# A Mechanistic Model for the Superglue Fuming of Latent Fingerprints\*

**ABSTRACT:** The use of superglue vapors to detect latent fingerprints, known as superglue fuming, is a chemical process that has not been fully described. The role of the fingerprint material in the process, leading to formation of methyl cyanoacrylate polymer at the site of the fingerprint, remains to be established. Films of liquid alkanes respond similarly to actual fingerprints in the fuming experiment. Their responses depended on the hydrocarbon used, viscosity, and film thickness. Aspects such as film thickness appear to be relevant for actual fingerprints as well. A model was proposed in light of these observations. The model compares the process with gas chromatography, in which molecules partition between the gas phase and a stationary phase. Aspects such as accumulation of superglue monomers by partitioning into a thin film (or wax) are consistent with the preferential response of fingerprints on surfaces relative to the background.

KEYWORDS: forensic science, superglue fuming, latent fingerprints, gas chromatography, mechanism, model

Of the many tools used by the forensic community, arguably few have received the attention of the use of superglue (methyl cyanoacrylate) for the fuming of latent prints on nonporous surfaces such as glass and tape (1). In this work, fuming is defined as the exposure of some object to an atmosphere of gas-phase superglue monomer molecules and water vapor, usually in an enclosed environment. The monomers are often generated by gentle heating of liquid superglue (2). The experiment may be performed at atmospheric or subatmospheric pressures (3). The method attracts attention in part because it has an interesting history, serendipitously discovered (4), and is easily demonstrated.

While it is a popular topic, there is a substantial amount of conflicting conjectures on how and why "it works." Specifically, why do gaseous methyl cyanoacrylate molecules accumulate and polymerize on fingerprint deposits, preferentially over the background substrate? There is still much to learn about the process, both in terms of the chemical and physical processes involved.

There is obviously something special about a fingerprint deposit that yields a visualized print by fuming. Many conflicting explanations can be found. Some explanations are vague, suggesting that superglue reacts with the "organic fingerprint deposits" that contain amino acids, fatty acids, and proteins. One reference lists superglue fuming as an "amino acid technique" (5). A number of sources identify amino acids as the components that catalyze polymer formation. There may be a confusion that, as the popular reagent ninhydrin responds to amino acids in fingerprints, other methods do so as well. One reference (6) suggests that superglue fumes develop latent prints "by binding the proteins in the prints." Another reference (7) interprets the need for high (80%) humidity as an indication that chlorides present in the fingerprint "take up water," which then initiates polymerization, that is, that the component responsible for the fuming response of fingerprints is inorganic. There is no clear distinction in most of these discussions of whether there is a chemical reaction that occurs between methyl cyanoacrylate monomers and deposit components, or weaker interactions.

Even the details of what a fingerprint is physically are varied. The thickness has been measured by one laboratory, which finds that it corresponds to essentially a monolayer (8). While some describe fingerprint ridge lines as a continuous film (9), the lines usually appears as a collection of small pools of material upon magnification. An Internet searche on fingerprint dimensions leads to the automobile manufacturer Audi (10). They build engines to the tolerance of a hundredth of a millimeter, sometimes even a thousandth (a micron). They explain that 1 µm corresponds roughly to the thickness of a fingerprint. Fingerprints have been described as a collection of microscopic globules, each varying in composition and size. The globules of material are  $0.05 \,\mu\text{m}$  in diameter or smaller, and are reported to be 600-800 µm in height (11). (While it is useful to have numbers to consider, these might be difficult to imagine. One must ask whether the surface tension of a droplet of "sweat," mostly water, could create a droplet or globule that is thousands of times higher than it is wide.)

Fortunately, many parts of this puzzle, such as the chemical composition of excretions from glands of the skin, have been well defined. There have been numerous attempts to define the chemical composition of fingerprints (12–17). Most are limited in that they report what they can detect with a given method. For example, an analysis of the molecules on the skin's surface by gas chromatography (GC)/mass spectroscopy (MS) yields a rich list of compounds, but will not provide information on salts and large biomolecules. There is considerable variation depending on the source, time of day, diet of the individual, age, as well as the age of the print. After the print is formed, volatile components start to evaporate (17). Some components are unstable and react to form new materials-some, such as fatty acids, can be processed by bacteria on the skin. Three kinds of glands generate excretions on the surface of the skin (11). Eccrine glands generate what is commonly considered perspiration. These are found on the surfaces of the fingers (and elsewhere). Eccrine glands generate fluid to serve as a coolant, which is more than 99% water. It also contains salts, amino acids, sugars, creatinine, and uric acid. Sebaceous glands

