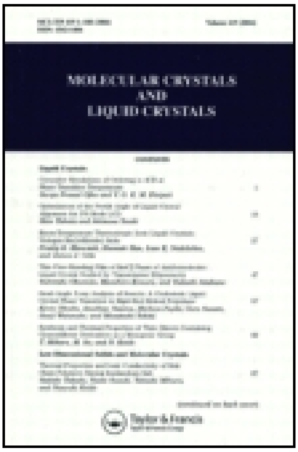

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LC Vision: The Dynamically Induced Structure Deformation Modes in Metal

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LC VISION: THE DYNAMICALLY INDUCED STRUCTURE DEFORMATION MODES IN METALS

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Abstract A new application of the NLC technique in metallography for visualizing the translational and rotational deformation modes in metals after dynamic loading is discussed.

INTRODUCTION

It was discovered that a thin layer of the homogeneously oriented NLC applied to a surface of optical quality as a free layer may visualize the structural defects of the surface due to local deformation of themselves [1,2]. The recording of these regions becomes possible when a LC structure is illuminated in transparent or reflective mode. Arising interference pattern is studied then through a polarizing microscope. To date, a quantitative theory stating the relation between dimensions of the natural defects and their images in the NLC layers, has been developed, which makes this technique metrological [3]. The simplicity in use and easy detecting of the valuable information open a wide area for its application in non-destructive material testing in optical engineering, crystallography and mineral analysis [4]. The goal of this work is to confirm the possibility of the new application area of NLC technique in metallography.

NLC TECHNIQUE

The investigation of structural changes during the deformation process is one of the most complicated problems of material science. These changes appeared to occur during plastic deformation in translational and rotational modes. The spatial size of deformation modes may be ranged from atomic-dislocational level ($10^{-8}...10^{-6}$ cm) to mesoscopic ($10^{-5}...10^{-3}$ cm) or superstructural level (10^{-1}cm). The nature of dynamic deformation modes is not clear enough.

In this paper, the results of visualizing the translational and rotational modes in metal targets subjected to dynamic loading are discussed. The different metal specimens such as M2 copper, Cr-Ni-Mo steel and Al were examined. The strain was produced by uni-axial loading using one-cascade light-gas 37 mm caliber gun. The samples had flat washer form 52mm in diameter and 2...10 mm thick. The flyer velocity was within 100...300 m/s. After loading the specimens were cut along the plane of wave propagation and then polished. The main and virtually the sole operation of the NLC technique was putting a uniform NLC layer, a fraction of micrometer thick, on the polished surface to fulfil the interference conditions. Such a layer is formed using a centrifuge or by plunging the surface in the solution of volatile solvent. The NLC heating to a temperature of transition into the isotropic phase makes the film more uniform in thickness. The thickness can be measured directly by special optical profilometer. The period between putting the NLC layer on the surface and its reorientation depends on many factors and may range from several fractions of a second to some hours. Thus, if a thin layer of the homogeneously oriented NLC is applied on the surface under investigation, the structure defects or the residual traces of dynamic deformation can be observed through a polarizing microscope as different color surface regions against the background. The visualizing efficiency of the NLC layer can be readily examined by removing the polarizing film.

The NLC layer deposition on the surface and removal by solvents (alcohol, acetone, etc.) did not violate the surface conditions providing the non-destruction of the object tested. The wetting is important and necessary condition for this. Most MBBA and MBBA:EBBA films were used as the MLC recording media on the samples tested. The application of other NLC such as talans or biphenyls was not so effective.

RESULTS AND DISCUSSION

The traditional methods of metallography analysis based on optical and electron microscopy could not answer two questions:

- does rotation of material really take place during the deformation process as it was theoretically predicted?
- what is the character of dynamic deformation mechanism in the case when the deformed regions are cured after the shock wave passing?

