Coated Versus Uncoated—Why the Difference In Density?

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Abstract

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It is well known in the industry that you can get richer colors (higher density) on coated stock than on uncoated stock. One common explanation is that ink does not transfer well to a rough, uncoated stock. A second explanation is that ink soaks into an uncoated stock. The paper fibers, in effect, hide the ink so that some of the pigment is lost. Another common explanation is that there is an incomplete lay-down of ink on uncoated stock. According to this explanation, the uneven topography of the paper fibers results in pinholes where white paper shines through.

A few simple experiments will be presented which show that the main reason that ink on a coated stock is richer than the same ink on uncoated stock has to do with how the surface reflected light is scattered from the two surfaces.

Explanations

When I started in the industry in 1992, I had the good fortune to have ready access to a number of seasoned press operators. These press operators knew the equipment well, and were especially skilled at making adjustments to effect the changes that they needed, fixing the presses when they broke, and doing preventative maintenance to avoid future problems.

To do this, they required a conceptual model of how the press operates, both on a grand scale and on the scale that can be seen through a loupe. But by and large, these folks did not have a great deal of training in physics. Nor did they, in general, have a scientist's mindset. Those who excelled at running the press typically had a "get 'er done" attitude, which is often antithetical to the scientist's mindset of

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"gee whiz, I wonder why that happened", followed by "let's take the press out of commission for a day to test my hypothesis". Taking a web offset press out of commission at an operating cost of $1,000 per hour was not something to be done on a whim.

One simple question I asked was "why can't you achieve a high density on uncoated stock?" I asked this of multiple press operators and got an interesting variety of answers.

1. Ink does not transfer as readily to an uncoated stock. Less ink means less density.
2. Coated stock has more *holdout*. When ink is applied to a coated stock, it sits on the surface, whereas on an uncoated stock, the ink soaks into the space between fibers. In effect, the pigment hides behind the fibers.
3. Because of the roughness of the surface, uncoated stock has pinholes in the ink coverage. These cannot generally be seen by the naked eye, but can be seen under a loupe.

Ink Transfer

The presses in the company I worked for were all offset presses, where the substrate comes in direct contact with the inked blanket cylinder. On these presses, ink transfer was a tangible variable that depended on temperature, tack, and viscosity. It is reasonable to presume that the ink transfer also depends on the surface of the substrate, although I am not aware of any experiments that verify this.

A simple experiment with another print technology can show that, while ink transfer may be part of the explanation, it is not the whole story. An ink jet printer can be told what type of paper it is printing on, and it will adjust the inking accordingly, but if it is not told, then it will spray the same amount of ink on a coated photo stock as on an uncoated office stock. The paper doesn't come in contact with the ink jets. Provided the inking level is not extreme (i.e., dripping off the edges of the sheet), the only place the ink goes is onto the surface of the respective papers.

A standard desktop ink jet printer was used to print on two sheets of paper, one coated and the other uncoated. The In both cases, the printer was told that this was glossy photo stick. We can be assured that within the variability of the printer, the same amount of ink was applied to the two sheets. Figure 1 shows the two samples, with the coated stock on top and the uncoated stock on the bottom. Illumination comes from the top, at 45˚.

