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Permanence Testing of 3D-Printed Objects Subjected to Fade Testing with Outdoor Daylight and with High-Intensity Fluorescent Illumination and Evaluated with a Multispectral Camera and Image Analysis System

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In the past two decades, 3D printing using mainly polylactic acid (PLA) and other plastics has become widely used for modeling, prototyping, and manufacturing, for both professional and amateur applications. Statistics website <www.statista.com> predicts that the global 3D printing market will grow from USD $12 billion in 2018 to $20 billion in 2021. [1] Like 2D-printed signs, prints, and photos, 3D-printed objects, if placed outdoors or in windows, will be exposed to visible light and UV radiation that can cause colourant fading, surface chalking, crazing, and other degradation (including a loss of brightness in the case of fluorescing colors). Very little work has been done on testing of fade and ozone resistance, and long-term dark storage stability of 3D-printed materials.

Figure 1. Photo of the Ryerson-Wilhelm Imaging Research 3D-printed color test target showing versions with 1-cm cubes (top) and 1×1×0.5-cm square tiles (bottom). The color cubes or flat, square tiles can be 3D-printed and exposed to high-intensity indoor illumination, placed in outdoor daylight weathering tests, subjected to ozone resistance tests, or long-term (Arrhenius) dark stability tests. During the course of the tests, the samples are measured spectrophotometrically with a multispectral camera and image analysis software is used to quantify fading, color balance shifts, and other degradation.

To develop a protocol for permanence testing of 3D objects, the authors first developed a 3D-printable target inspired by the well-known Macbeth ColorChecker. The target includes a holder with 6 columns and 4 rows of indentations into which 1×1-cm 3D-printed cubes or flat, square tiles ("chicklets") can be placed. Once in the holder, the 3D-printed materials can be subjected to fade testing. The design also includes a clear lid with 0.5×0.5-cm holes that keeps the test blocks in place during transport. The 3D print files for the target will be available on the Wilhelm Imaging Research and Ryerson Print Media Research Center websites. A similar, 2D customizable target is available from Image Science Associates. [2]

Fade-resistance testing of samples in the 3D color target was conducted under accelerated fluorescent illumination and in outdoor daylight. After being exposed to 25 klux fluorescent light for 24-hour, 1-week, and 1-month, intervals, the samples were measured with a Megavision EV Multispectral camera and delta-E color difference values were calculated. [3]

As an example of results obtained, Table 1 compares the delta-E color difference values of eight color rectangles after exposure to fluorescent illumination and outdoor sunlight for 24 hours.

Table 1. Results of 24-hour light fade testing of 3D-printed color target exposed to high-intensity accelerated fluorescent light and to outdoor sunlight.

patch	color	ΔE fluor	ΔE sun
A0	pink	0.465914	0.64737
A1	orange	2.000361	0.900647
A2	blue	0.388649	4.489793
A3	red	0.511821	0.751219
A4	cyan	0.478265	0.511948
A5	black	0.898337	1.14111
A6	yellow	0.757147	0.416372
A7	white	0.351361	0.446425

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3D printing, permanence testing, fade resistance

Biographies

Richard Adams is an Associate Professor in Ryerson's School of Graphic Communications Management, where he teaches document design, web design, and color management. After completing his Ph.D. at Cornell University and working on scientific publications, he earned a Master of Science degree in Printing Technology at Rochester Institute of Technology. He has taught at several universities and was a research scientist at the Graphic Arts Technical Foundation (now the Printing Industries of America), where he worked on press test forms and their measurement with spectrophotometry.

Henry Wilhelm is Director of Research at Wilhelm Imaging Research, Inc. in Grinnell, Iowa, USA. Wilhelm has authored or co-authored more than 30 technical papers presented at conferences sponsored by the Society for Imaging Science and Technology (IS&T), the Imaging Society of Japan (ISJ), and the American Institute for Conservation (AIC) in the United States, Europe, Japan, and other countries. He was one of the founding members of American National Standards Institute

(ANSI) Committee IT-3, established in 1978. The Committee is now known as ISO Working Group 5/ Task Group 3 (a part of ISO Technical Committee 42). Working together with Yoshihiko Shibahara of Fuji Photo Film Ltd. In Japan, Wilhelm served as Co-Project leader of the "Indoor Light Stability Test Methods Technical Subcommittee" of ISO WG-5/TG-3. ISO International Standard 18937 – Imaging Materials – Photographic reflection prints – Methods for measuring indoor light stability (58 pages) was published in January 2014.

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