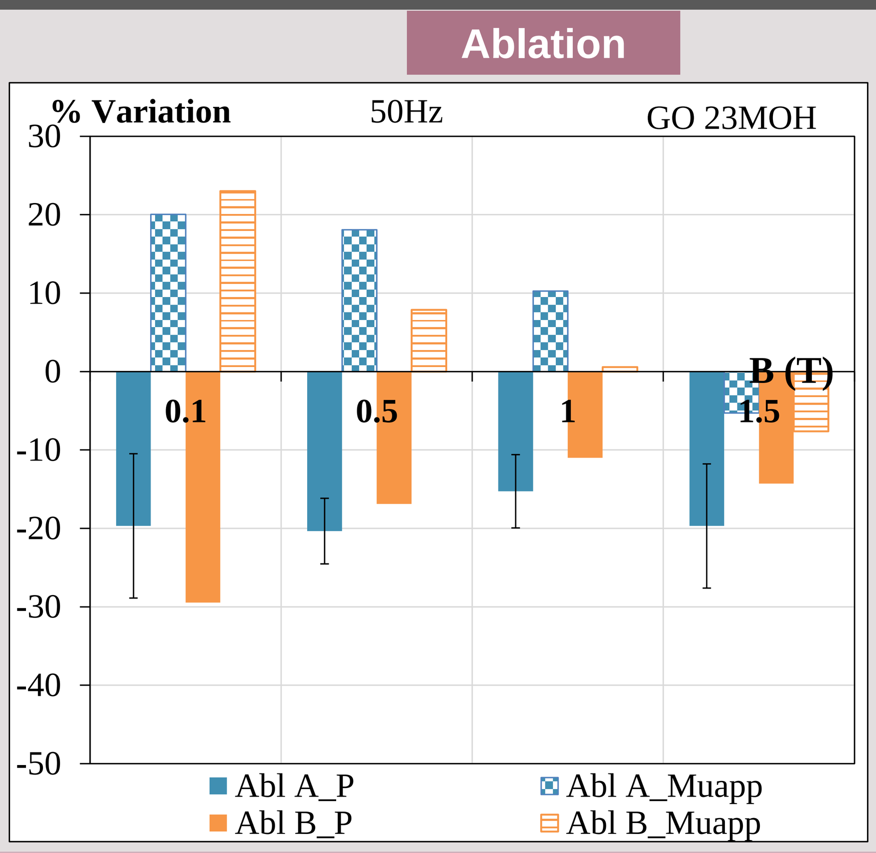
Configuration	Peak power density (MW/cm^2)	Energy density (J/cm^2)	Cumulative energy density (J/cm^2)	Type
Scr_A	127.32	0.50	509.296	Scribing
Scr_B	38.19	3.81	15.279	Scribing
Abl_A	$23.4e^6$	11.71	1171.38	Ablation
Abl_B	$10.1e^6$	5.09	50.92	Ablation

3. Total Power Loss and Apparent Permeability Variation measured with "SST"

Scribing



Ablation



4. Modeling

Scribing

Linear Thermal Equation: $\frac{C}{G}\ \partial_t \Delta T + \Delta T = q/G$

G thermal conductivity coefficient, *C*:heat capacity coefficient, *q*: laser heat flux

Induced Thermal Stress: $\sigma_{th} = (\alpha_i . \Delta T_i - \alpha_m . \Delta T_m). E$

Thermal expansion coefficient of SiFe (α_m) and of the insulating coating (α_i),
Metal temperature (ΔT_m) and coating temperature variation (ΔT_i), *E*: Young modulus

Ablation

Based on the two Temperature Model: $L \approx \alpha^{-1} \cdot \ln\left(\frac{F_a}{F_{th}}\right)$

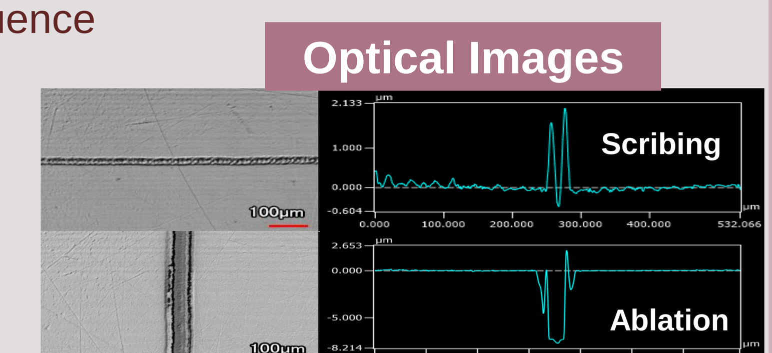
L: groove depth, α: optical penetration depth, F_a: laser fluence
F_{th} : threshold fluence for ablation

