J Forensic Sci, Oct. 1978, Vol. 23, No. 4

Jan Andrasko,[1] *Ph.D.*

Identification of Burnt Matches by Scanning Electron Microscopy

An arson case recently investigated in our laboratory started the work reported in this paper. A fire broke out in one of the detention cells at the Stockholm police headquarters. The fire was restricted to a plastic board mounted on the wall of a high security cell. During the investigation of the cause of the fire several small fragments of some burnt material were found in one of the small holes in the board. These were sent to the National Laboratory of Forensic Science (NLFS). The fragments were examined in a light microscope. The dimensions, the cross sections, and the fiber structures resembled those of burnt matches. The investigation was continued in the scanning electron microscope (SEM). Morphological observation showed very good agreement between burnt matches and the examined fragments. A small amount of nonfibrous substance was observed at the edge of one of the fragments. With energy dispersive X-ray analysis (Fig. 1*a*) the following elements were detected: chlorine, potassium, silicon, aluminum, sulfur, phosphorus, iron, manganese, chromium, zinc, and magnesium. The same elemental composition was found for the burnt heads of the most common match in Sweden (brown head, Svenska Tändsticks AB). A typical analysis is shown in Fig. 1*b*. Furthermore, the elemental composition of the suspect fragments agreed with that of the wood from burnt matches (Fig. 2). The strong phosphorus signal originates from additives to the matchsticks. The phosphorus signal in Fig. 1*a* stems presumably from the same source.

This arson case induced us to do a more extensive investigation. The possibility of positive identification of burnt matches in the SEM by examining the morphology and by analyzing the elemental composition was tested. Sixteen different makes of matches were examined. Matches with different colors of the head, different cross sections, and different lengths were chosen from the reference collection of our laboratory. Most of the samples had been manufactured in Sweden but some other countries were also represented. Four of the matches were made of paper. The samples were investigated morphologically and the match heads and matchsticks were analyzed. Prior to the examination the matches were burnt and the match heads removed to be analyzed separately. All the analyses were carried out at least twice on the same sample.

Morphological observation of the matches revealed that the fiber structure remains essentially unchanged by burning. In many burnt samples, spherical particles attached to the wood fibers were observed. These particles were found to contain phosphorus and originate presumably from the additives in the matchsticks. An example is shown in Fig. 3.

The results of X-ray analysis of the match heads and the matchsticks are listed in Table 1. The elements found in the match heads are divided into two groups. The first group comprises lighter elements (atomic number ≤ 20), the presence of which seems to be

Received for publication 23 Dec. 1977; accepted for publication 31 Jan. 1978.

[1] Research associate, The National Laboratory of Forensic Science (Statens kriminaltekniska laboratorium), Linköping, Sweden.

