Summary

The object of the study was the problem of greasy, sooty depositions of dust particles which can occur on various surfaces in the room suddenly or over short periods. This is a problem which has been increasing over the last 10 years. The phenomenon is often called *fogging.* In Germany, it is referred to as “sudden black particle deposition in apartments” or, more graphically, as *black flat*.

Climatic change, cold thermal bridges, leaky chimneys and building materials which give off plasticising agents are some of the culprits most often blamed. Following previous studies carried out to identify the cause, a distinction has been made between fogging and other phenomena caused by demonstrable factors such as soot deposition due to defective heating systems or chimneys, and penetration of outside pollutants such as diesel soot and industrial emissions. In addition to this, information has been gathered on the preconditions and accompanying factors. In some cases, the depositions reappear after they have been removed. Since so far no reproducible initiating factors have been found which can explain the phenomenon, there are no effective treatment concepts which will prevent particle deposition from occurring.

As well as other physical conditions relating to construction, it was also suspected that electrostatic forces were a factor in the deposition of particles on surfaces. This assumption was not only supported by deposition patterns, but also primarily by the fact that electrostatic charging processes can suddenly change according to room utilisation, weather conditions and – dependent on these – the rapidly changing indoor microclimate. Thus, electrostatic charging processes were a plausible explanation for the often sudden effect. The subject of this research project is a study of electrostatic charging processes on indoor surfaces in connection with ambient and structural conditions. The aim of the project was to either confirm or eliminate such electrostatic forces as one of the causes of sudden particle deposition.

The assumption of deposition caused by electrostatic forces requires a complex interaction of influences such as air humidity and temperature, intensity of utilisation and air convection, as well as the affected surface structures and materials. Unfortunately, these circumstances could not be simulated or induced in a laboratory. The only option, therefore, was to carry out a field study of potentially affected apartments over a lengthy period during the winter heating period with relatively dry air, high convection and increased dust levels.

During the winter heating periods of 2001/2002 to 2002/2003, we selected affected apartments which might be suitable for the investigation, in co-operation with three housing associations in Berlin. Of these apartments, we selected four where measurements would be taken during the heating periods from 2001 to 2003. They were examined during the first series of measurements from December 2001 to February 2002. Due to the unexpectedly mild weather, we were unable to take any measurements from February 2002 onwards, and had to abandon the tests since it would have been impossible to ask the landlords and housing associations not to repair the damage that year.

The research project was therefore extended, and during the next winter, 2003, four other reported cases in apartments were selected for detailed examination, where the landlords and tenants gave their permission for the observation fields to be installed for a period of roughly three months.

In the eight apartments which were affected and examined as part of the field study, we carried out the following actions and measurements:

- We asked the tenants and landlords to complete a questionnaire.
- We recorded all traceable renovation materials and products. We noted the design of components and recorded the most commonly used surface materials in the affected rooms.
- We set up a preliminary climate measurement lasting 8 to 11 days, depending on the opportunities in each case.
- We measured the wall surface temperature, the relative air humidity on both the wall surface (to ensure the material was not damp) and at a distance of 5 mm as part of the microclimate measurements for areas affected by black particle deposition.
- We made manual measurements to record temperature differences between individual areas of deposition directly on the surface.
- We took one or more swab samples and an air sample of VOC/plasticising agent and evaluated them to see if there was any correspondence between air pollution, the material and product components we researched and substances in the depositions.
- We measured the surface and leakage resistances $\mathbf{R_S}$ and $\mathbf{R_G}$ on affected surfaces with different structures and materials.
- We measured the rate of leakage of the surfaces found to be electrostatically chargeable.
- We installed observation fields in four flats in winter 2003 on selected affected wall surfaces. We fitted discharge fields and observation fields next to each other, attached to the necessary temperature and humidity sensors. The passive, highly insulated and electrostatically chargeable test fields were hung in a convection current (above a radiator). The observation continued through a further cold spell until the end of April 2003.
- We recorded outside climate data for the entire period from December 2002 to April 2003, including the temperature, air humidity and air pressure.

As well as the tests in the field study, we also made additional measurements on surface and leakage resistances and on specific discharge rates:

- Discharge rate of the chargeable observation field after an induced charge.
- Surface and leakage resistance of surfaces with different structures and materials as a control test for the measurements in the apartments.
- Discharge rates on chargeable room surfaces after an induced charge.

