

## Building Science Digest 150

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### **Black Stains on Carpets and Ghosting of Framing**

2006-12-21 by Joseph Lstiburek

Abstract:

*This digest offers a detailed explanation of the causes of carpet discoloration, particulate deposits on surfaces and "ghosting" of wood stud members on the interior gypsum board surfaces of exterior walls.*

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We have investigated numerous units over the years that have been experiencing discoloration of carpeting due to particulate accumulation (see Figure 1). In many units we also observe particulate deposits on window blinds, inside of kitchen cabinets and on appliance surfaces (microwave ovens, CD players and refrigerators). Additionally we typically notice "ghosting" of wood stud members on the interior gypsum board surfaces of exterior walls.



Photograph 1: Carpet Dust Marking

The problems are related to four deposition mechanisms: filtration, electrostatic attraction, thermal deposition due to Brownian motion and impaction. These deposition mechanisms cause tiny microscopic airborne particles to:

- "filter out" in carpets;
- "plate out" on charged surfaces due to electrostatic attraction
- "plate out" on cold surfaces due to "Brownian motion"; or
- "plate out" on surfaces due to impaction.

All of these mechanisms require really tiny particles - particles that can become aerosolized or lofted into the air and remain airborne for many minutes or hours. Big particles are not related to the problems observed. Big particles fall out of the air too fast - their movement and distribution is dominated by gravity rather than airflow, electrostatics or molecular movement such as Brownian motion.

The particle sources for the types of really tiny particles that can cause the problems observed are many:

- tobacco smoke
- candle smoke
- fireplace smoke
- pilot light smoke from gas fireplaces
- carpet smoke from carpet fibers pyrolysis on heat exchanger surfaces (when you vacuum, you throw up fibers into the air and these fibers get pulled into your furnace where they can get fried/cooked/burned on the hot surfaces in your home)
- lint smoke from pyrolysis of lint in dryers that don't vent to the exterior, or don't vent well
- incense smoke
- insulation smoke from insulation getting sucked into buildings or ductwork and pyrolyzing on heat exchanger surfaces
- gas smoke from gas water heaters or gas furnaces
- cellulose smoke from paper particles pyrolyzing on baseboard heaters
- just plain old dirt - but really tiny dirt because it has to be able to float up in the air for a long time - typically clay dust from a nearby construction site - clay because usually only clay gives you the right size of particle that can float for a long time
- concrete dust from grinding mechanisms or concrete cutting
- gypsum board dust from sanding and finishing gypsum board

Aside from really tiny dirt, concrete cutting and gypsum sanding most of these sources have something in common - something has to get burned, cooked, fried or pyrolyzed in order to create the size of particles required. There are a few other potential sources of particles that could provide them in the size range necessary. However, we typically dismiss them as not likely for obvious reasons: particles from industrial grinding or cutting operations, fumes from welding and carbon black from copiers or laser printers. Of course it is possible that someone has unusual habits we don't know about or an unusual lifestyle that we don't notice. Just the same we don't typically notice any welding or industrial grinding going on inside the typical unit. We also don't often notice a Kinko's like business in most units. Ongoing renovations to interior gypsum surfaces do happen on occasion.

## Brownian Motion

The oldest known deposition mechanism will be described first - Brownian motion. A long dead English botanist (yes, botanist not physicist), R. Brown, noticed tiny particles behave much like molecules with respect to vibration. Under the kinetic theory of gases, molecular vibrations are directly related to temperature. The higher the temperature the greater the molecular vibration. Brown observed that tiny particles in fluids get jostled or bounced around depending on temperature. The higher the temperature, the greater the jostling or movement of the tiny particles. He believed that the vibration of molecules in the fluid bounced the particles around. He was correct and became famous - hence the term Brownian motion. Okay, so far this is an interesting story, but how does this relate to our problem.

Well, air is a fluid and particles in air get jostled around based on the temperature of the air. When air with all of these bouncing particles brushes against the interior of an exterior wall it gets cooled. Not all of the air gets cooled, only the air right against the interior surface of the exterior wall. We call this layer of air the boundary layer. Now it gets a little complicated. Not all of the air in this boundary layer cools at the same rate. Some spots are colder than others. Where there is higher heat loss such as at a wood framing member, say a 2x4, the air in the boundary layer right at this spot is colder than the air in the boundary layer just inches away. Well, the air doesn't bounce around as much in these cold spots which means the tiny particles in the air at these cold spots also don't bounce around very much. If the particles are not bouncing around very energetically, it is easier for them to get stuck to the surface of the wall. The particles in the air next to the wall tend to "plate out" on colder surfaces. Since every stud is a "thermal bridge" the outlines of the studs can be sometimes seen due to the accumulation of tiny particles at the cold spots. This is often called ghosting and was very common in the old days, before MTV, even before Ozzie and Harriet. It was common back then because we typically had poorly insulated walls (real cold spots) and lots of people that smoked. The smokers supplied the particulates. The tobacco particulates plated out on the cold spots, usually at the studs due to Brownian motion.