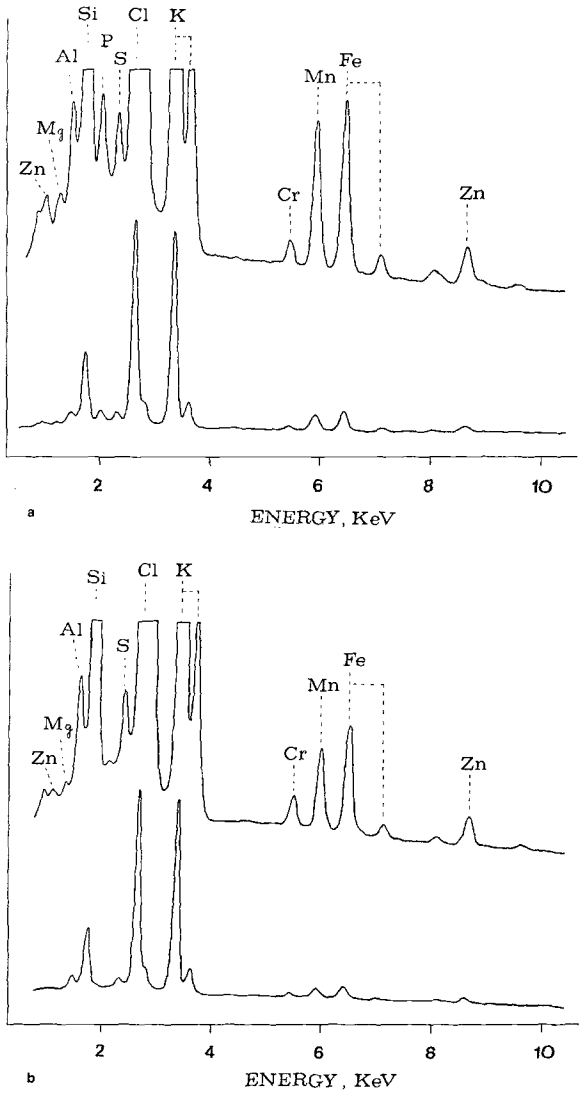

FIG. 1—(a) *X-ray analysis of nonfibrous material (match head?) from a suspect wood fragment. An area of approximately 0.04 by 0.04 mm was analyzed.* (b) *X-ray analysis of a burnt match head. The match had a brown head and was manufactured by Svenska Tändsticks AB. Each spectrum is the result of a 400-s analysis.*

characteristic for all the matches investigated. Magnesium and calcium are also included in this group, although these elements are not always present.[2] The second group lists additional elements detected in match heads. These generally occur in lower concentrations. Some of these elements originate from inorganic pigments.

Table 1 shows that the differences in the elemental composition of the match heads investigated appear predominantly among the elements listed in Group 2. Also in this

[2]The K_α lines for calcium cannot be used for its identification because the strong K_β lines for potassium interfere. The elemental concentrations of calcium listed in Table 1 are therefore based on the intensity of the K_β lines for this element.

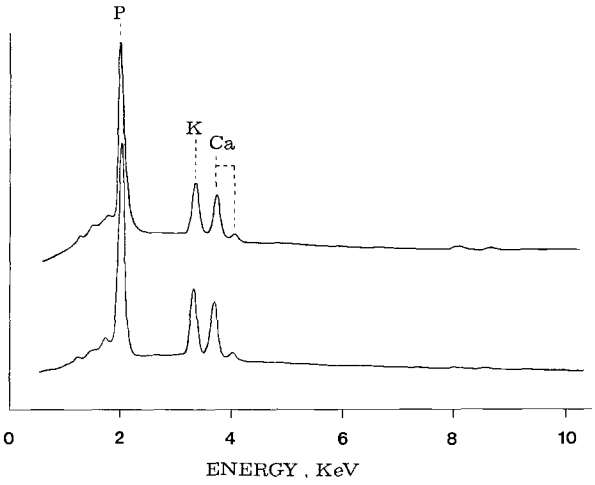

FIG. 2—*X-ray analysis of a suspect wood fragment* (upper spectrum) *and of a burnt matchstick* (lower spectrum).

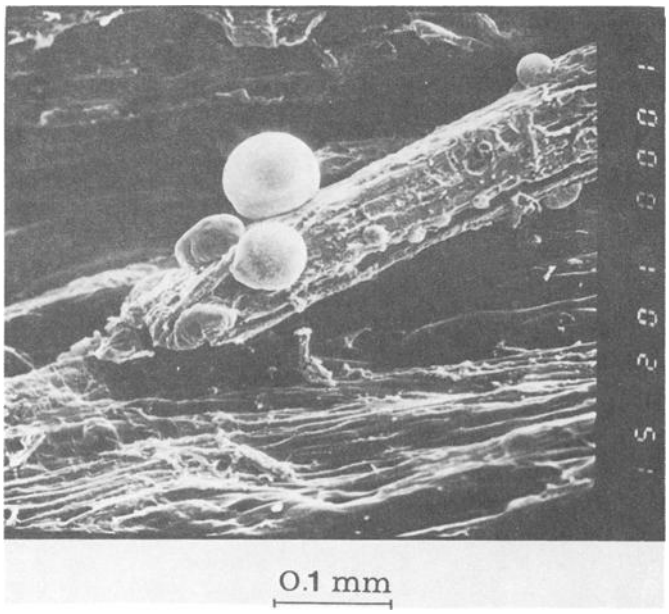

FIG. 3—*An SEM micrograph of a burnt matchstick. The instrument was a JEOL JSM-35 scanning electron microscope and the accelerating voltage 15 kV.*

group are elements typical for matches. Thus, chromium and zinc are found in 15 and 14 of the samples, respectively. However, the relative concentrations of Group 2 elements vary considerably. The relative intensities of X-ray elemental signals are roughly indicated in Table 1.