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produce a greasy fatty wax called sebum—composed largely of lipids (14-C, 16-C, and 18-C), glycerides, wax esters, squalene, cholesterol, and hydrocarbons. Sebaceous glands, which produce the oily material on skin that is most obviously associated with oily superglue-active prints, are associated with hair follicles, and are found everywhere on the skin except on the palmar and plantar surfaces. Clearly, oils are found on the fingertips. This is due to two processes—migration of materials from where they are formed to other locations on the surface of the skin, and natural activities of humans—touching the hair, the skin, the nose, etc. to transfer oily material to the fingertips. Apocrine glands generate a mixture of iron compounds, lipids, water, vitamins, ascorbic acid, proteins, and carbohydrates.

The polymerization of alkyl cyanoacrylates is also well understood. The polymerization of acrylates is considered to be an anionic polymerization (18), in which an anionic initiator such as OH<sup>-</sup> reacts with a monomer, creating a new, reactive form that can react with subsequent monomers to make a substituted polyethylene-like product, Fig. 1a and b. In the case of alkyl cyanoacrylates, with two electron-withdrawing groups on the same carbon atom, the polymerization mechanism is still technically anionic, but the initiator can be a neutral water molecule (18), as shown in Fig. 1c, and the propagating species is zwitterionic, having both a positive and negative charge. Both linear and branched oligomers can be formed, as resonance structures of the growing polymer chain can result in more than one anionic reactive site. Thus, when superglue monomers and water molecules are present, there is no need to evoke the participation of any other molecule to catalyze polymer formation. Note that the term "fuming" is related to the fact that, when colorless gas-phase alkyl cyanoacrylate molecules interact with gas-phase water molecules,

#### Super Glue Polymerization

based-catalyzed initiation/activation



c. water-catalyzed initiation/activation



FIG. 1—Mechanism for superglue polymerization. If the reaction is base catalyzed, (a) monomers are activated and (b) chain propagation follows. In (c), activation by neutral water yields a zwitterionic species.

they form visible white airborne polymers—"fumes." While the amounts of water necessary to initiate polymerization are naturally present on all surfaces in a typical environment, it should be noted that many other components could contribute. Water and  $OH^-$  are just two examples of nucleophiles that can initiate superglue polymerization (19). Amino acids are nucleophiles as well. It has been reported that even caffeine can be used to initiate polymerization (20).

While much is understood, there are some persisting questions. Consider a print on a glass surface. What feature of the fingerprint leads to preferential polymer formation at its location, without substantial polymer formation on the background surface? What roles do the components of the fingerprint residue play? And, importantly, of what use is a detailed model of the process? That is, what new aspects might be developed based on a better understanding? These questions will be addressed here.

This investigation began as an attempt to determine what components of a fingerprint residue were important in providing a successful fuming response. This led to an expanded evaluation of the response of nonpolar compounds (i.e., hydrocarbons) to the fuming process. Further studies allowed a model to be proposed, which is a familiar one.

## Methods

The superglue fuming experiments were conducted on a small scale. The enclosed container used was either a 400 mL beaker on an electric cup warmer (model 5562, NORPRO, Everett, WA) or an 800 mL beaker on a conventional hotplate. Initially, the beaker, which contained a small metal foil boat and a small beaker of water, is heated, with a watch glass on top. After an initial heating of c. 5 min, to heat all surfaces and establish the elevated humidity, the sample was introduced for fuming and several drops of liquid superglue were added to the foil boat. Typically, a small beaker was added and the glass slide containing samples was then placed on top of this beaker, such that it could remain in a horizontal position. The watch glass is quickly replaced and the sample is monitored as fuming proceeds. In these experiments, the sample was either a fingerprint or other sample on a 1 in.  $\times$  3 in. glass microscope slide (Pearl model 7101).

