# Dissecting an Instant

by Ryan Harriman

A high-speed photomacrography technique reveals the beauty that happens in a flash

## Introduction

Most people are familiar with the act of lighting a match. However, few are familiar with the exact appearance of a match as it is being ignited. This document demonstrates the moment of ignition in fascinating detail.

Viewing a familiar object close-up can often times reveal details that make the object look entirely different. Photomacrography reveals new worlds not visible to the naked eye. When combined with high-speed photography, something that typically seems to happen in a flash can be imaged over an extremely short time span, revealing surprising and beautiful new details.

The goal of this document is to "dissect" the brief moment of ignition of a match by combining techniques in photomicrography and high-speed photography. While they are scientific in nature, these photographs display artistry as well.

# History of Matches

Matches are classified into three major categories: strike anywhere matches, book matches, and safety matches. Even such simple tools have a remarkable history. While matches today are much more functional than in the 1600s, they operate on the same basic principles.

**1680**: Robert Boyle, from England, discovered that phosphorus and sulfur ignite instantaneously when friction was applied.

**1830**: French chemist Charles Sauria invented matches using white phosphorus. Though less odorous, one box of matches contained a lethal amount of phosphorus.

**1832**: Meter long "sulphureted peroxide strikables" were invented by John Walker of England, which are a precursor to modern matches.

**1855**: Safety matches were introduced by Carl Lundstrom of Sweden, utilizing red phosphorus.

**1889**: Cigar smoker Joshua Pusey of Pennsylvania invented paper matches, after complaining that wooden matches were too bulky to carry. The idea did not become popular until 1897, when books of paper matches exploded into popularity.

**Present Day**: Though butane lighters have gained popularity, Diamond Match Company produces over 15 billion wood matches annually. Each year, over 500 billion matches are used in the US.

The Chemical Reactions

In order to catch fire, safety matches need only one thing: heat. Heating up the head of a match is achieved two ways: from the friction of being struck across the striking surface of a match box, or being lit by another match or lighter. To understand this better, one must know the chemical composition of a match head and a striking surface.

Typical match head composition:

- ♦ 45-55% potassium chlorate
- ♦ 15-32% powdered glass
- ♦ 9-11% animal hide glue
- ♦ 5-6% diatomaceous earth
- ♦ 3-5% sulfur
- ♦ 2-3% starch
- ♦ Trace amounts of color dyes

Typical striking surface composition:

- ♦ 50% red phosphorus
- ♦ 25% powdered glass
- ♦ 16% animal hide glue or casein
- ♦ 5% calcium carbonate
- ♦ 4% carbon black
- ♦ Trace amounts of color dyes

The powdered glass in both components rubs against each other when the match is struck. This friction produces enough heat to allow for an explosive reaction between the potassium chlorate, sulfur, and red phosphorus. The flame that results from the near-instantaneous chemical reactions then uses the wood of the match as fuel to continue to burn for several seconds. Heat,



light, and smoke are all products of these chemical reactions.

When being lit by a lighter, no friction is involved in the system. However, enough heat is being transferred to the match head to cause an explosive reaction in the match.

Both of methods of igniting a match are visually recorded and analyzed in the following pages of this document.

#### The Photographic Technique The Setup Behind the Photographs

In order to take close-up photographs of matches, one first has to carefully select camera equipment, set up a small studio, and decide on a plan for lighting.

Many combinations of equipment can be used. Here is the specific equipment which I used that I would suggest utilizing:

- ♦ Canon 1D Mark III and/or 1D Mark IV
- ♦ Canon 100mm f/2.8 USM Macro Lens
- ♦ Canon 580EX II flash unit
- Rechargeable AA batteries
- ♦ Sync cord for the flash unit
- ♦ Sturdy tripod
- ♦ Handheld shutter release
- ♦ Laptop and USB cord (for tethering)
- ♦ White paper, aluminum foil, and tape
- ♦ A long fireplace lighter
- ♦ Hundreds of matches
- Modeling clay (to hold matches in place)
- Black construction paper (background)
- A bowl of water (to discard the matches)

Since this process involves working with fire, the first step in setting up a studio is finding a safe location. This must be done in a well-ventilated room, preferably in an area with a concrete floor (such as a basement). The working area should be covered with aluminum foil. This will protect the surface from potentially catching fire. Another benefit of using aluminum foil is that it also acts a reflector in the lighting setup.