The last section in Table 1 deals with the analysis of matchsticks. In addition to the elements occurring generally in wood (or paper) the burnt matchsticks were found to contain considerable amounts of phosphorus. The presence of phosphorus is thus also

TABLE 1—*Energy dispersive X-ray analysis of burnt matches.*

Sample	Country of Origin	Match Head			Matchstick		
		Color	Elemental Composition[a]		Material[b]	Cross Section	Elemental Composition[a]
			1	2			
1	Sweden	brown	Cl, K-Si-Al, S	Fe, Mn-Cr, Zn	w	■	P-K, Ca-Mg, Al, Si
2	Sweden	white	Cl, K-Si-Al, S- (Ca)	Ti-Zn- (Fe, Mn)	w	■	P-Ca, K-Na, Mg, Al, Si, Fe
3	Sweden	red	Cl, K-Si-Al, S-P, Mg,Ca	Cr-Fe, Zn	w	■	P-K, Ca-Na-Mg, Al, Si
4	Sweden	blue	Cl, K-Si-S, Al	Zn-Fe-Cr	p	▬	Si, P, Al-Ti-Ca, K, S-Fe[c] Si-Al-Mg-K-P, Fe-S, Ti[d]
5	Sweden	yellow	Cl, K-Si-Al, S-Mg, (Ca)	Cr-Fe	w	▬	P-Ca, K-Na, Mg, Al, Si, Mn, Fe
6	Sweden	red	Cl, K-Si-Al, S, Mg-Ca	Cr-Fe-Zn	w	▬	P-Ca, K-Al, Si, Fe
7	Japan	red	Cl, K, Si-Al, S-Ca	Zn-Ba, Cr, Fe	w	■	P-Ca, K-Na-Mg, Al, Si, Fe
8	Spain	white	K-Cl-Si, P-Al, S, Ca	Zn-Fe- (Cr)	p	●	Al-Si, S, P, Ca-Cl, Fe, Mn
9	Austria	red	Cl, K-S, Si, P- (Al, Ca)	Zn-Cr	w	▬	P-Ca, K-Mg, Al, Si, Fe- (Mn)
10	Switzerland	green-yellow	Cl, K-Si-S- (Ca)	Zn-Cr-Fe	w	▬	P-K, Ca-Mg, Al, Si
11	U.S.A.	blue	Cl, K-Si-S-Mg	Zn-Cr, Fe- (Mn)	p	▬	Si-P-Al-Ca-S, Ti-K, Fe[c] Al-Si-P-Ti-Ca, S-Fe- (K)[d]
12	W. Germany	yellow	Cl, K-Si-S, P-Ca	Zn-Cr, Ba	w	▬	P, K-Ca-Mg, Si, S (Na, Al)
13	Austria	brown	Cl, K-Si, S-Al, Ca	Zn-Fe, Mn-Cr	w	■	P-K, Ca-Mg, Al, Si, Fe
14	U.S.A.	red	Cl, K-Si-S-Ca	Cr, Fe- (Mn)	p	▬	P-Si, Al-Ti, Ca, K, Fe[c] Si, Al-Ti-P, Ca-S, Fe-K[d]
15	Austria	red	Cl, K-Si-S-Al, Ca	Zn-Cr- (Fe)	w	■	P-K, Ca-Mg, Al, Si
16	Czechoslovakia	brown	Cl, K-Si, S- (Al)	Mn-Zn-Cr, Fe	w	■	P-Ca, K-Al, Si, Mn

[a] The elements are listed in decreasing order of signal intensities. Signals of nearly identical intensity are separated by a comma; the dash is used to illustrate a considerable difference in signal intensities. The elements in parentheses were found in concentrations close to the detection limit of the method used.

