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Imaging materials — Scratch resistance of photographic prints —

Part 1: General test method

Matériaux pour l'image — Résistance à la rayure des épreuves photographiques —
Partie 1: Méthode d'essai générale

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 42, *Photography*.

A list of all parts in the ISO 18951 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is one of a series ISO 189xx relating to permanence and durability of image prints, which is the resistance to mechanical, chemical and/or environmental stresses in conditions of use.

The permanence of the image under environmental stresses is tested by each stress factor individually: light (ISO 18937[8]), heat (ISO 18936[7]), ozone (ISO 18941[9]), and humidity (ISO 18946[10]). These stress factors are given by the ambient conditions, over which the user often has limited control. The exposure to mechanical and physical stress may often be controlled by the user, unless intense handling is integral to intended use. Tests for rubbing of prints resulting in abrasion or smearing of the image are handled in ISO 18947 (all parts)[11], scratch resistance is addressed in ISO 18922[5] (for film) and durability tests to simulate accidental exposure to water are described ISO 18935[6].

Photographic prints are also susceptible to scratching when handled during their intended use. This problem is particularly evident with digital prints, which may have colorants on the surface without protection from physical damage. The test methods in this document for evaluating the scratch resistance of photographic prints provides another means of characterizing the physical durability of photographic prints.

Scratching tends to occur in a specific location at a single point of contact, as opposed to abrasion which affect larger areas of the print material. And it might occur accidentally or repeatedly by handling of the print.

This document provides standardized requirements to evaluate the scratch resistance of image prints in their various formats. As a test method for scratching, pencil hardness is well-known. However, the pencil test is proved difficult to carry out in a reproducible manner with photographic prints.

In the same point of view, test devices for scratch test show wide variety of the test conditions and parameters. Therefore, the test method and test conditions should be carefully determined taking into account the mechanical stresses that are expected during the use of the printed matter, and also consideration of print material.

This document describes the general guidelines of the scratch test and general considerations for the test device and parameter setting, test sample preparation, general test procedure, assessment of results, reporting requirements and examples of test equipment. The scratch test in this document can be used not only by a printer manufacturer, but also by a system integrator in a printing house to optimize the selection of ink set and substrate combination which will offer strong scratch resistance of the image, or it can be used as an agreeable QC test method between a photo print supplier and their customers, or it could be used by an ink developer to select desirable ingredients that will yield inks with strong scratch resistance, etc. ISO 18951-2[12] describes a specific test method with detailed test parameter selection, test procedure and results assessment for a sclerometer.

Imaging materials — Scratch resistance of photographic prints —

Part 1:
General test method

1 Scope

This document specifies test method, test target, and reporting requirements to determine the scratch resistance of prints with photographic images. Photographic images can be produced by a wide range of printing technologies, including silver halide, electrophotography, inkjet, dye diffusion thermal transfer, commonly known as dye sublimation, and dye transfer processes. This document is applicable to prints with paper substrate and other type of substrates including prints on plastic, glass, metal and other materials. This document is applicable to photographic prints that have no protection as well as photographic prints that are protected by a coating or lamination.

It is not the purpose of this document to define limits of acceptability or failure. They would be determined by the user and the intended application.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 18913, *Imaging materials — Permanence — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 18913 and the following apply.

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
nano scratch
scratch with a testing device using a stylus, which diameter is smaller than 10 µm

Note 1 to entry: An example is a spherical stylus with diameter 2 µm providing a contact area with a diameter of~500 nm.

3.2
micro scratch
scratch with a testing device using a stylus, which diameter is equal or larger than 10 µm and smaller than 0,5 mm

Note 1 to entry: An example is a spherical stylus with diameter 50 µm providing a contact area with a diameter of ~12 µm

3.3
macro scratch
scratch with a testing device using a stylus, which diameter is equal or larger than 0,5 mm

Note 1 to entry: An example is a spherical stylus with diameter 4 mm providing a contact area with a diameter of ~1 mm or less.

3.4
cohesive failure
breaking that occur inside the boundary between the uppermost layer and the layer underneath or within the uppermost layer, caused when the local stress level introduced by the stylus movement exceeds the yield point of the layers

Note 1 to entry: Cohesive failure is observed as fracture, cracking (forward and rearward), buckling, and flaking on the print surface.

3.5
buckling
deformation of a layer by compression and/or shear upon scratching manifesting itself as local variations of the cross-section of the layer

Note 1 to entry: Analogous observations are bowing of a column of material under compression or wrinkling of a plate under shear

3.6
flaking
cracking and chipping of a layer along the scratch line forming small pieces that flake off

3.7
plastic deformation
permanent distortion that occurs when a material is subjected to tensile, compressive, bending, or torsion stresses that exceed its yield strength and cause it to elongate, compress, buckle, bend, or twist

3.8
adhesive failure
separation between the base material and the coating layers or between different coating layers

4 Principle

4.1 General scratching test method

Typically, scratch resistance is a desirable property of prints and substrates. The degree to which it is required depends on the intended applications of the photographic print. Scratch resistance depends on two main factors, namely the properties of the print and the parameters of the scratching. The scratch test for the print is applied using a stylus which moves relative to the print with a specific force. The vertical load on the stylus tends to cause a surface indentation. During a relative movement of stylus and test surface, compressive/tensile/shear stresses are introduced due to friction. And the stresses tend to result into deformation of the printed layers.

