SHORT COMMUNICATION

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LASER ABLATION OF Nd–Fe–B MAGNETS

Arvi KRUUSING[a], Vitali PODGURSKI[b], and Valdek MIKLI[c]

[a] Tallinna Tehnikaülikooli aparaadiehituse instituut (Department of Instrumental Engineering, Tallinn Technical University), Ehitajate tee 5, EE-0026 Tallinn, Eesti (Estonia)
[b] Tallinna Tehnikaülikooli materjalitehnika instituut (Department of Materials Technology, Tallinn Technical University), Ehitajate tee 5, EE-0026 Tallinn, Eesti (Estonia)
[c] Tallinna Tehnikaülikooli materjaliuuringute keskus (Centre for Materials Research, Tallinn Technical University), Ehitajate tee 5, EE-0026 Tallinn, Eesti (Estonia)

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Nd–Fe–B MAGNETITE LASERABLATSIOON. Arvi KRUUSING, Vitali PODGURSKI, Valdek MIKLI

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1. INTRODUCTION

Due to its good magnetic properties, Nd–Fe–B has been widely used in such equipment as electric motors, electroacoustic transducers, electron devices [1, 2].

Furthermore, there is great interest in using Nd–Fe–B magnets in microdevices [3, 4]. On the microscale, conventional sintering technology of fabricating rare earth magnets is not applicable. As an alternative, laser ablation machining and deposition [5] may be used to fabricate tiny magnets.

Laser ablation may be used to generate fine magnet powder [6], which could be used for *in situ* manufacturing of polymer-bound magnets for microdevices.

Earlier work on laser processing of Nd–Fe–B covered surface glazing to enhance the corrosion resistance [7–9]. No information on laser ablation or particle generation of this material is available.

The main goal of this work was to clarify the possibilities of excimer laser micromachining of Nd–Fe–B magnets. In addition, the powder, generated in the ablation process, was characterised.

2. SURFACE MACHINING OF Nd–Fe–B BY EXCIMER LASER LIGHT

The magnetic material used was NEOREM 410a of Outokumpu magnets Oy, Finland. The sintered unmagnetised pellets had the diameter of 25 mm and thickness of 3 mm. Their composition was, %: Nd – 31, Dy – 1.5, B – 1.15, Al – 0.25, and Fe – balance. For surface machining studies, thin plates were cut out of the starting material with a diamond saw and ground to surface roughness R_a 0.8 µm.

In our experiments, we used an excimer laser model ELI-94 (Estonian Acad. Sci.), generating at 308 nm with pulse energy 50–60 mJ at 10 Hz, pulse length 25 ns.

The laser beam was focused by silica lens onto the specimen surface, where maximum energy density of about 15 J/cm^2 was created. The specimen was scanned in the air at the velocity of about 2 mm/s in the direction of the longer axis of the laser light spot.

Irradiated surfaces were investigated by profilograph model 201 and by a scanning electron microscope (SEM) model JEOL JSM 840A at the Centre for Materials Research of Tallinn Technical University.

Figure 1 shows the surface profile of the sample in the course of machining and illustrates the corresponding SEM micrographs.

In the initial phase, original fine grained surface structure preserved, although on outer grains, melting was observed. The material was locally removed. Further, the melted areas expanded and the hollows between melted plateaus became deeper. After 50 passages 5 µm deep trench with surface roughness R_a 2.0 was formed, which gave for an average ablation rate of about 0.1 µm/pulse. This ablation rate was close to that of iron [10]. The metal target roughening during laser ablation was observed also in [11, 12].

These results suggest that excimer laser ablation may be used to cut or drill Nd–Fe–B, but is not well suited for 3D micromachining due to surface roughening in the ablation process. However, in other cases, the surface roughening may be used to improve the adhesion of protective or functional coatings on the material [13].

3. FINE POWDER GENERATION BY LASER ABLATION OF Nd–Fe–B

The material, evacuated from the ablation zone, may form a fine powder and may be used, for example, as a starting material for nanostructured materials [14].

Laser ablation is recognized as a superior method to produce fine powders of various compounds with uniform size distribution [6, 15, 16].

For micromechanical devices, *in situ* fabrication of polymer-bounded magnets by simultaneous laser ablation deposition of magnet powder and polymer would be of interest.