[b] w = wood; p = paper.

[c] Outer layer.

[d] Inner layer.

characteristic for the matches examined in this study. When various types of matches examined in this study are compared, some differences in elemental composition of the samples may be seen. These differences, especially noticeable in Group 2 elements, are of qualitative or semiquantitative nature, or both. When trying to distinguish between different samples of matches, one must keep in mind the homogeneity of the examined material. In an actual case only traces of the match head may be found. To test the homogeneity of burnt match heads, several samples of the same type of match were analyzed at various magnifications. Some variations in signal intensities were observed when different parts of the same match head were analyzed. Nevertheless, the relative order of elemental concentrations was found to be the same as that already noted in Table 1. A typical result is shown in Fig. 4. It should be noted that Figs. 1*b* and 4 show the elemental analysis of two different samples of brown match heads (Samples 1 and 16).

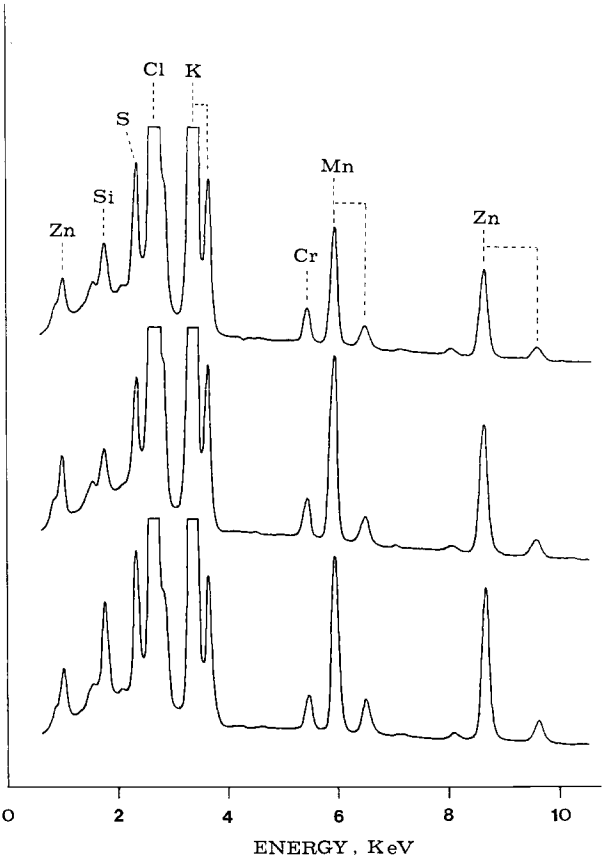

FIG. 4—*X-ray spectra resulting from a 400-s analysis of a burnt match head. The spectra were obtained by analyzing various parts of the same match head at three different magnifications. The analyzed areas were 0.5 by 0.5 mm* (top), *0.05 by 0.05 mm* (center), *and 0.017 by 0.017 mm* (bottom).

A comparative analysis of unburnt and burnt match heads was also performed. With the exception of weaker total signals and a higher concentration of sulfur, unburnt match heads exhibited the same elemental composition as burnt specimens.

The presence of phosphorus in matchsticks, the composition of match heads (that is,

Group 1 elements in Table 1), and the morphology of matchsticks appear to be typical for all the matches investigated. Nevertheless, on the basis of this investigation, it appears that the identification of burnt matches by SEM is possible within certain limits. Matches manufactured in different factories show characteristic elemental compositions. Different types of matches may thus often be distinguished by X-ray analysis. Care must, of course, be taken to ascertain that the samples are sufficiently free from interfering inorganic impurities.

Address requests for reprints or additional information to
Jan Andrasko, Ph.D.
Statens Kriminaltekniska Laboratorium
S-581 01 Linköping, Sweden