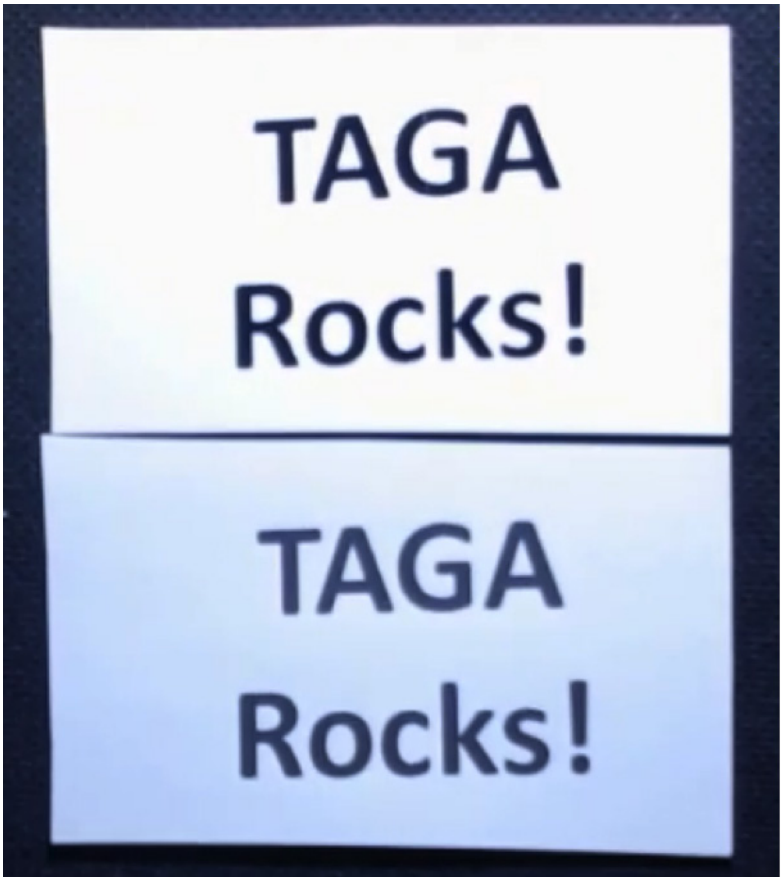

Figure 1 *– Comparison of equal amounts of ink on coated (top) and uncoated (bottom) stocks*

The density of the black ink on uncoated stock is 1.20 D. On the coated stock it has a density of 2.79 D. While it may be true that there is a difference in ink transfer on an offset press, and that this may account for some difference in density, there is obviously something else going on.

Holdout

Is ink on uncoated stock less rich because some of the ink gets lost behind paper fibers? A bit of cellophane tape can show that this cannot be the whole story. Figure 2 shows a black rectangle printed with the same ink jet printer on an uncoated stock. The upper left-hand corner has been covered with a clear cellophane tape. While the uncovered area has a density of about 1.20 D, as before, the area covered by the tape has a density of 1.42 D.

***Figure 2** – The effect of tape on ink on uncoated paper*

The tape obviously did not add any ink to the paper. The tape is not drawing the black ink out from behind the paper fibers. The tape itself is reasonably clear, so it has not, by itself added much in the way of density. And yet, the tape has somehow significantly improved the efficiency of the ink.

The conclusion is similar to that of the "ink transfer" explanation. Holdout cannot explain the results of this experiment.

Pinholes

Are pinholes in the ink layer on uncoated stock the explanation? Figure 3 shows a portion of the printed image under a USB microscope. Figure 4 shows a higher magnification of the same area. This second image is perhaps a slightly higher magnification than one would see through a good loupe.

***Figure 3** – A section of black ink on uncoated stock*

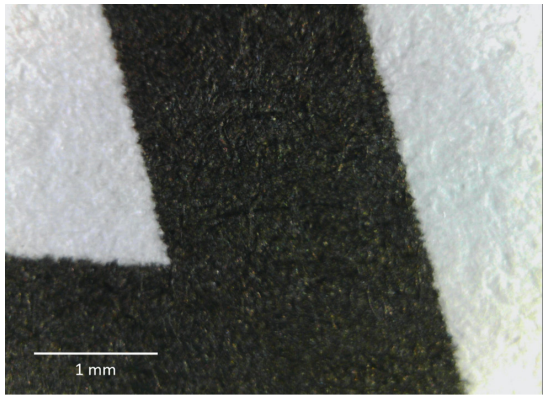

Figure 4 – *Higher magnification of Figure 3*

Figure 4 seems to confirm the pinhole explanation. White dots can be seen in the image, with a rich black in between. As a back-of-the-napkin plausibility test, if the white dots covered only 5% of the area, they could reduce the density from 2.0 D to 1.2 D. Without doing much analysis, this seems plausible.

Figure 5 tells a slightly different story. The image in Figure 4 was illuminated with a flashlight to the right of the image, angled at approximately 45˚. A portion of this image is duplicated on the right side of the montage in Figure 5. The other three images in the montage were collected without moving the sample or the microscope, but moving the flashlight so that it pointed from the top of the sample, from the left of the sample, and from the bottom of the sample.