Bertotti's Model: Loss separation

$$P = P^{(hyst)} + P^{(class)} + P^{(exc)}$$

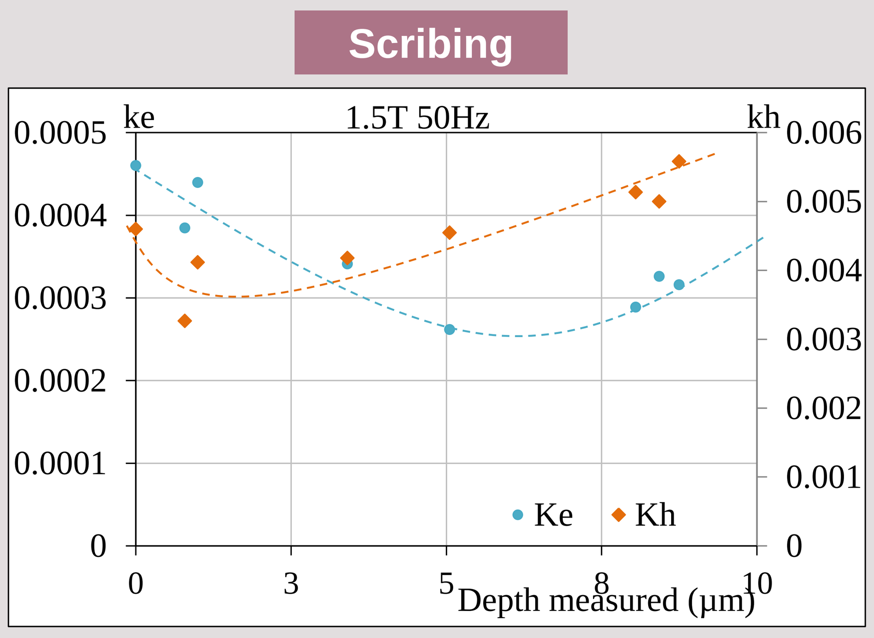
$$= k_h\, f B_m^2 + k_c\, f^2\, B_m^2 + k_e\, f^{\frac{3}{2}}\, B_m^{\frac{3}{2}}$$

