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Patterning Design in Color at the Submicron Scale

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ABSTRACT

We demonstrate the generation of patterns on overhead projector paper (OHP) and glass slides with the dimension at the submicron scale and in various colors. We have used the commercially available permanent marker pen to write lines on the surface of OHPs and glass slides and transferred the patterns of a compact disk (CD) onto the line. Observation under an optical microscope exhibited various color patterns on the film as per the design of the mold. When the mold was pressed twice on the same parent line in perpendicular geometry, cross patterns could be observed.

The rush for creating fast, easy, relatively inexpensive, high-resolution two and three-dimensional patterned structures on solid surfaces has led to the discovery of a number of methods for imprinting patterns in addition to photolithography. Prominent among them are soft lithography[1] and micropen lithography.[2] In soft lithography, different micromolding techniques are used to generate structures at multiple length scales and dimensions using a variety of substrates and imprint materials.[3] Use of the principle of molecular self-assembly has helped improve the resolution of structures further.[4,5] The fundamental objective of all the above methods has been to manufacture structures that are guided by applications such as microreactors, sensors, microelectromechanical systems, and electronic devices at micro- and nanoscales.[6−15] None of the above methods has emphasized the generation of a color pattern that has enormous application potential in information storage, sensors, and the so-called "E-paper"[16,17] for displays. If information could be stored in "true" colors, the processing time for retrieval of information would be shortened considerably. Also, imprinting a pattern on flexible plastic materials would enhance the versatility toward material application. Although ink-jet printing has been used to obtain organic light emitting devices of doped polymers,[18] as we know there have been no reports of making patterns in color at the submicron scale.

Here we introduce a simple, versatile and inexpensive method of generating submicron-scale color patterns on various surfaces. We have used overhead projector (OHP) "permanent marker" pens of various colors to write on OHP paper. We also show that the same pattern could also be imprinted on a glass surface. The molds used were the polycarbonate disk and aluminum foil line patterns in an ordinary compact disc (CD).[19] Generally, a line mark was made with the help of an OHP pen on the paper and then the mold was placed on the mark after about 1 min, finger-pressed before the ink had completely dried. For patterns of various colors we have used pens with various colors of ink. The same procedure was used for patterning on a glass slide.

A CD is typically made of a polycarbonate disk on which patterns are drilled in the form of a single spiral track. The typical width and depth of each line in the spiral track are 0.8 and 0.5 μm, respectively, and separation between two such lines is about 1.6 μm.[20] The diameter of a typical CD is much larger than the separation between two lines and hence under an optical microscope the lines appear parallel with nearly infinite radii of curvatures. The aluminum coating on the polycarbonate membrane also has the structural patterns that appear as parallel lines under an optical microscope.

The polycarbonate disk and the aluminum foil could be separated and be independently used as molds for two-dimensional pattern generation. For our experiments we have used parts of both the aluminum foil and the polycarbonate disk to imprint patterns. Optical micrographs of patterns found in polycarbonate disc and aluminum foil in a CD are shown in Figure 1. It is clear that even after the CD is dismantled, the original lines remain intact and hence could be used as molds. A schematic view of the present method of imprinting patterns on various surfaces is shown in Figure 2.

In Figure 3, we show the ordinary lines (insets) drawn using blue, green, and red permanent marker pens and optical micrographs of each of them after imprints of pattern from molds. The polycarbonate part of the CD was used to make

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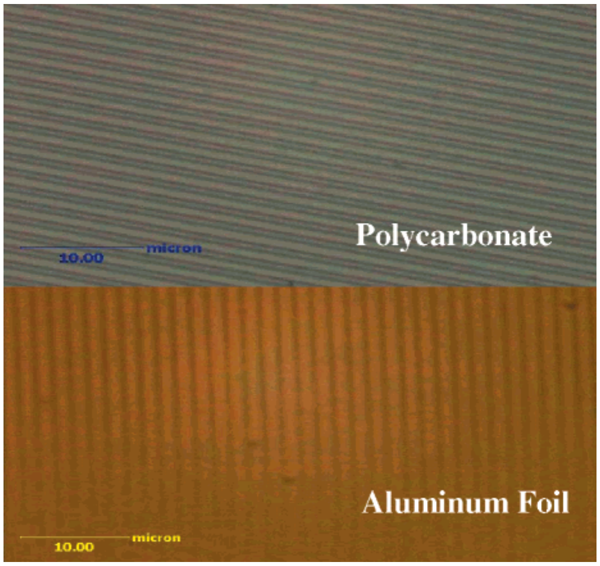