We chose the following representative surfaces for the electrostatic measurements in the affected apartments and for the control tests:

Interior wall 1	10 mm fibrous gypsum, water-base paint
Interior wall 2	Brick wall, PII plaster, water-base paint
Interior wall 3	Brick wall, PII plaster, woodchip wallpaper, water-base paint
Interior wall 4	Brick wall, P II plaster, vinyl foam wallpaper or latex coat

Interior wall 5	Brick wall, P II plaster, glued ceramic bath tiles
Exterior wall 1	Brick wall, PII plaster, water-base paint
Exterior wall 2	Brick wall, PII plaster, woodchip wallpaper, water-base paint
Window 1	Painted wooden frame
Window 2	PVC-steel frame
Window 3	Double glazing
Window 4	Single glazing
Floor 1	Pine floorboards, glaze with grain
Floor 2	Chipboard, wood veneer, glaze
Floor 3	Chipboard, melamine

Unfortunately, during the long-term observation phase, no fogging reoccurred in any of the flats which had been affected before and not modified since. We cannot draw any conclusions from this fact alone, as it may be a random result. Accordingly, the observation fields installed for longer periods in the apartments exhibited no changes or results.

The results of the surface measurements in the apartments, as well as the accompanying measurements of the surface and leakage resistance of specific surfaces and of the discharge rates showed that with the exception of insulated, fastened objects made of materials with a high specific resistance (such as many plastics used in curtains or insulated floor coverings) the surfaces normally found in apartments are unable to retain a charge over a sufficiently long period. The resistance measurements showed that especially on walls without insulating wallpaper, the earth discharge resistance, at less than 10^8 to 10^9 Ω, was so low that the surfaces must be classed as non-chargeable. This was confirmed by tests with artificial charging. The following materials were found to be chargeable:

- Window glass
- Window frames
- Wooden surfaces with a melamine resin coat (such as cupboards and furniture)
- Painted wooden surfaces (such as doors and window frames)
- Cotton and synthetic curtains

The discharge rates measured for these surfaces after an artificial surface charge showed that the windows and all the furniture and other wooden surfaces had discharge times of no more than 5 to 10 minutes, and were thus unable to maintain a surface charge for a sufficient period. We considered the necessary period to be at least one or more hours, due to the necessity of the simultaneous occurrence of ionised fine particles in the air in the room and mechanically generated electrostatic surface charges.

The result does not mean that electrostatic forces have no effect on deposition processes. Wherever there are especially insulated conditions – mainly on synthetic curtains, floor coverings and especially near artificially maintained electric fields – deposition of ionised particles can be expected. However, when this effect occurs it is restricted – in a similar way to cold thermal bridges – to appropriately conditioned surfaces, and exacerbates sudden black particle deposition, but does not cause or trigger it, as was the assumption of this study.

During the interior and exterior climate measurement, there were no remarkable features as regards indoor climatic conditions. There were no correlating deviations from humidity and temperature levels which could be considered as common or normal. This is also true for room temperature fluctuations and vertical stratification. With one exception (caused by utilisation) all the recorded data was within the tolerance range of the normal indoor values specified in DIN 4701 and stated as a basis for calculation in DIN 4108.

The long-term measurements of the differences between the surface temperature and the air temperature directly in front of the surface (3-5 mm) also showed no deviation from those which could normally be expected. All the measured data was within the calculated value Δ t for brick walls of that type with normal interior temperatures.

The accompanying manual measurements showed that there was often, but not always, a correlation between the areas of deposition and specific, structurally determined cold thermal bridges on the indoor surfaces, with the exception of all windows. This was also true for depositions at the top of exterior walls. Thus, for example, smooth surfaces on interior doors of neutral temperature are just as susceptible to deposition as window glass.

On the other hand, there appears to be a correlation between the intensity of deposition and the absolute difference in surface temperature on small areas. Differences of 1.5 to 2.5 °K were measured on the depositions we examined. It did not matter whether the temperature was above or below the temperature of the room. This confirmed the assumption that thermophoresis is a factor which affects particle deposition.