The lighting diagram in Fig. 1.1 shows the basic setup for match photography used in



4) Aluminum foil reflector

Fig 1.1: Lighting Diagram

all photographs in this report. Essentially, the match is held in place with some modeling clay. Off to one side of the match is the portable flash unit, set to 1/16 power output to achieve a short flash duration. The flash is diffused simply by a piece of white paper, placed directly in front of the flash unit. The flash is aimed towards the match, and a piece of aluminum foil is placed on the opposite side of the match as a reflector.

I chose to use the Canon 1D Mark III and the 1D Mark IV because these DLSRs are able to shoot in RAW format at 10 frames per second. The choice of DSLR is up to the user, but be aware that the faster the continuous shooting speed of the camera, the better the results. The Canon 580EX flash unit, attached to the camera with a sync cord, was fast enough to stay in sync with the shutter at 10 frames per second.

I ignited the matches either with a long

#### The Photographic Technique The Setup Behind the Photographs

fireplace lighter, shown in Fig. 1.2, or by striking them against the surface of the match box. The camera, pre-focused on the match using manual focus, was triggered by holding down the shutter on the handheld shutter release as the match was being lit. An assistant is helpful for this part, but it is possible to do it by oneself. As soon as the match is about to be lit, it is necessary to start taking as many photographs as possible. This is a short moment to try to capture, and a certain amount of luck is involved. As soon as the match is ignited and then blown out, safely discard it in the bowl of water.

Using a sound or infrared trigger is not practical for this application. Instead, using a camera with a high continuous shooting speed is far more practical.

The cameras I used were typically set to 1/250 sec exposure, f/8, ISO 400. This exposed both for the flame and the fill light from the flash (which was set at 1/16 power).

The cameras were also tethered to a laptop via a USB cord, so that the RAW files could be written directly to a hard drive, rather than a memory card. Even though the RAW files were 10-16 megabytes each, the camera's buffer, as well as USB 2.0 transfer speeds, were still fast enough to sustain a transfer of over 50 images at 10 frames per second without slowing down.

Minor variations of magnification and lighting were used to achieve the images in this document. For example, the photographs of smoke required the flash unit and the



Fig 1.2: Fireplace Lighter Igniting a Match

camera lens to be rotated up a few inches.

For post-processing of the images, very little had to be done. I used Adobe Lightroom 4 to do minor adjustments to exposure, color saturation, and some dust removal. The "Clarity" slider was extremely useful because it made the smoke in many of the photographs ghostly.

I shot over 4,000 photographs throughout the process of capturing all the images in this report. Sorting through the photographs is time-consuming, but it was remarkably entertaining to do. The feeling you get when you capture a "lucky shot" is very gratifying.

#### Dissecting an Instant Striking a Match on a Matchbook Part 1: Friction



Fig 2.1: The match head begins its short and fatal course across the striking surface of the match box. After just a few millimeters, the match already begins releasing smoke and debris.



Fig 2.2: A few centimeters later, the tip of the match head is ignited. Smoke billows out from the ignition site, and the match head bubbles and shoots out flames.



Fig 2.3: The boiling tip of the match head breaks off and is left behind on the match box. Small particles are also elevated into the blue haze.

#### Dissecting an Instant Striking a Match on a Matchbook Part 2: Ignition



Fig 2.4: The size of the flame increases, and more of the match head begins burning. The debris from Fig 2.3 releases particle-laden smoke on its own.



Fig 2.5: The match head has finished its path along the striking surface and continues to bubble and boil as the flame size increases.



Fig 2.6: In the course of just over half a second, the match is fully lit and lifted away from the match box. Smoke, debris, and a large scar are all that remain on the matchbox.

