A Simple Method of Measuring the Etch Depth in Metallic Specimens Using Speckle Photography

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A two step method using speckle photography is proposed for the measurement of etch depth in metallic specimens.

When a laser beam which is a highly coherent source of light falls on a diffusely reflecting surface, the scattered light gives a granualar appearance. As one moves the eye , the light appears to shimmer. This is called speckle and it can be described as a random interference patterns of the light scattered from points on the surface. The laser speckle phenomenon has found extensive application in science and technology, for the measurement of displacement, stress, strain, vibration [1], etc. In this paper it is demonstrated that laser speckle can be used to measure the thickness of material removed by etching a metallic surface.

PRINCIPLE OF SPECKLE UTILISATION

Speckle pattern from a diffusely reflecting object can be recorded on a high resolutions photographic plate or film (1500-2000 lines/mm) using a camera or directly placing the film in the speckle field. If the object is displaced in its own plane, the speckle pattern which is displaced can also be recorded on the same photographic plate. The result of the super imposed speckle pattern is also a speckle pattern. The displaced speckle can be observed under a microscope and would give the object displacement. However an easier method would be to place the developed photographic plate in an unexpanded laser beam, when Young's interference fringes will be seen on a screen. These are Youngs fringes due to displaced speckles. From the spacing of the interference fringes one can infer the displacement of the object. This technique of studying displacement is called the speckle photography. One can use double exposure speckle photogrphy for the in-plane displacement, out of plane displacement and also slopes of displacement [2,3,4]. The speckle photography does not demand stringent antivibration environment compared to holographic techiniques. The authors have extensively used speckle photography for different applications [5,6].

EXPERIMENTAL

In this paper a novel application of speckel photography to measure the etch depth is proposed and the experimental method is reported. Fig.1 shows the schematic of the experimental set up.

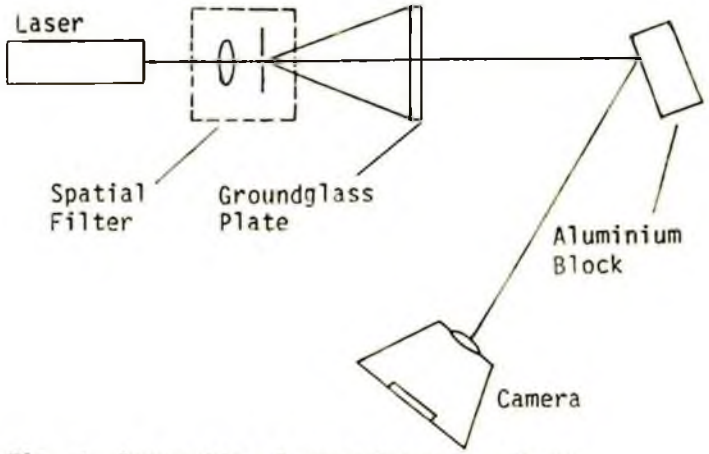


Fig. 1 Schematic of experimental set up.

Laser beam from a 1mW He-Ne laser is expanded and 'cleaned' through a spatial filter. The pin hole spatial filter consists of a IOX microscope objective at whose focus a pinhole of 10 microns is placed. This effectively eliminates the diffraction patterns from dust particles and imperfections in the objective lens. The output beam is uniform. If the pinhole is not used all kinds of interference and diffraction patterns will be observed. The expanded beam is allowed to fall on a ground glass plate, which gives rise to a higly scattered illumination. This illumination falls on the rigidly fixed aluminium block. The metallic surface is imaged using a bellows extension camera. The high resolution photographic film like S0253 is loaded in the camera and the image of the object surface is initially recorded on the film using laser illumination. The laser beam is now covered and the metal surface is smeared with the etchant (in this case dilute NaOH solution). The etchant was allowed to remain on the surface for a known time, when etching takes place. The surface is now wiped clean with a swab dipped in water and dried. The second exposure is made. The film is developed using a high resolution developer like Kodak D-19 and fixed in a special fixer.

The developed film, called the speckle gram is placed in the path of an unexpanded laser beam when, a diffraction halo is seen on the screen. Within the diffraction halo, one sees straight interference fringes. Because of the nature of these fringes, it is recognised that they are the same as the young's interference fringes. Fig 2 gives the photographs of fringes in some typical cases.

These fringes represent an in-plane displacement of the speckle pattern on the photographic film.

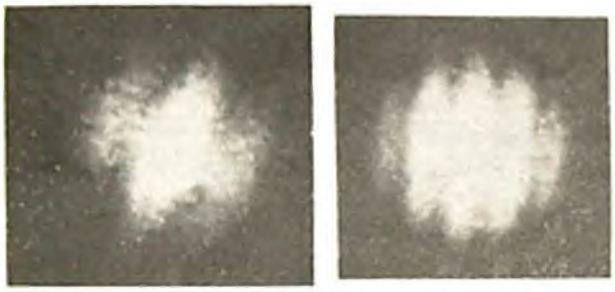


Fig. 2 Photographs showing the young's interference fringes from the specklegram (a) etching time 4 mts. (b) etching time 6 mts.

The displacement of the speckle is given by $d_f = \lambda.D/\beta$ where d_f=the displacement of the speckle on the film, D=the distance between specklegram and screen. β=distance between the fringes and λ is the wavelength of laser light. The speckle displacement on the object is obtained by dividing d_f by a factor m which is the magnification of the photographic system used. The speckle displacement on the object is do = $\lambda D/m$.

From Fig.3 one can infer that the depth of etch t can be calculated from the geometry as $t = do/2\sin\theta/2$

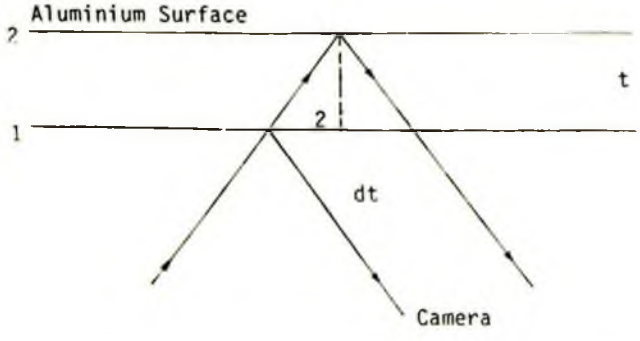


Fig. 3 Geometrical explanation for the speckle displacement due to removal of material.

Where is the angle subtened by the laser beam and the camera at the object plane.

RESULTS

Table 1 gives the etch depth determined for three experimental conditions chosen.

Exp. No	Etching time	depth in microns
1	2 mts	52.23
2	4 mts	84.82
3	6 mts	123.39

CONCLUSION

A simple method of the experimental determination of etch depth in metallic specimens has been demonstrated.

A minor disadvantage of the method is that it is a two step process. However it can be overcome by what is called an electronic speckle pattern interferometry(ESPI).

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