In some experiments, known amounts of liquid samples were introduced to wells made on the glass slide using tape. The concept is presented in "Results and Discussion." Basically, a hole punch is used to punch holes in the tape, with a hole diameter of 0.6 cm, and the tape is placed on a slide. The sample is introduced into the resulting well using a micropipette. The tape serves to confine the sample into a known area of c. 28 mm<sup>2</sup>. In these experiments,  $1-3 \mu L$  of sample may be introduced into a well for subsequent fuming. One needs to consider the amount of material and the thickness of the tape that is being used to confine the sample. This can be difficult as many kinds of office tape do not carry information on tape thickness. To respond to this, we have successfully used tape-on-tape, making multiple layers for a thicker mask. Also, it may be advantageous to use a thicker tape such as 3M Scotch packing tape. To appreciate what may be appropriate, consider a 1  $\mu$ L amount of liquid. If confined to an area of 28 mm<sup>2</sup>, the resulting film thickness would be c. 0.04 mm (40 µm). Packing tape can be found that is on the order of 3 mil thick (a mil is a thousandth of an inch, 0.08 mm). Scotch Commercial Performance Heavy-Duty Packaging Tape, for example, is sold in a 50 m role, 44 mm wide, and 3.1 mil thick. Thus, when working with microliter amounts, it is feasible to construct a well that will effectively contain the liquid volume using one or more layers of commercially available tape. When the punched tape is applied to the glass slide, it should be firmly pressed into place, to limit liquid moving under the tape. This can be done using a pencil eraser. When constructing such wells, there is always the temptation to press down on the tape using one's fingers—this is less than ideal when superglue fuming follows. Tape was removed before the fumed-slides were scanned, for easier visualization of the films. Observations reported here represent replicate experiments.

The alkane *n*-dodecane was obtained from Fisher Scientific Company (Fairlawn, NJ). Undecane and hexadecane were obtained from Sigma-Aldrich (St. Louis, MO). 2,2,4,4,6,8,8-Heptamethylnonane was obtained from ACROS Organics (Geel, Belgium).

## **Results and Discussion**

This project began in an undergraduate Forensic Chemistry class at The College of New Jersey, CHEM 360. Students learned how to perform traditional superglue fuming, and how to use fuming wands. The class then investigated the chemical complexity of the mixture known as a fingerprint (11), and designed experiments to investigate whether specific components, known to be present, may or may not be responsible for the fuming phenomenon. In these early experiments, a "model print" was made, using a rubber stamp, on a glass slide next to an actual print, to determine whether the model print behaved similarly to a real one under fuming conditions. The experiments were instructive but flawed, because it was difficult to know whether amounts deposited were similar to those encountered in an actual fingerprint, or whether this was even a relevant variable. The fuming response of pure compounds was studied, for inorganic salts, amino acids, fatty acids, and hydrocarbons. Mixtures that are thought to represent fingerprint components such as cooking oil, chicken broth, and motor oil were also studied.

One clear observation from these experiments was that inorganic salts and amino acids alone will not lead to preferential fuming. Amino acids are solids. If a dilute amino acid solution is made, deposited on glass using a rubber stamp, and allowed to dry completely, the deposits do not lead to preferential polymer formation in the fuming experiment. As most consider fingerprint fuming as involving an oily target, solid amino acid crystals would not be expected to be the site for preferential polymer formation, and they are not. The same is true for salts such as NaCl. Many samples showed a fuming response similar to a fingerprint, although selective fuming, in which part of the deposited film responded more efficiently than others, was not uncommon. Thin films of alkanes such as n-decane, CH<sub>3</sub>(CH<sub>2</sub>)<sub>8</sub>CH<sub>3</sub>, responded similarly to an actual fingerprint. As the chain length (and therefore molecular weight) of the alkanes used increase, melting points increase to the point where they are no longer liquids, but solids at room temperature. The largest straight-chain alkane that is a liquid is *n*-hexadecane,  $CH_3(CH_2)_{14}CH_3$ , with the 17-C member of the homologous series, heptadecane, having a melting point of 22°C (21). In preliminary experiments with decane and hexadecane, it appeared that while both would respond, the smaller hydrocarbon always fumed first (i.e., faster). Thus, the observations suggest that, when hydrocarbons are subjected to fuming, fuming rates may be a function of molecular weight (MW). In a separate experiment, considering minor variations such as branching, two 16-C compounds were compared-hexadecane and 2,2,4, 4,6,8,8-heptamethylnonane, (CH<sub>3</sub>)<sub>3</sub>CCH<sub>2</sub>C(CH<sub>3</sub>)<sub>2</sub>CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub> CH<sub>2</sub>C(CH<sub>3</sub>)<sub>3</sub>. Both have an MW of 226 g/mol, but the branched compound appeared to consistently fume faster, suggesting that



FIG. 2—Wells can be made on a glass slide by using a hole punch and tape. In this case, sample A resulted in superglue fuming, exhibiting white polymer formation after exposure to methyl cyanoacrylate monomers and water vapors.