#### Dissecting an Instant Lighting a Match with a Fireplace Lighter







Fig 3.1: The composite images on this page essentially demonstrate the match on the y-axis, and time on the x-axis. Time passes to the right, giving viewers insight on what occurs in the flash of an instant. Here, the match on the left is fresh out of the matchbox. Moving forward in time, the same match is shown a fraction of a second before ignition. When observed very closely, one can see yellow bubbles on the match head as the heat from the fireplace lighter (not shown) draws close.

Fig 3.2: The progression of the match igniting is visually dissected over time. Each image of a match is the exact same match separated by only 1/10th of a second. The dramatic eruption of flames, the boiling of the match head, and the change in colors become distinct through this imaging technique.

Fig 3.3: Here, the match is blown out and begins releasing smoke as it cools. The smoke flows downward due to the air current of blowing out the match from above. Then the warm smoke wisps upwards before fading over time. The thirteen frames in Figures 3.1-3.3 mean that this dissection of time occurred over approximately 1.3 seconds.

#### Dissecting an Instant More Insight from High-Speed Videography

Note: To playback the videos on this page, it is recommended to open this PDF using the free <u>Adobe Reader</u> software. A new version of <u>Adobe Flash Player</u> must be installed on your device as well. Simply click to activate and playback the videos.

While this project initially aimed to be done entirely with still photography, an experiment with high-speed videography resulted in astonishing footage.

Using the Casio Exilim Pro EX-F1, an inexpensive supplemental macro lens, and a set of continuous white LED lights, video of matches being ignited were captured at 300 frames per second at reasonable resolution. While a high definition, high-speed camera such as the Phantom HD camera would produce better results, the consumer level Casio camera produced acceptable results, albeit a low bit-rate and some vignetting due to the supplemental macro lens.

Figures 4.1 and 4.2 demonstrate almost exactly what was analyzed in Figures 2.1-3.2 above, but reproduce it in a different way. Now being captured at 300 frames per second and played back at 1/10th speed, these two videos provide fascinating insight on something not visible to the naked eye.

The videos speak for themselves. With such a high frame rate at capture, they provide enough temporal resolution (measurement with respect to time) to express a profound understanding of the ignition and extinction process of matches.



Fig 4.1: Match Struck on Matchbox Video (Click to image to play)



Fig 4.2: Match Ignited by Fireplace Lighter Video (Click to image to play)

#### Material Health and Safety Surprising Health Concerns Are Exposed



Fig 5.1: Flaming Debris



Fig 5.2: Airborne Particles

High-speed photography reveals that "safety matches" may not always live up to their name. When a safety match is forced across the striking surface of a matchbox, the match head does not just catch on fire, it literally explodes in all directions.

Particles of potassium chlorate, red phosphorus, sulfur, animal hide glue, diatomaceous earth, powdered glass, and more are released into the air. These particles are either then inhaled or land on a surface. Would anyone choose to have any of these chemicals enter their lungs or land on a birthday cake?

While many would consider the flammability of matches to be their only safety concern, these photographs reveal that more safety precautions need to be taken when igniting matches. Based on the amount of smoke released into the air every time a match is lit, one must take care not to inhale any of the smoke to prevent irritation to the lungs. Also, one must avoid striking a match near any food (such as birthday cakes) because the debris from matches travels further than most people would expect during the explosive reaction of ignition.

These images serve as prime examples of photography revealing what cannot be seen by the naked eye. Scientific photography is a powerful tool for a wide variety of applications, and material safety concerns can definitely be revealed with careful photographic documentation.

### Artistry Revealed More Beautiful Images with this Technique







#### Other Possible Projects Smoke Photography Uses Virtually the Same Technique





# Other Possible Projects

Dissecting an Instant: Lighters



#### Works Cited More about Matches and High-Speed Photography

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### About Me

I am a senior pursuing a BS degree in Biomedical Photographic Communications at Rochester Institute of Technology. I am currently studying high magnification photography, ophthalmic photography, and digital publishing. A "gearhead" who loves the latest technology, I enjoy teaching others how to use the newest and greatest photography equipment. I am pursuing a career in the field of ophthalmic photography, specifically diagnostic imaging, as well as hoping to train medical professionals on how to use diagnostic imaging equipment.

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