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MicroStamping for Improved Speckle Patterns to Enable Digital Image Correlation

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Surface strain measurements using image correlation require a pattern to be applied to the surface of the object being measured. Lithography, the most widely used method for repeatable patterning is expensive, requiring dedicated technical staff and significant infrastructure. Lithography is time consuming, often requiring several days for each patterning application, which limits throughput. An innovative method has been developed and tested whereby repeatable patterns for image correlation are applied without dedicated technical staff or special infrastructure and can be completed in a few minutes rather than days. This new method is more amenable to application of patterns to complex surface geometries and larger surface areas. The new micro stamping method allows for higher contrast patterning materials, which improves the accuracy of strain measurements using image correlation.

Accurate surface strain measurements using image correlation are dependent on the application of a high-contrast pattern to the surface of the object being measured. Error in the strain measurement is dependent on the particular pattern applied, and repeatability of the pattern on various surfaces is ideal. Micro texture stamping is a repeatable, high throughput, high-resolution, low cost, parallel patterning method in which a stamp surface pattern is replicated into a material by mechanical contact. Details of the flexible micro textured stamps produced by 1900 Engineering have been published [1-2]. The stamps were fabricated with a 10 μm base-element size. The electron-beam lithography (EBL) process for generating the stamp master took 57 hours to complete a 12.7 mm x 12.7 mm area using an e-beam resist [3]. Without the stamping procedure, EBL would need to be repeated for each subsequent specimen to be patterned; however, after fabricating the stamp, the pattern application took approximately 10 minutes per subsequent specimen.

A diagram for the stamp usage is in Figure 1. The procedure for application of the stamp to create a speckle pattern is: (1) Sonicate the specimen in acetone, then methanol, and dry; (2) With a fine liner, apply MCC primer on clean specimen; (3) Let stand for 15 s and gently apply compressed air from the top; (4) Bake for 3 min at 115 ºC on a hot plate, then remove the specimen. (5) Let the hot plate cool to 60 ºC, (6) Place two specimens side by side (to allow level stamping – the procedure can be applied to one specimen); (7) Apply Shipley 1805 photo resist on one specimen; (8) Wait 20 s; (9) Apply the Shipley in the same specimen; (10) Align the stamp by touching first the dummy specimen and then let the stamp lay down over the specimen to be stamped. (11) Adjust the hot plate for 115 ºC; (12) Place a piece of cook paper over the stamp, to allow a non-stick surface for the weight; (13) Apply weight (~4 psi); (14) Bake for 8 minutes; (15) Remove the weight and the specimen from the hot plate; (16) Carefully peel the stamp off the specimen; (17) Check the gauge section on the microscope for the patterns. The resulting speckle pattern for the 10 μm pattern is shown in Figure 2a.

The accuracy of measured strain results improved as compared to the patterns applied using EBL, because an optically-opaque material was used with the stamping procedure to create a higher-contrast pattern. Results of the surface strain measurement using the stamped pattern for image correlation are shown in Figure 2b for deformation with the microstructure elucidated by electron backscatter diffraction [4]. After usage, the stamps are easily maintained by solvent cleaning to remove any pattern material residue from its surface. It is expected that these stamps can be reused approximately 100 times before losing some of the fine detail in the pattern. The stamps can be created with a wide range of sizes, resolution of features, and patterns. This technique has been used to create patterns with 2 μm base-element size and a fractal-motivated pattern that contains 10 μm and 1 μm features, which allows for strain measurements at multi-scales with the same speckle pattern.

References:
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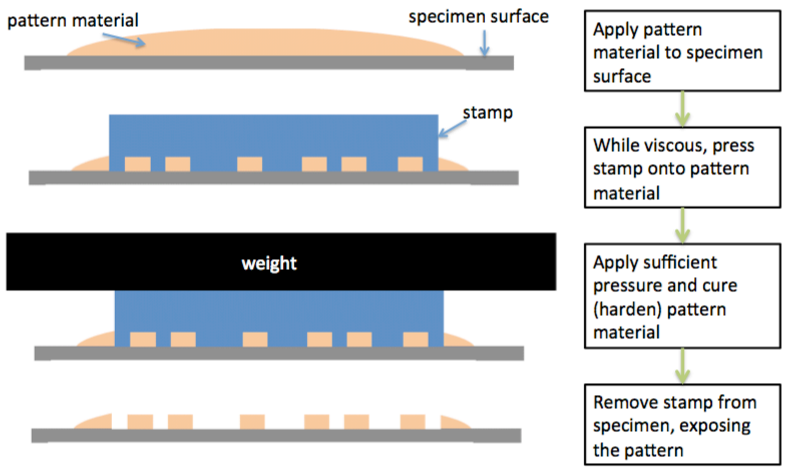

Figure 1. Procedure for applying the microstamp to create the reference speckle pattern.

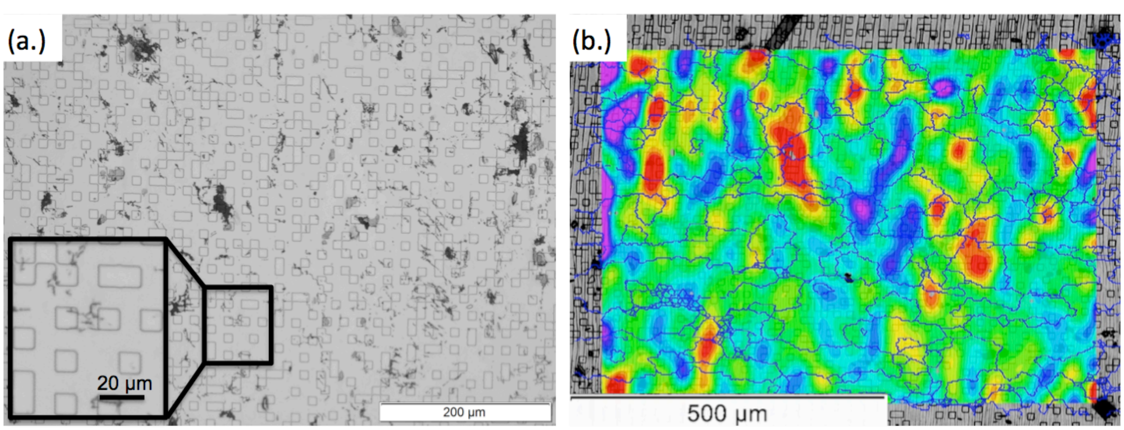

Figure 2. (a) 10 μm speckle pattern produced by the microstamping procedure. (b) 7050-T7451 Al (in the L-T orientation), displaying axial strain after an average strain of 2.45%.