Damage level of the deformation is classified into four levels. The details of the damage levels (level 0 to level 3) are described in 8.2.

The critical load, F_c denotes the minimum load that just causes the specific damage assigned for each level, i.e. $F_{c,1}$, $F_{c,2}$ and $F_{c,3}$ for damage levels 1, 2 and 3, as mentioned before, respectively. The measurement of a critical load is highly dependent on the performance of the equipment. However, "critical load" is useful to compare the test results quantitatively as far as the same kind of the equipment is used.

NOTE 1 The critical load can be determined by constant load method (see 7.3) with stepwise change of load or variable load method (see 7.4)

NOTE 2 L_c is also used as a symbol of the critical load instead of F_c.

4.2 Properties of print

The type of damage varies widely depending on physical properties of the prints. For example, physical properties of the print surface (coefficient of friction, smoothness, strength of the surface layer) can affect the damage types. In addition, properties of the whole print (thickness of the coating layer, coating adhesion strength, inter-layer adhesion strength, elasticity and resistance to deformation of the coating layer, elasticity and resistance to deformation of the substrate) can affect the type of damage.

4.3 Parameters of the scratching

The stress level used in a scratch test greatly depends upon the geometry of the stylus used in the test, the load applied to the stylus and the linear velocity of the stylus. The geometry of the stylus, which can be described by shape and diameter, is one of the important parameters for scratching. The contact area between the stylus and the print will depend on the stylus geometry, the surface properties of the print and the force applied. For example, spherical sapphire stylus of 0,050 mm or 0,075 mm diameter give different results from a spherical stylus with large diameter (e.g. 1 mm diameter tip). For this reason, scratch levels obtained with different stylus geometries shall not be compared.

Choosing stylus diameters that are smaller or comparable to the coating thickness, can provide additional information on the damage introduced by scratching, especially when evaluated with microscopic or topographic methods.

Another factor is the material of the stylus, which can result in a different friction coefficient between the stylus and the print surface. As the typical materials for styli, inorganic materials such as sapphire, ruby, diamond, tungsten carbide, metals (e.g. steel), metal oxide (e.g. aluminium oxide), synthetic resin (e.g. polyacrylate) and some natural materials can be used.

The load applied to the needle and the linear velocity are important parameters also. They should be selected considering the supposed application. On the other hand, these parameters depend on the type of test equipment. The recommended range for the parameters is described in Table 1.

When using similar shape, size, material of stylus and similar load and moving speed, the test results can be compared.

5 Test device

5.1 Test device description

As described above, the scratch test devices are composed as follows:

— Stylus: needle like component;

— Load-generation component;

— Scanning mechanism;

— Flat plane, on which the specimen is fixed;

— Optional monitoring functions to detect the load, depth of stylus.

The test device shall have a flat sample stage, on which the specimen is fixed. The stage shall have a smooth surface in comparison to the print substrate. During the scratching, sample and stylus shall not be moved except the intended movement. Therefore, samples shall be fixed with enough force using clasps, screws, springs or weights. Annex A gives examples of the devices; however, other equipment

with the above-mentioned components can be used. Annex B gives examples of devices not included in this document.

NOTE When a curved surface is tested, the load and the stylus motion is adjusted carefully. Under the condition that the scratching parameters are controlled appropriately, this document can be applied on curved surfaces (e.g. photo mug cup).

5.2 Selection of stylus

Because the scratch test result greatly depends upon the geometry and the material of the stylus used in the test, the stylus shall be selected in accordance with the objective of the test. A good practice to select the test condition and the stylus is to take into account the mechanical stresses that are expected during the use of the prints. For example, if the problem in the market is the scratch with a sharp object, then a sharp stylus should be used. In this test method, typically a stylus with a hemispherical shape shall be used. Other shapes of stylus (such as diamond shape, flat shape, nail-like shape, etc.) may be used when required for the specific use case. The material for the stylus can be selected from the typical types written in 4.3, also considering the usage of the print and equipment of the test. Some of crystalline materials (e.g. sapphire, diamond) are available for relatively small stylus, and synthetic resins are available for larger stylus. However, regarding the hardness of the stylus, inorganic compounds are recommended rather than synthetic resins.

Spherical sapphire styli of 0,050 mm or 0,075 mm diameter are widely used in the field of photographic films as referenced in ISO 18922[5]. When scratching with a sharp and hard material is appropriate for the intended use, this kind of stylus is recommended. In other application context, a relatively larger stylus (e.g. 0,5 mm to 2,0 mm diameter) may be regarded as a typical stylus.