MW may not be a key variable. Based on these preliminary observations, the decision was made to investigate the behavior of alkanes in the superglue fuming experiment in more detail.

A second observation was considered to be relevant. In rubber stamp-deposited films of material on glass, where parts of the "latent print" fumed more extensively than others, it appeared that the rate of fuming was proportional to the amount of material at a particular location—i.e., film thickness.

The decision was made to focus on developing a model—a description of the superglue fuming process that would take into account experimental observations. First, a reproducible experimental protocol had to be established.

A very simple experimental setup was used, shown in Fig. 2. Figure 2a represents tape placed on a glass slide. Uniform holes from a hole punch are made in the tape, creating "wells" with a uniform area. Thus, when different hydrocarbon volumes are micropipetted into the wells, films of different thicknesses can be reproducibly made. The film thickness thus created will be greater than that encountered in an actual fingerprint, but the reproducibility provided allows for experimentation. Multiple wells on a single slide were loaded with hydrocarbon samples and fumed. This allowed for relative responses to be determined—with each well experiencing the same fuming conditions. In a given period of exposure to superglue monomers and water vapor, one may see the slide shown in Fig. 2a become that shown in Fig. 2b; if fuming successfully occurs, in this case for sample A, the white poly-methyl cyanoacrylate polymer appears.

One can conduct multiple experiments. One option is to monitor the target and continue fuming until one target turns white—to determine which responds at the highest rate. A second approach is to use longer observation times, to determine the order in which a series of different samples responds.

# Experiment 1

In this experiment, equal amounts of three straight-chain hydrocarbons, hexadecane, undecane, and dodecane were introduced into the three wells  $(1.0 \,\mu\text{L}$  in each, so film thickness is not a variable). Consider wells 1, 3, and 4 shown in Fig. 3. The undecane sample (well 4) formed the white superglue polymer first, followed by the dodecane (well 3) film. Given sufficient development time, the hexadecane film will result in polymer formation, last. Thus, for straight-chain hydrocarbons, there does appear to be a correlation between fuming rate and molecular weight.



FIG. 3—Comparison of reaction rates for wells 1, 3, and 4 shows that, for equal amounts of 11-C, 12-C, and 16-C straight-chain alkanes, smaller chain lengths result in fuming faster than larger chain lengths. Also, in comparing results for wells 1 and 2, the branched 16-C alkane fumes faster than the linear analog.

The data in Fig. 3 also address the question of whether branching is a variable that needs to be considered. Consider wells 1 and 2, containing 1  $\mu$ L each of two 16-C alkanes. Figure 3*a* shows the sample plate at an intermediate fuming time where the two lower MW alkanes have already fumed. Figure 3*b* shows the same plate after additional exposure. At this point in the experiment, the branched 16-C hydrocarbon has resulted in successful fuming, before the linear 16-C analog, confirming earlier observations. If fuming continues, all four will result in successful fuming.

Apparently, then, the important variable in these experiments involving fuming of liquid hydrocarbons is not alkane MW, because both 16-C compounds have an MW of 226 g/mol. It is not density. If one considers the densities, they increase in the order dodecane (0.749 g/mL), hexadecane (0.773 g/mL), heptamethylnonane (0.793 g/mL), which does not correlate with the order of fuming. It is interesting to note that viscosities (21) do correlate, 1.311 cSt (dodecane), <3.00 (heptamethylnonane), 3.06 (hexadecane), and thus, we suggest that this is a relevant variable.

# **Experiment** 2

Film thickness as a variable must be investigated. If polymer formation occurs on the surface, this will be unimportant. One may assume, in such experiments, that the chemical nature of the film is much more important than the amount that lies under the surface. Figure 4 shows results where 1.0, 2.0, and  $3.0 \,\mu\text{L}$  were added to three wells. The first well to fume was that containing  $1.0 \,\mu\text{L}$ , the thinnest film. Over extended time periods, the others successfully fumed in the order of increasing thickness. Thus, the time required for successful polymer formation does depend on the thickness of the film.