Figure 1. Optical micrographs of the polycarbonate disk and aluminum foil of a CD that were used as mold in the present experiments. The microscope was a Carl Zeiss Axiotech model.

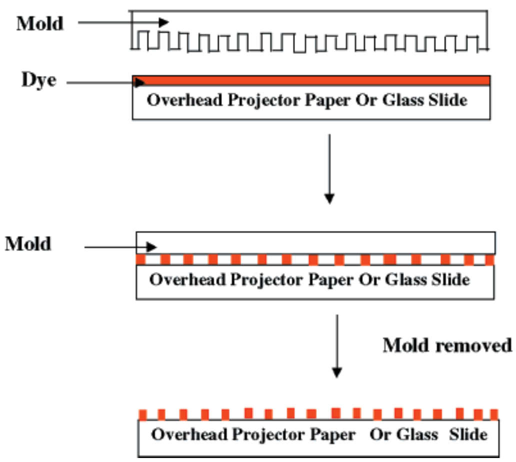

Figure 2. A scheme of the present method of imprinting pattern.

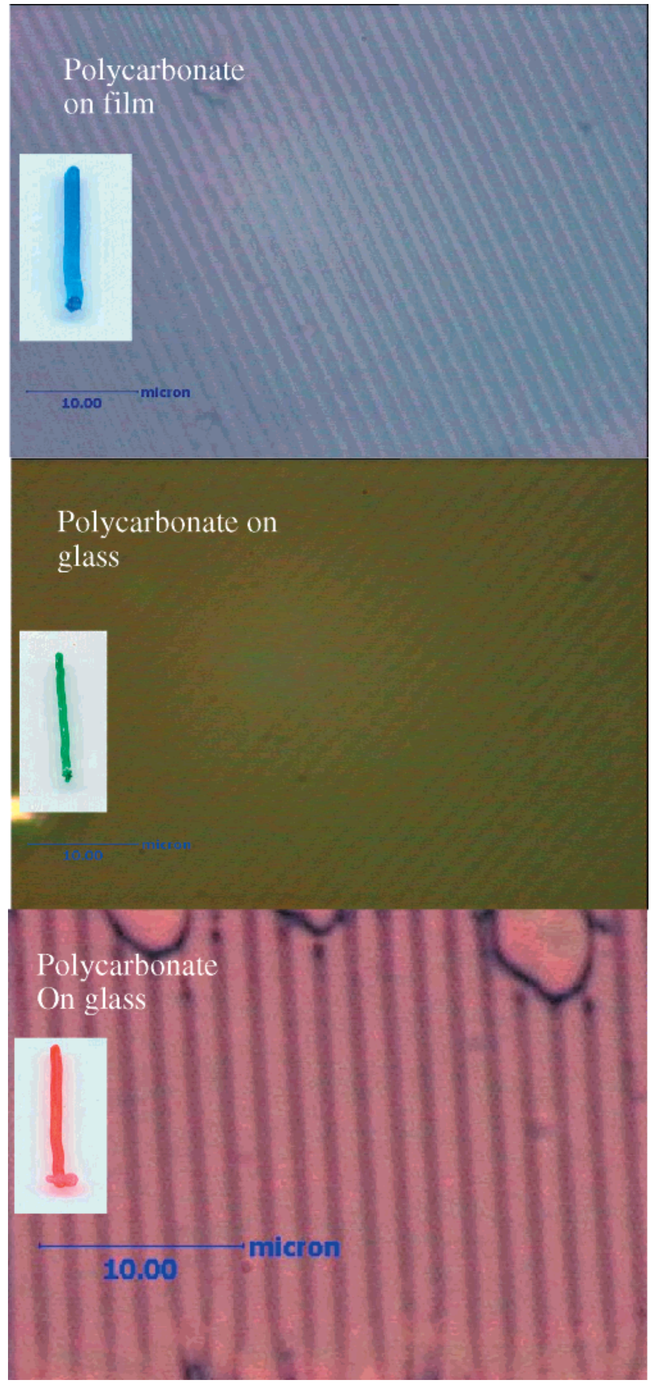

Figure 3. Patterns using polycarbonate molds on OHP film and microscope glass slides. Insets are the pictures of lines, of about 1 mm width, that have the patterns imprinted on them by the molds. The pictures were recorded by an EPSON Perfection 610 scanner.

the imprints. The colors in the micrographs are true colors of the imprints. As clear from the figures, distinct parallel lines of submicron scale could be drawn by just pressing the disk onto the ink. It may be pointed out here that in the cases mentioned above we did not normally observe smearing out of the ink under pressure. On the other hand, if the mold was pressed earlier than the reported time, the smearing of ink could be observed and the lines observed were sparse and indistinct. Similar pictures of imprints of lines from Al foil are shown in Figure 4. Here also distinct lines characteristics of the mold could clearly be observed. In all pictures in Figures 3 and 4 the depth of lines vary from picture to picture as the exact pressure when finger-pressed also varied with higher pressure, generating more distinct lines. There are also defects due to leakage and overflow of inks from the substrate, as could be seen in various pictures.

Shown in Figure 5 are cross-patterns generated on two separate sets of lines on glass by a polycarbonate mold. In each case, at first a single line was drawn by the marker pen on a glass slide. The polycarbonate mold was then pressed onto the line to make parallel microlines as before. The mold was then placed on the line at an angle different from the first position and then finger-pressed. The result was the production of microarrays of ink positioned at angles determined by the relative angles of positioning of the molds. In the above figure, the two sets of arrays were generated by positioning the mold at about 90° and 55° angles, respectively, with respect to initial imprints. The variation of the clarity of impression is a reflection of the variation of pressure exerted while imprinting the design.