Why doesn't this particular phenomenon happen as much today? Two reasons: our houses are better insulated and there are fewer smokers. Fewer people smoke inside and those that do typically accept the fact that smoking not only causes their house to smell but smoking also makes their house dirtier due to the tobacco particles plating out on cold surfaces. We point this out since many units we inspect contain heavy smokers and the problems in those units are usually due to tobacco particulates. Don't smoke inside and your white walls won't go brown, nor will your light colored carpets discolor - same for your blinds. You should accept the consequences when you live in an ashtray.

## **Electrostatic Attraction**

Another well-known deposition mechanism is electrostatic attraction. When tiny particulates become electrically charged they will become attracted to other electrically charged surfaces. The particulates can become charged due to many reasons. Friction and proximity to electrical and magnetic fields are some of the most common. Plastic surfaces and surfaces that contain electrical equipment also become easily charged. The particulate depositions observed on window blinds, inside of kitchen cabinets and on appliance surfaces (microwave ovens, CD players and refrigerators) are due to electrostatic attraction.

One of the recent health fads has been responsible for creating electrically charged particles - a home ionizer. Many individuals purchased ion machines for health reasons. Home ion machines tend to cause dirty walls as the ion machine causes the particles to become charged and plate out on surfaces. The air is clean, but your walls are not.

## **Impaction**

Impaction occurs when moving air carrying tiny particulates flings or throws the particulates against a surface. This typically happens when air moves under a door due to an air pressure difference. As the air rushes under a closed door it has to "bend" under the door. When air in the middle of the room (height-wise) has to go under a door, it moves downward. The particulates in the moving air have their own momentum (as do the air molecules). The air makes the curve and bends under the door, but the particulates don't - they travel in more or less a straight line and end up hitting the carpet directly under the door leaving a dark line.

## Filtration

The last deposition mechanism, and the most common, is the filtering of particulates by carpeting. When air flows through a carpet the carpet acts like a filter and removes particles from the air that passes through it.

Air moves under baseboards in exterior and interior walls due to air pressure differences caused by wind, temperature differences and the operation of heating and air conditioning systems. As the air moves under baseboards, the carpet at these air pathway locations becomes discolored if the air contains particulates.

## The Big Picture

Most of the deposition typically observed is carpet filtration. The carpet filtration issue is one of the most common complaints we now get from homeowners. Why is this now such a big issue? Why didn't we have the problem before? We've had carpets for a long time and the air pressure differences are also not new. So what is different? Simple:

- we have more of the right-sized particulates
- we have lighter colored carpets
- we have consumers with higher expectations

We are not about to argue against light colored carpets or argue against consumers with higher expectations. However, lets talk about the particulates.

We estimate that in the typical home we experience a 100 fold increase in the quantity of indoor microscopic particulates in the less than 10 micron range principally due to candle smoke. Candles, candles, candles are everywhere. There are tall ones, short ones, fat ones, colored ones, ones that smell. There are candles that make you feel good. There are candles that make you romantic. There are candles that are your best friend. You get the message.

In 1989 the sale of candles in the United State was less than \$75 million per year (a guess on my part). Candle sales are now a multi-billion dollar industry (not a guess on my part). For example, Yankee Candle is one of the hottest stocks on the New York exchange.

In one of the units we recently investigated we counted over 30 candles. In another unit one owner refused to believe that a candle could be responsible for the observed damage even as we lit the candle and watched the candle smoke. She gave us the "who are you going to believe, your lying eyes or me" look.

Many units also have problems not related to candle smoke particulates. We've already talked about the smokers. Another not-candle-related particulate problem is the gas fireplace. In these types of units the particulate source is typically a backdrafting pilot light in a gas fireplace. Smoke pencil testing can be used to illustrate the backdrafting.

We believe the problems in most units are not due to construction defects. We believe the problems are due to particulates from candle smoke. The responsibility is with the candle industry for not warning the consumer about the particulate emissions from candles and the potential damage to carpets and other surfaces.

**Joseph Lstiburek**, Ph.D., P.Eng., is a principal of Building Science Corporation in Westford, Massachusetts. He has twenty-five years of experience in design, construction, investigation, and building science research. Joe is an ASHRAE Fellow and an internationally recognized authority on indoor air quality, moisture, and condensation in buildings. More information about Joseph Lstiburek can be found at [www.buildingsciencecorp.com](http://www.buildingsciencecorp.com)

Direct all correspondence to: Joseph Lstiburek, Building Science Corporation, Westford, MA 01886

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