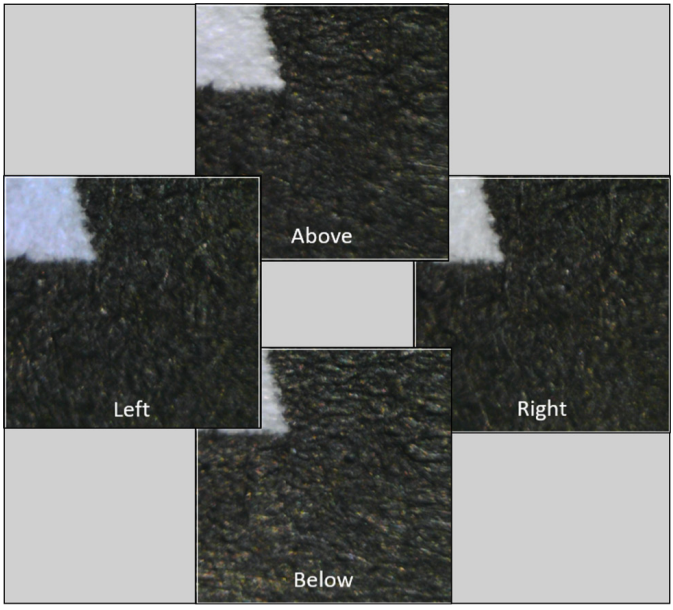

Figure 5 – *The same area, illuminated from four different directions*

Those white dots are not pinholes – that is, small areas where the ink did not transfer. Pinholes do not move as a result of the direction of illumination. Those white dots are glints – areas where the surface of the black ink on the paper fibers is oriented such that a portion of the incoming light is reflected directly up to the camera in the microscope.

Figure 6 illustrates the microscopic difference between a glossy, semi-glossy, and matte surface. The total amount of surface reflected light is nearly the same. For printing ink, about 5% of the incident light is reflected specularly regardless of the surface finish. The difference lies in the range of angles of the reflected light..

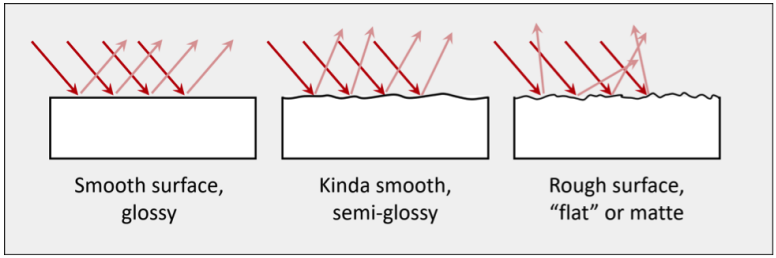

***Figure 6** – Difference in specular reflection due to surface structure*

Ironically, we refer to a matte paint as *flat* because the surface is not flat. Glossy paint is truly flat.

Specular reflection and gloss

When light hits a surface, such as ink on paper, it may take a variety of paths. As print geeks, we are accustomed to considering the light that 1) enters the ink layer, 2) is selectively absorbed by the ink according to the color of the ink, 3) reflects from the paper, 4) passes once again through the ink layer for more selective absorption, and 4) which passes out to the air for us to see. This simple model neglects the small amount of light that is specularly reflected, that is, which reflects at the surface.

Figure 7 illustrates how ignoring the effect of specular light happens not just at the conscious and scientific level. In this image, the flashlight in the upper right-hand corner is seen shining on the two prints. The upper paper is the coated stock and the lower is the uncoated.

Figure 7 – *Light reflecting at or near the specular angle*

In this image, the black ink of the T, the A, and part of the R on the coated stock cannot be seen, since the level of specular light washed it out. When we encounter this in the real world, we tilt the glossy magazine or reposition our head so as to avoid this specular light. We are conditioned not to consider this specular light as being part of the color of the object.

We have demonstrated that for an uncoated stock, we are seeing the specular light for all the letters, regardless of the angles. Due to the unevenness of the surface at the microscopic level, the specular reflection occurs at such small areas of the printed surface that the eye is not capable of resolving the glint. Hence the brain has no way to discount the specular light.

We see ink on uncoated stock as being a different color, a lighter color, than the same ink on a coated stock. We do this not because the total reflected light is substantially different, but because our eye/brain is incapable of ignoring the specular light reflected from a uncoated stock.

Addendum

The careful reader may have noticed that the narrative did not mention the "Magic Tape" in the lower right corner of Figure 2. This tape has a less dramatic effect, in part because the tape is milkier in color, that is, slightly opaque. The larger effect, however, is that the tape does not have as glossy of a surface as the cellophane tape.