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Direct laser-writing of optical micro-structures for robust traceability marking of metal components

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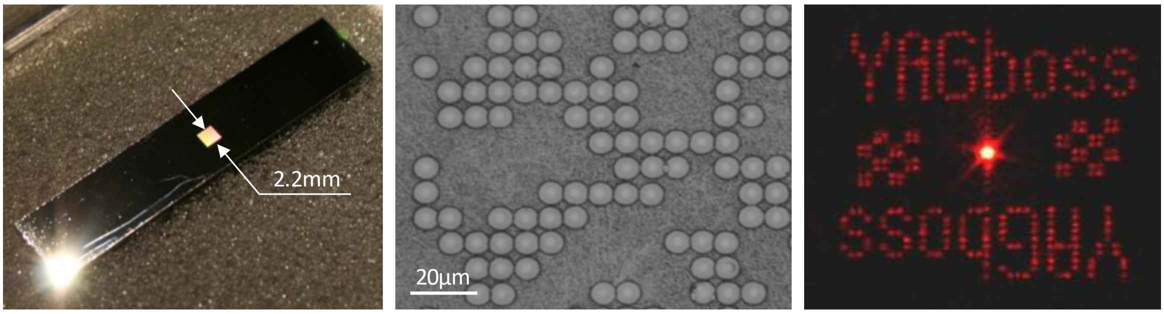
Full traceability of components is essential in medical and aerospace sectors. Common approaches to unique marking include etching of serial numbers and bar codes or the use of a polymer holographic sticker which is typically produced by a mechanical embossing process. The hologram is robust to local damage, its information being distributed over a wide area, where serial numbers and bar codes are not. The serious disadvantage of such holograms, however, is that they are not embedded into the metal surface, but are rather attached as an adhesive tape, and therefore are vulnerable to tampering and present biocompatibility problems for implants.

This paper presents a laser-based process for the direct embossing of phase holograms on the surface of metal parts (e.g. 304-grade stainless steel). In order to achieve an optical surface finish, we use a nanosecond laser operating at a 355 nm wavelength. This approach allows the metal surface to be structured (either by melting or the combination of melting and evaporation) with the required sub-micron depth control. As reported elsewhere [1], surface structuring by a melt-only process is possible because UV nanosecond laser pulses produce a very shallow melt pool with a transverse thermal gradient since the laser beam is more intense in the centre. This gives rise to a surface tension gradient across the surface of the melt pool which causes a flow of the molten material. This type of flow is known as the Marangoni effect [2].

Figure 1 (a) shows a sample of 304-grade stainless steel with a laser-written micro-structure containing coded information (the small square in the centre). The micro-structure represents a binary (two-level) diffractive optical element (DOE) whose design was performed using the Iterative Fourier Transform Algorithm [3]. The DOE was generated by a 10 µm diameter focused laser beam with pulse energy of 2.5 µJ. At this pulse energy, each pixel of the DOE is an optically-smooth crater with a peak-to-valley depth of approximately 300 nm. The close-up (top) view of the DOE is shown in Figure 1 (b). When the DOE is illuminated with a laser source (e.g. a He-Ne laser), it produces a clear diffraction image with the undiffracted (zero-order) laser beam in the centre, as can be seen in Figure 1 (c).



(a) (b) (c)

Figure 1 (a) 304-grade stainless steel with a laser-written DOE, (b) optical microscope image of the DOE, and (c) image generated by the DOE when illuminated by a He-Ne laser beam.

A detailed discussion of the laser-based process for the generation of traceability markings (DOEs) on metal surfaces will be presented, and more complex microstructures than that shown in Figure 1 will be demonstrated. Results with different metals (e.g. nickel) will also be presented.

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