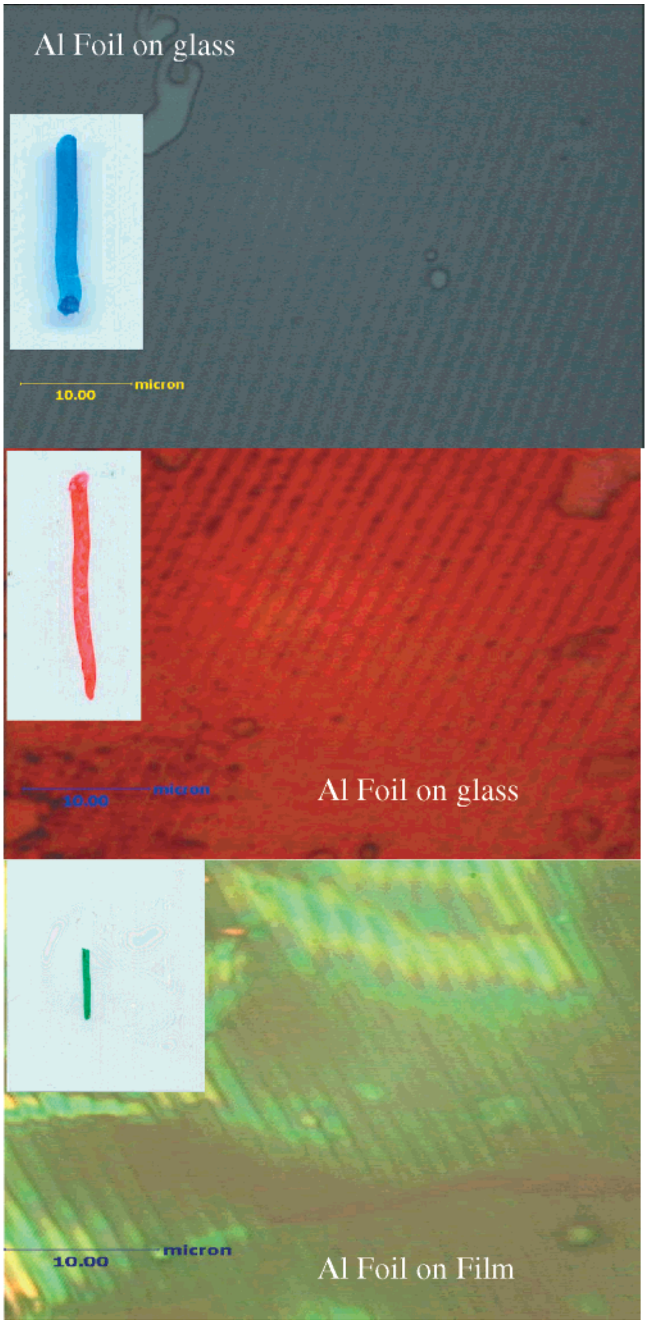

Figure 4. Patterns using Al foil molds on OHP film and microscope glass slides. Insets are the pictures of lines, of about 1 mm width, that have the patterns imprinted on them by the molds.

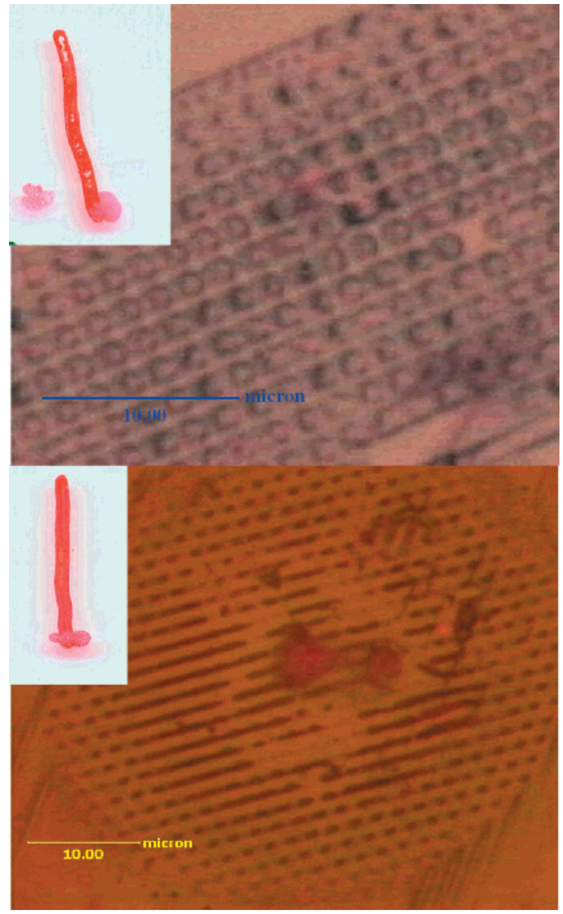

Figure 5. Cross patterns generated by pressing the molds at two different angles one after the other on previously drawn lines. Insets are the macroscopic lines onto which patterns were imprinted.

Here, we have demonstrated a method of imprinting lines and arrays of various colors on glass slides and OHP films. Parallel lines with submicron dimensions could be imprinted on such substrates by using polycarbonate and Al foil molds of a CD. Also, microarrays of ink spots positioned at predetermined angles and spacing determined by the separation of lines in the mold could be generated. Even though the dimensions of the lines and arrays are in and around the micron range, the resolution could further be increased using a mold with lines and patterns of higher resolution. The same principle could be used for imprinting designed arrays of various materials on plastic and glass substrates in accordance with their use. The use of flexible plastic material like OHP paper enhances the possibility of storing designs in foldable substrates.

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