Optical Images



5. Correlations

Scribing



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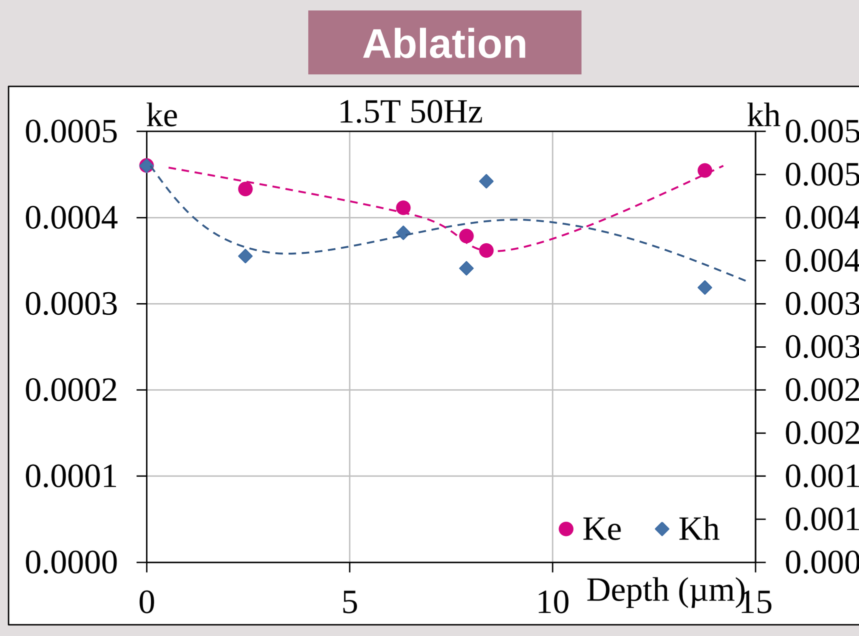
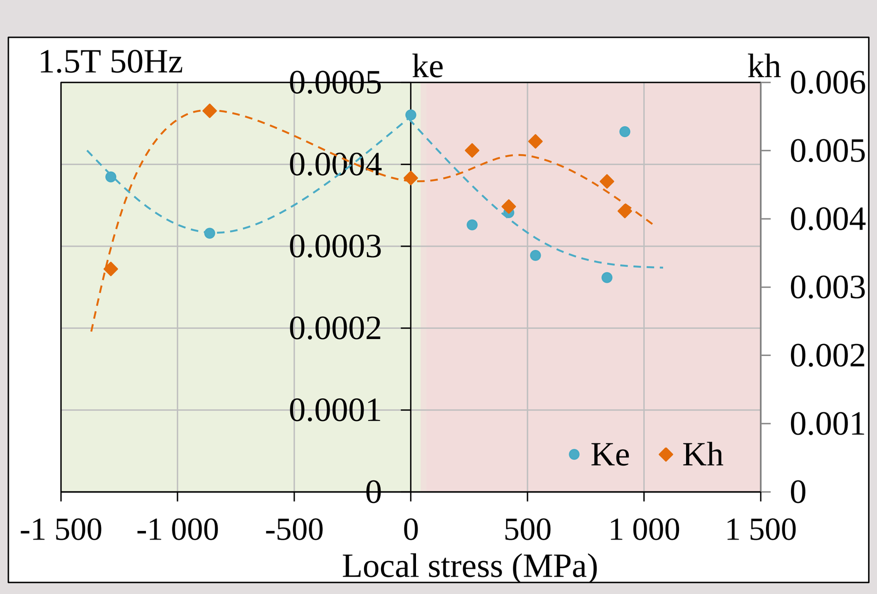
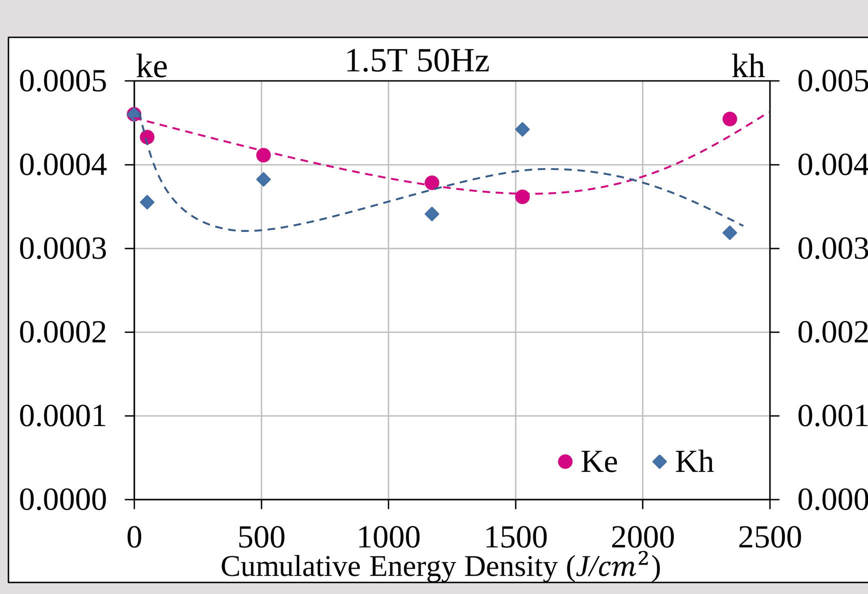