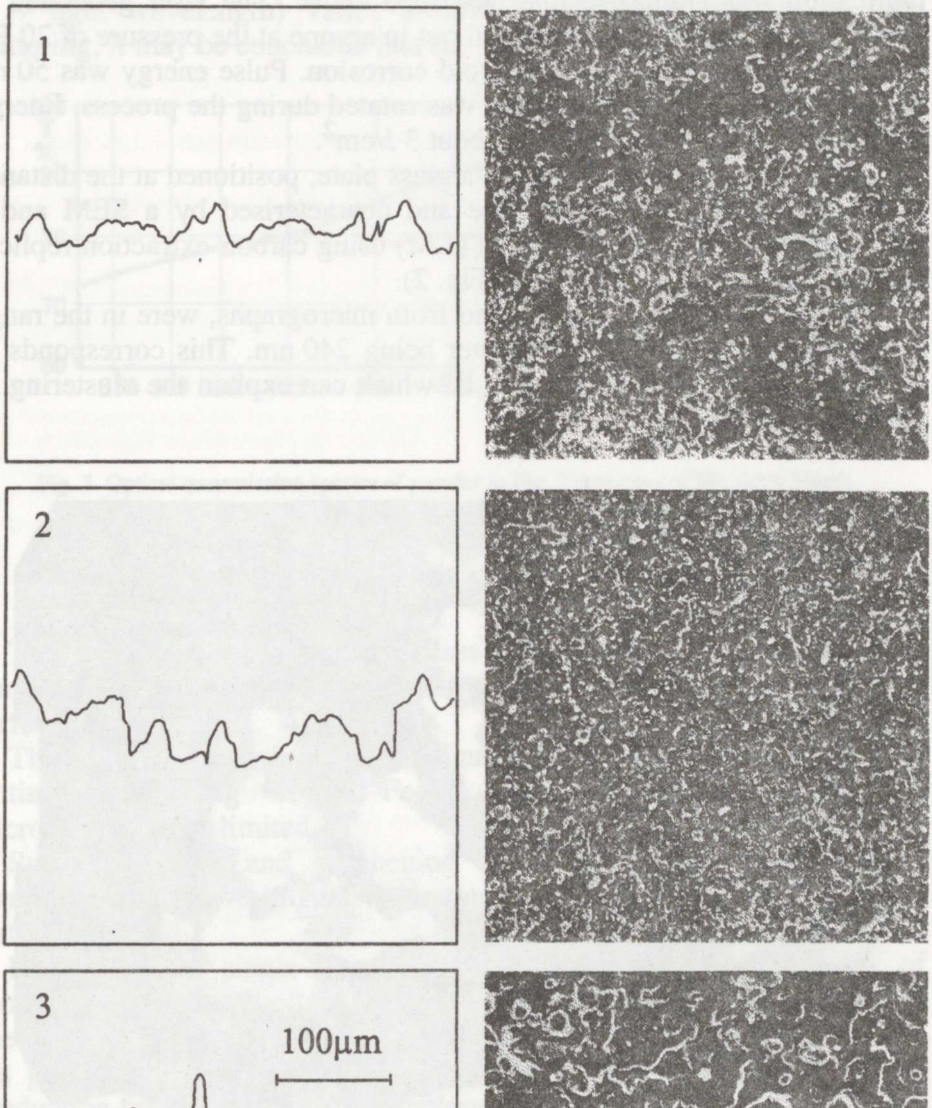

Fig. 1. Surface modification of sintered Nd–Fe–B in the course of excimer laser light treatment. Energy density on surface was about 15 J/cm^2. *1* – nonirradiated surface, *2* – after 20 pulses, *3* – after 50 pulses.

The experimental set and starting material for Nd–Fe–B powder fabrication was similar to that described above. The laser generated at 193 nm and the process was carried out in argone at the pressure of 20 Pa, to achieve finer powder and to avoid corrosion. Pulse energy was 50 mJ and pulse length 15 ns. The target was rotated during the process. Energy density on the target surface was about 3 J/cm^2.

The particles were collected on a glass piate, positioned at the distance of 20 mm from the ablation zone and characterised by a SEM and a transmission electron microscope (TEM) using carbon-extraction replicas from the powder collection glass (Fig. 2).

The particle diameters, measured from micrographs, were in the range of 43–930 nm, the average diameter being 240 nm. This corresponds to the single domain size of $Nd_2Fe_{14}B$, which can explain the clustering of particles (Fig. 2).