An additional observation is that the polymerization chemistry does not stop when the sample is removed from the fuming chamber. Figure 5a shows three targets containing three different alkanes. Undecane had clearly fumed when the sample was removed; the reaction at the dodecane sample had commenced; no reaction had taken place for the hexadecane spot. Figure 5bshows the same plate after it had been removed from the fuming chamber and had been sitting on the lab bench. The dodecane spot shows more complete polymer formation and the hexadecane spot now exhibits white polymer formation as well. (Fig. 5 also shows

undecane - C11H24



amount in well: 1.0 2.0 3.0 microliters

FIG. 4—Fuming rates depend on film thickness. The thickness of the film for the 1.0  $\mu$ L sample is c. 30  $\mu$ m.

what can happen when tape is not carefully applied—sample can leak out of the well.)

## A Model

Based on these observations and established facts, a mechanism can be suggested for this system—a collection of elementary steps with which kinetic models can be developed, and that are consistent with observations. The following steps are considered to be important in developing an overall model:

Adsorption/Desorption of Reactants onto a Fluid Surface— Both methyl cyanoacrylate monomers, M, and water molecules react to initiate polymer formation. Both begin in the gas phase (g) and collide with all surfaces including the fingerprint film. One option, which each molecule has, is adsorption (ads), steps (1) and (3), and subsequent desorption, steps (2) and (4), without reaction.

$$M(g) \rightarrow M(ads)$$
 (1)

$$M(ads) \to M(g) \tag{2}$$

$$H_2O(g) \rightarrow H_2O(ads)$$
 (3)

$$H_2O(ads) \rightarrow H_2O(g)$$
 (4)

Rates for steps (1) and (3) would depend on the partial pressure of each gaseous component and a quantity referred to as the sticking coefficient for each molecule–surface pair. The sticking coefficient reflects the probability that a molecule on a surface will remain bound (22).

a. b. hexadecane dodecane undecane

FIG. 5—Polymer formation can occur after fuming and removal of the sample from the (monomer+water) atmosphere, as monomers trapped in the film diffuse to the surface and eventually form polymer.

#### Immediately after fuming

Diffusion of Monomers into the Fingerprint Film-

$$M(ads) \to M(soln) \tag{5}$$

Methyl cyanoacrylate monomers will not remain adsorbed onto the surface of the liquid but, in response to a concentration gradient and limited by solubility, will diffuse into the fingerprint solution (soln). The rate of diffusion through a solution is a function of the diffusivity of the molecule in that solution, which should be related to the viscosity of the liquid film.

Formation of Zwitterionic Activated Monomer,  $H_2O-M^{+/-}$ , on the Surface—

$$H_2O(ads) + M(ads) \rightarrow H_2O - M^{+/-}(ads)$$
(6)

$$H_2O(ads) + M(soln) \rightarrow H_2O - M^{+/-}(ads)$$
 (7)

Steps (6) and (7) represent the following scenario: water is essentially insoluble in the hydrocarbon film under study here, so a monomer–water reaction will likely take place on the film surface. The monomer may be adsorbed, close to a water molecule, or a monomer molecule may be supplied from the bulk solution, i.e., diffuse from within the print volume. The monomers accumulate in the liquid over time. The rates of steps (6) and (7) depend on the surface concentration of the water and either the surface or solution diffusion rates of M to an H<sub>2</sub>O(ads) reaction site. Note that, at/in the fingerprint, the monomer molecules M have two choices. They can desorb, reaction [2], or can react and be "trapped" at the site of the fingerprint.

Chain Propagation-

$$\mathrm{H_2O-M_2^{+/-}(ads)+M(ads \, or \, soln) \rightarrow H_2O-M_2^{+/-}} \qquad (8)$$

$$H_2O-M_2^{+/-} + M \rightarrow \rightarrow \sim \rightarrow H_2O-M_n^{+/-} \eqno(9)$$

Just as in steps (6) and (7), subsequent monomers can be supplied to the site of the growing chain from the surface or the bulk. Growing polymers may remain largely on the surface of the film or, as the polymer length increases, they may become increasingly soluble in the fingerprint film and diffuse within. (For a real fingerprint, which has been described as an oil/water emulsion (23), a reaction clearly takes place both at the surface and within.)

Chain Termination—

$$H_2O - M_n^{+/-} \rightarrow H_2O + M_n \tag{10}$$

There could be a variety of chain termination steps, leading to an oligomer that will not continue to react. As an example, step (10) shows simple water loss. Water molecules on the surface can then desorb, step (4).