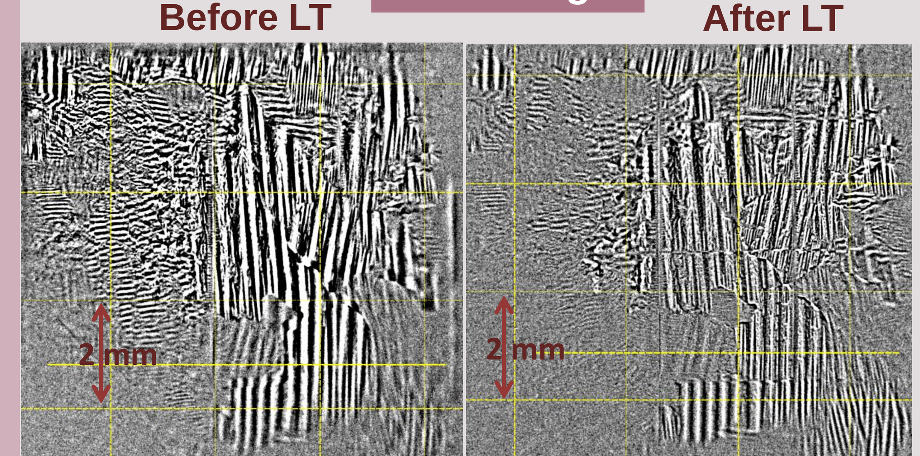




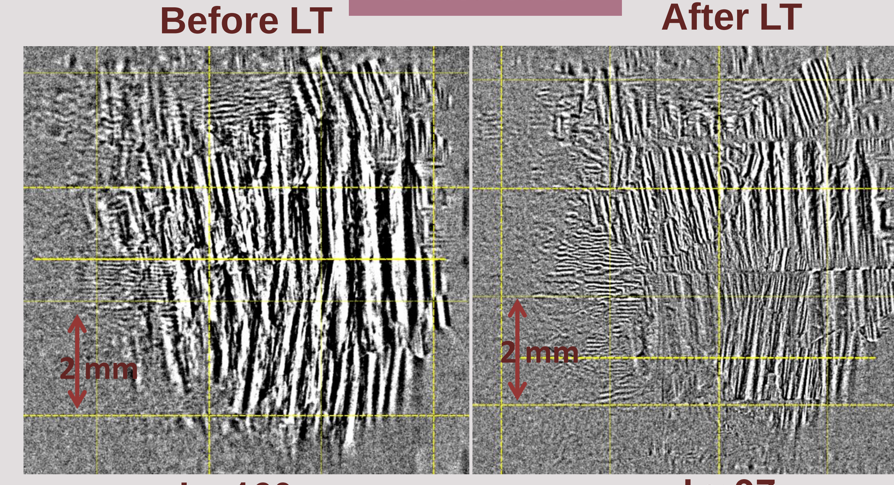
6. Magnetic Images

MOIF : Mgneto-optical imaging film Magnetic domain Refinement (d: domain width)

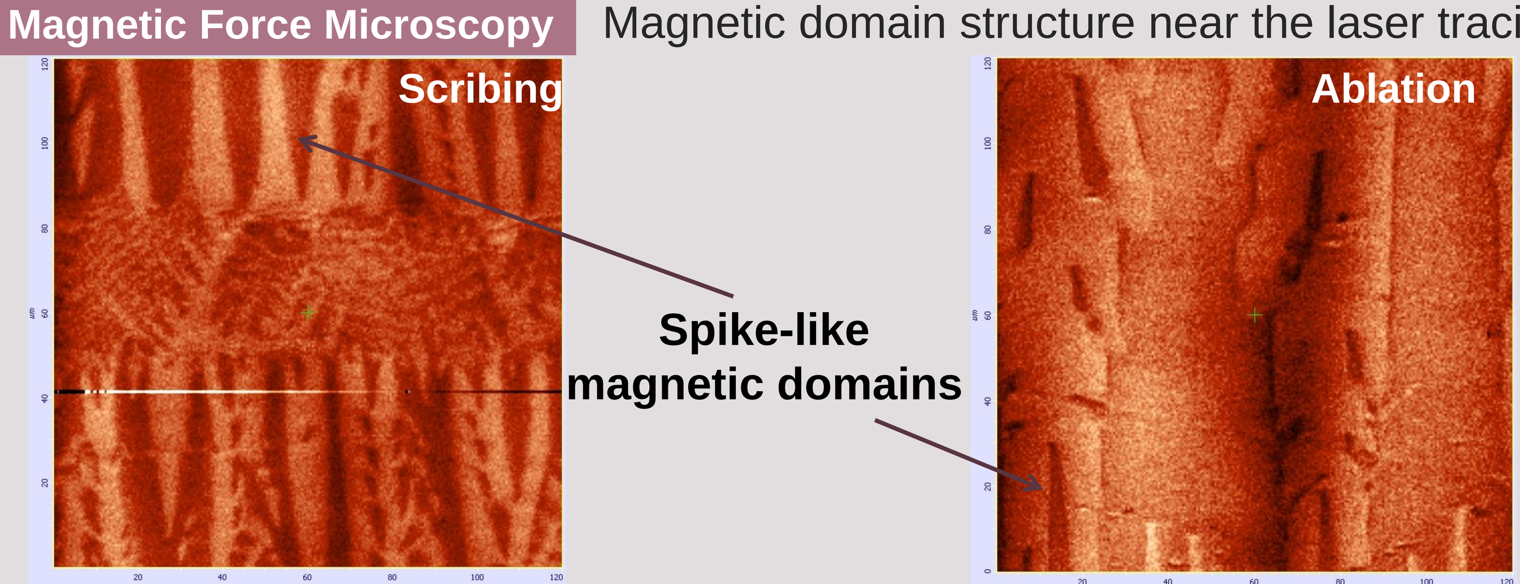
Scribing



Ablation



MFM: Magnetic Force Microscopy Magnetic domain structure near the laser tracing line



Acknowledgments This work was carried out within the frame of the project ESSIAL, funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 766437