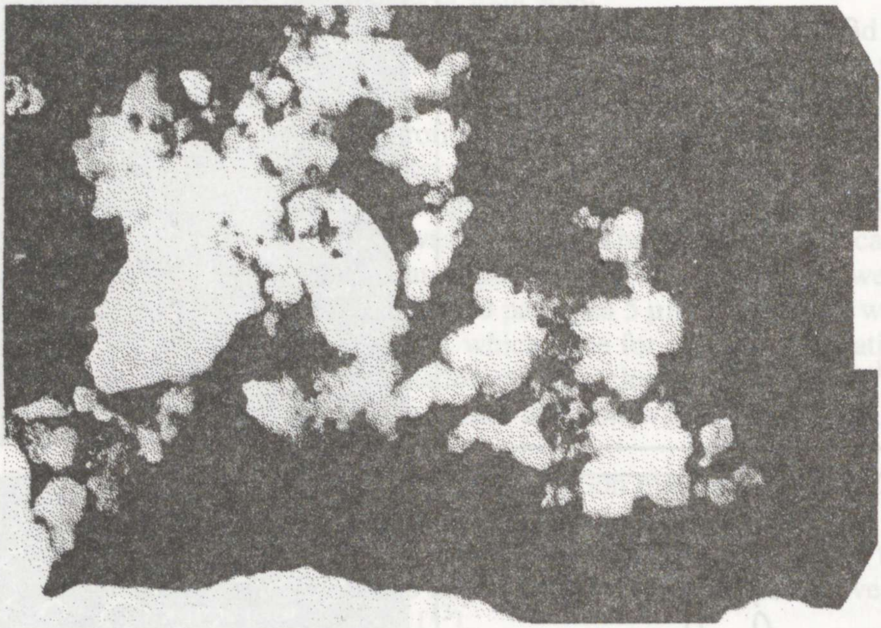

Fig. 2. TEM micrograph of powder, generated by ArF laser ablation of sintered Nd–Fe–B in argon at pressure 20 Pa. Magnification 30 000 ×.

Furthermore, the powders were characterised by optical spectroscopy, which is proven to give versatile information about electrical and electronic properties of small particles [17, 18]. The authors of [18] have investigated the quantum effects of the separation of the energy levels in the particles of different sizes, ranging from 4–50 to 100–400 nm of Nd–Fe–B.

Figure 3 demonstrates optical transmission spectra of the laser-generated Nd–Fe–B powder, recorded by Beckman Ratio Recording Spectrophotometer DK-2. The spectrum is similar to that discussed in [18] with chemically produced powders. Since d/λ (d – particle diameter, λ – light wavelength) varies around 1 which corresponds to Mie scattering, it may be concluded that the particles were conductive.

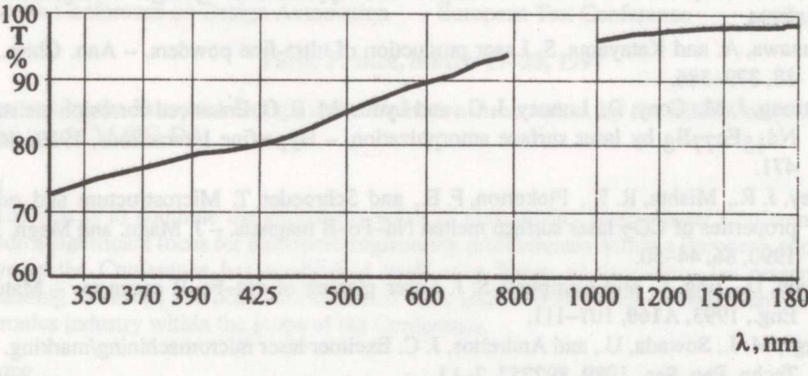

Fig. 3. Optical transmission spectra of powder in Fig. 2 (courtesy of Mr. Arvo Mere).

CONCLUSIONS

The results show that excimer laser light impact to Nd–Fe–B at high fluences is similar to that of metals – the ablation rate is low, and rough surfaces build up.

Thus it may be concluded that ordinary excimer lasers may be used for cutting or drilling of Nd–Fe–B, but their application for 3D micromachining is limited.

Surface melting and roughening in the ablation process may be beneficial to improve protective coatings adherence and is the subject of further studies.

Production of single-domain magnet particles by ablation is of considerable interest both in terms of fundamental studies and practical needs. By laser ablation, free clean particles may be generated. However, the particles yield is low, and the method is not suitable for powder production for macroscopic applications.

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