The key aspect of this model is that, by considering the fingerprint (when working with superglue fuming) as a liquid film in which superglue monomers are soluble, it provides an explanation of the process. With a fingerprint on a glass surface, monomer and water may adsorb/desorb on the glass but not necessarily accumulate. Monomer and water molecules collide with both the glass surface and the print—the number of collisions/sec/area depend only on the partial pressures and is the same for both surfaces. However, monomers can accumulate in the oily film, possibly to the point where the film is saturated in M. This would depend on the volume of the liquid, that is not only film area but also thickness. A thin film would be saturated in monomer more quickly than a thick film of similar area. If the film accumulates monomer that must diffuse back to the surface to react with water, this could explain the observations made here with thick films. If the thick film is exposed to fuming conditions for a short period, there may be no visible response; however, the film was accumulating monomer molecules. If the sample is removed from the developing chamber, water can still populate the surface, due to humidity, and monomer molecules slowly diffuse to the surface where polymer eventually forms. This can only occur if the film serves to accumulate monomers.

In this proposed model, gas-phase molecules are exposed to a thin film. Some partition into the film. This must be an option. The model is essentially that for column chromatography, such as GC (24), with two differences. First, this is a static, not a flowing system. Second, in GC, molecules are adsorbed by the stationary phase, diffuse into it, and then diffuse to the surface to re-enter the gas phase. In this experiment, the desorption and reaction steps are competitive. Reaction leads to chemically trapping of monomers at the fingerprint film location.

All of the considerations such as film thickness, volume ratio, and diffusion coefficient considerations, so useful in the rate theory for GC modeling (25), apply here. Also important, the model explains how polymer formation occurs on a fingerprint preferentially to the nearby exposed substrate surface (such as glass).

## Relevance of Observations

The suspect of a white-collar computer crime is not a touch typist, so he broke into the corporate main frame by typing a stolen password one letter at a time with his left index finger. Could one tell the order in which the keys on his keyboard were struck using superglue fuming? Well, probably not yet, but if one makes multiple, successive latent prints, each will contain less material and thus represent films of decreasing thickness. In Fig. 6 are three sets of prints. For each slide, the prints were made from left to right, so the thickest print was on the left, thinnest on the right. The slides were fumed and the fingerprints corresponding to the thinnest films fume most successfully. Under conditions where the thinnest print fumes to yield a good visualized print, parts of the thickest did not fume. Thus, response does depend on film



thickest -> thinnest

FIG. 6—In these experiments, successive prints are made, left to right, so less material, thinner films, are on the right side of each glass slide. Fuming occurs fastest for the thinnest prints. In the thickest print on each, regions where film may be thickest do not appear to fume.

thickness when working with actual prints. Even within a single print, the influence of film thickness can be seen. If pressure is not uniform across the print when it is formed, the resulting film thickness will not be uniform. Often, edges fume better, where contact varies due to curvature of the finger, so fuming can be more extensive around the edges. This can be clearly seen at the tops of the thickest prints on each slide of Fig. 6.

There are several observations that can be made, for those who use superglue fuming for the detection of latent prints. First, if the sample is being monitored during the fuming experiment and a print becomes visible, this is not necessarily the best point in time to end the experiment. There may be thicker prints present that will appear after additional exposure. There is no one correct exposure time for optimal results. Second, look twice. After fuming and removal of a sample from the fuming chamber, thicker prints (films) may appear later.

# Conclusions

It is not the point of this discussion to suggest that alkanes are the component of a fingerprint responsible for fuming. However, it should be acknowledged that more than 58 different hydrocarbons, including hexanes, heptanes, and hexadecane, have been detected on the surface of the skin (17). Hydrocarbons respond similarly to real prints and that is why they were a useful model for study. Squalane ( $C_{30}H_{50}$ ) and fatty acids such as hexanoic ( $C_6H_{12}O_2$ ) and heptanoic acid ( $C_7H_{14}O_2$ ) have boiling points less than room temperature. Lipids and fatty acids are liquids as well and surely a variety of compounds are responsible for the oily film that behaves as the "stationary phase" in the experiment called superglue fuming.

With a working model, one can consider other aspects of the process. Fuming is not just (monomer+nucleophile  $\rightarrow$  polymer). There are a number of physical and chemical steps, each occurring at unique rates, some of which depend on viscosity, thickness, and all depending on time—which may be an important variable to consider when superglue fuming.

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