To answer these questions, the NLC technique was used. For the beginning its efficiency was examined by visualizing the grain structure of copper samples before and after dynamic loading. The comparison of grain structure images obtained by etching and the NLC showed their similarity [5]. Most important was the discovered NLC capability of visualizing the traces of dynamic deformations after loading that could not be visualized by etching. A typical example of the rotation cell visualization in copper is shown in Fig.1.
The NLC technique gives also the unique possibility to observe and measure the angles of material rotations about solid matrix. These measurements are valuable for theoretical calculations. The fields of deformations around the rotational cell are visualized in Fig.2. This photograph allows one also to observe the direction of local material rotation. Figure 3 illustrates a quite different translational mode of deformation visualized in another region of the same copper sample. These photographs show only the fragments of deformation modes while the NLC technique permits obtaining the integral topographic picture of complicated deformation fields.

Fig.1 Rotational deformation mode visualized on M2 copper section by the NLC MBBA:EBBA. The angle of material rotation about solid matrix is equal to 90°. 250* magnification.

Fig.2 The fields of deformations around the rotational cell visualized by the NLC. 250* magnification, t = 20°C

This photograph allows one also to observe the direction of local material rotation. Figure 3 illustrates a quite different translational mode of deformation visualized in another region of the same copper sample. These photographs show only the fragments of deformation modes while the NLC technique permits obtaining the integral topographic picture of complicated deformation fields.

Figure 4 illustrates the rotational dipole of deformation modes in a steel sample which were earlier predicted theoretically but never observed before. The visualization of these deformation traces takes the time of fractions of a second, while visualizing of rotational modes in Al sample (Fig.5) takes some hours. The difference of this "exposure" time is the subject of future investigations.

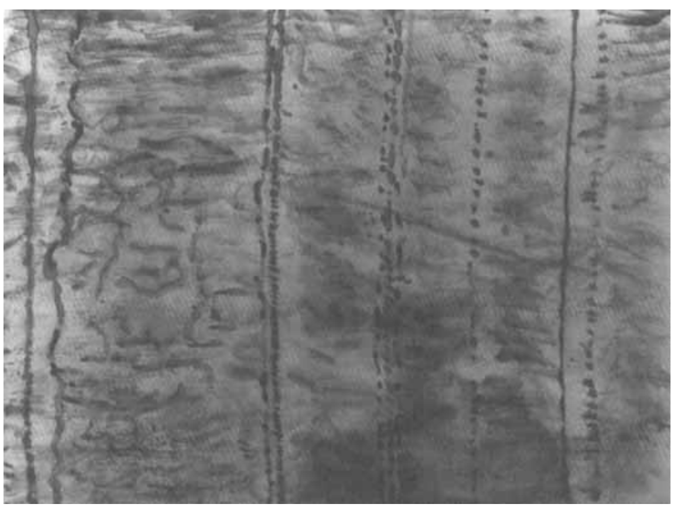

Fig.3 Translational deformation mode in copper visualized by the NLC. 60* magnification, t = 20°C.

Fig.4 Rotational dipole of deformation modes visualized in steel by the NLC. 60* magnification, t = 20°C.

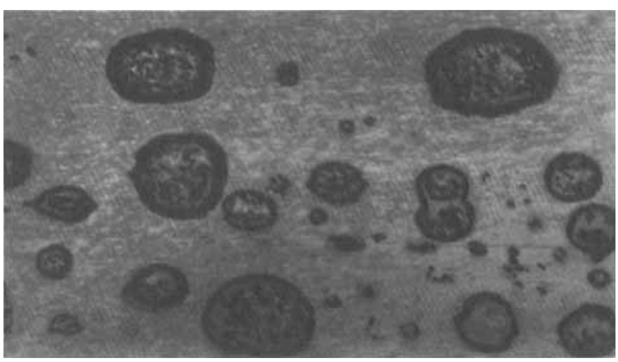

Fig.5 Rotational deformation modes visualized in Al by the NLC. 60* magnification, t = 20°C, T exp. = 24 hours.

CONCLUSION

The possibility of the NLC technique application for visualizing the structure changes and deformation modes in different metals after dynamic loading is confirmed. The unique information concerning visualization of translational and rotational deformation modes in copper, steel and aluminium samples that could not be visualized by any other technique, e.g. etching, is obtained. A strong difference in exposure time for visualizing the structure defects in different metal samples is discovered. The NLC technique can be used in metallography as a new tool of investigations.

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