When using a larger stylus (e.g. 3,0 mm to 4,0 mm diameter tip), the types of the damage will vary depending on the material type of the print and also the load used. Sometimes, scratching with a larger tip will cause a plastic deformation, such as a “dent”. It will also cause fracture for relatively brittle materials. Considering the wide variety of materials and use cases, a 0,5 mm diameter stylus is recommended as the starting point for the tip selection.

Choosing a very small stylus that is comparable to or smaller than the coating thickness, can provide additional information on the cohesive damage of the coating layer, which may not be accessible when the stylus diameter is much larger than the coating thickness.

NOTE The actual size of contact area between stylus and print depends on load, elasticity and softness of the substrate. Even with the round stylus (e.g. 4,0 mm diameter), the diameter of contact area is less than 0,5 mm in most cases. The pressure on the print could be calculated from the load and the contact area, however, it is difficult to determine the actual contact area, because it varies depending on the load and the print characteristics.

6 Samples

6.1 General

Samples to be tested may be prints from regular print runs or test prints. Samples may also be prints treated on either side (varnished, laminated, bonded, backed, etc.). Samples shall be of a size appropriate for the test device to be used.

When photo-images are printed on coated substrates, paper direction does not have much influence on the results. The test may be carried out without regard to paper direction in such case. However, two orthogonal directions may be tested when there is a difference between scratching along horizontal direction to vertical direction.

6.2 Preparation

The method of printing and handling of the printed test samples shall be consistent with the anticipated product end use, including the presence of an image overcoat or laminate, if the print will generally be supplied with an overcoat or laminate.

The size of the imaged area in the test sample shall be large enough to sufficiently cover the scratching length required by the test. In order to reduce variability in the observation of scratch marks, solid colour patches are recommended as test prints. For example, C, M, Y, R, G, B, grey, pure black, composite black, white and the non-imaged area (substrate itself) may be used as the colour patches. When investigating the effect of colorant, printed colour patches such as C, M, Y and black are recommended.

Recommended colours for test target are:

— the 100 % patches of the primary colours, typically cyan, magenta, and yellow, which are addressed by sRGB values (255, 255, 0), (255, 0, 255) and (0, 255, 255), respectively;

— black with sRGB values (0, 0, 0) and secondary colours, typically red, green and blue, addressed by sRGB values (0, 0, 255), (0, 255, 0) and (255, 0, 0), respectively;

— the $D_{\min}$ patch as controlled by the sRGB values (255, 255, 255), respectively;

— 100 % patches of any system spot colours, e.g. orange, green, violet.

$D_{\min}$ patch has the optical density corresponding to the maximum transmittance (e.g. film) or reflectance (e.g. paper) that a photographic product can achieve. Usually, it can be achieved either by a non-imaged area (if the substrate is white) or by printing with a white ink. For monochrome imaging systems (e.g. silver halide or true monochrome inks) the requirements for the test target design collapse into one colour patch, in addition to the $D_{\min}$ patch.

NOTE A monochrome print can involve more than one ink. In such case, the patches printed with each of the ink can be tested, instead of CMY patches in a colour print.

An example of the test target design is shown in Figure 1. The patches for the test can be selected by the users. For a colour print, it is recommended to test at least three different colours, for example, three colours from cyan, magenta, yellow and black.

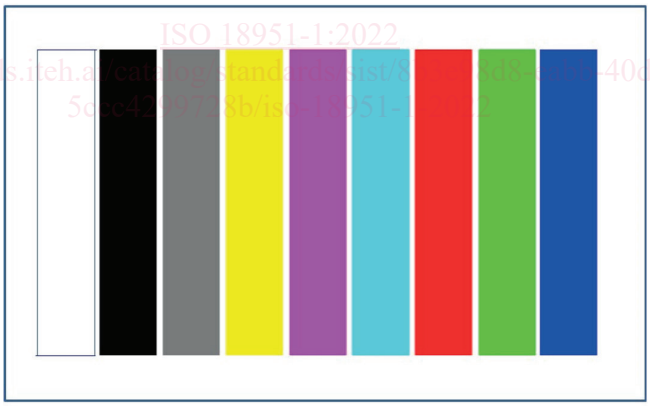

Figure 1 — Example of test target design

6.3 Conditioning

Scratch test shall be conducted after conditioning. Prints of any type that do not require a specific extended period of curing/stabilization/dry-down shall be conditioned for 24 h or longer at (23 ± 2) °C and (50 ± 10) % relative humidity. Aqueous and solvent inkjet prints and prints of any type that require curing/stabilization/dry-down shall be conditioned face up until the process is finished. If the duration of curing is unknown, prints should be conditioned a minimum of 14 days after printing, in an environment with a temperature of (23 ± 2) °C, with a relative humidity of (50 ± 10) % prior to scratch testing.

A shorter conditioning time may be agreed upon when the purpose of the test is to evaluate the scratch resistance at a shorter time after printing.