FORMATION OF PERIODIC GRATINGS IN STAINLESS STEEL USING FEMTOSECOND LASER INTERFERENCE ABLATION

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Laser ablation is a micro-structuring method where sample is irradiated with high energy fluence ultra-short pulses. High amount of energy is then transferred to the atoms in the material allowing the direct transition from solid state to plasma. By using pulses that have durations of hundreds of femtoseconds the temperature diffusion cannot occur. This way the material is ablated only in the region of irradiation enabling one to create fine structures [1, 2]. Resolution of patterns is diffraction limited and can be overcome only by using interference.

Optical security tags with holographic effects, i.e. arrays of diffraction gratings are used for anti-counterfeiting applications. They are commonly created in light sensitive materials (e.g. photoresists). After many technological steps the final shim is obtained and is used for high throughput replication process in reflective films via mechanical embossing. However, this method can be applied only in relatively soft materials like polymer films.

During current research, Yb:KGW femtosecond laser Pharos (Light Conversion) and micromachining workstation FemtoLAB (Altechna R&D) were employed to create arrays of 60x60 µm squares that contained micrometer pitch interference pattern in stainless steel. Square shape was formed by using square aperture on the expanded beam. Second harmonic (515 nm) laser beam was split into two employing diffractive optical element and then re-focused on the surface of stainless steel sample to create interference field. Circular polarization was chosen to avoid formation of self-reorganized ripple structures [3]. Each square contains a grating of 1.3 µm pitch.

2D array of squares ablated using different parameters was fabricated. In one direction of the array laser fluence was changed. In the other – number of pulses was varied. Different laser ablation effect dependence on combination of these two parameters was observed.

Fig. 1. Squares ablated in stainless steel with 4900 pulses at 40 kHz pulse repetition rate with laser fluence:

a) 3.3 J/cm² b) 5.1 J/cm² c) 6.6 J/cm²

Two different modes of laser ablation were observed. Using laser fluence higher than 1.1 J/cm² the first ablated randomly dispersed lines starts to occur (Fig. 1 a). By increasing the laser fluence the pattern becomes homogenous over all surface (Fig. 1 b). Such patterns provide highest diffraction efficiency of reflected non-zero diffraction maxima. When the fluence reaches 5.1 J/cm² strongly ablated pattern occurs at the center of the area (Fig. 1 c). This could be explained as non-uniform Gaussian beam intensity distribution over the aperture. The ablation threshold of the interference was determined at this fluence. The squared diameter of strongly ablated area has logarithmic dependence on pulse fluence [4-6]. The ablation threshold dependence on the number of pulses was also observed. However, even with a few pulses the undesirable strong ablation area in the middle of the sample occurred while desirable pattern is still weak. The most promising pattern was fabricated with 5 J/cm² using from 1000 to 5000 pulses.