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PbS-based Detector for Industrial Fire Prevention – a Hidden Champion

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Summary:
Lead sulfide-based spark detectors have been successfully used for more than four decades to safely detect highly mobile ignition sources in pneumatic transport, protecting countless industrial plants and human lives from fire and explosion incidents. The physics of infrared radiation, targeted field measurements and simulations are used to classify ignition sources in pneumatic transport into four types and to describe their detection reliability with established sensor materials even under high loads.

Keywords: PbS, Lead Sulfide, Fire Prevention, IR Detection, Industrial Application, Spark Detector. Explosion Protection, Ignition Sources, Black Body Radiation, Pneumatic Transport

Challenges in Industrial Fire Prevention

In many industries such as wood processing, food and animal feed production, plastics or metal processing, combustible dusts or bulk materials are generated. During the processing, for example, frictional heat can create potentially dangerous ignition sources. In pneumatic transport, these ignition sources are transported to other production areas and can cause fires or even explosions. Preventive fire protection begins with process design and regular maintenance, which can reduce many of the origins of these ignition sources (Fig. 1).

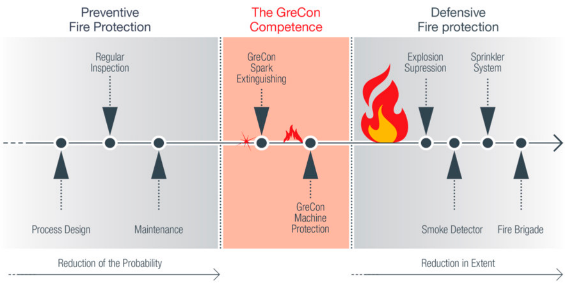

Fig. 1. Sensor-based protection of industrial plants at the edge of preventive to defensive fire protection.

To prevent fires and explosions from still occurring ignition sources and to prevent defensive fire protection from taking effect, these ignition sources must be reliably detected and eliminated. This is where spark extinguishing systems come into play.

Spark Extinguishing Systems

Spark extinguishing systems work in a minimally invasive way, protecting tens of thousands of industrial plants worldwide and the people who work there, almost invisibly and unnoticed. They consist of IR-detectors for the detection of ignition sources. Via an automatic control panel these are connected to an automatic extinguishing system, which eliminates the ignition sources with the aid of water mist a few hundred milliseconds and thus a few meters after detection (Fig. 2).

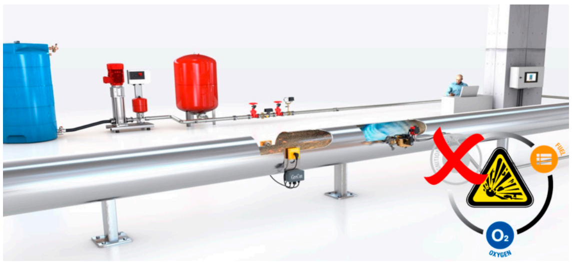

Fig. 2. Safe detection and elimination of highly mobile ignition sources in pneumatic transport by spark extinguishment systems.

Classification of Ignition Sources

Thanks to the studies of the University of Wuppertal, we have gained some important insights into ignition energy and ignition-effective particles in pneumatic transport. There was a long-term research project in the years 2015 to 2018 with the aim of investigating the controlling of ignition sources in pneumatic transport. With a multitude of results [1], [2].

The most important finding is that these so-called highly mobile ignition sources can be classified into four different types with different risk potential. Properties such as size, lifetime (LT), temperature (T) (which can lead to ignition), active burning, from which their risk potential (RP) can be deduced:

(1) Mechanically generated sparks: E: small, T>1200°C, inert, LT<1 sec, RP:3

(2) Burning Particles: E small to medium, T<900°C, active, LT<1 min, RP: 5

(3) Hot Particles: E: high, T >400°C, inert, LT>1 min, RP: 7

(4) Smoldering Nests: E: high, T <350°C, active, LT>5 min, RP: 10

The first type are mechanically generated sparks. These are produced during metal processing or are generated by fans. If, for example, the bearing is damaged.

The second type are the burning particles, which occur during drying processes, for example with direct heating or during mechanical processing.

The third type are hot particles. In other words, impurities that are created in shredding processes. They can also be welding balls, i.e., very hot particles that do not burn itself, but are so hot that they can cause dust deposits to ignite.

The last type are smoldering nests. They are created wherever there is drying or where self-ignition can occur due to environmental influences.

From Ignition Sources to the Best Fitting Sensor Material

Since the invention of the spark extinguishing system in the mid-1970s, two sensor materials have become established. On the one hand, they have the necessary robustness and detectivity and, on the other hand, they operate continuously and reliably under rough industrial conditions between -40°C and 70°C (ambient) or 300°C (process): silicon (Si) and lead sulfide (PbS). The detectors developed from these materials are very often located in potentially explosive atmospheres, which places special demands on the power supply. The smaller the power requirement, the more feasible and affordable, and thus more suitable for practical use, the detector is.

To a first approximation, each particle with a specific temperature emits a continuous spectrum of electromagnetic radiation comparable to blackbody radiation. If enough emitted radiation falls within the spectral sensitivity window of the sensor material, these particles can be reliably detected. Figure 3 shows the typical blackbody spectra of the sun, the visible glowing and the ambient light. The positions of the 4 types of ignition sources, where sufficient detectable radiation is still present, are marked. Additionally, the spectral sensitivity of the two sensor materials is shown.

The less hot the ignition source is, the more important is the reliable detection by PbS-based detectors. Especially smoldering nests, which are "cold" on the outside and very hot inside and whose lifetime is often several minutes, present a very high risk potential.

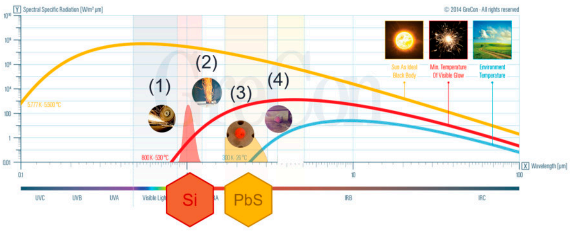

Fig. 3. Spectral specific radiation and spectral sensitivity of spark detecting sensors vs. radiation wavelength for the four different types of ignition sources

Modelling-based predictability of detection reliability

Knowledge of the types of ignition sources in pneumatic transport allows the calculation of models that consider specific application parameters and material properties. Supported by experiments validated in the lab and test field, the detection reliability and its limits can be determined for each ignition source and both sensor materials. This enables the optimal selection and parameterization of the spark detector used. Fig. 4 shows an example of such signal characteristics on Si- and PbS-based detectors. The signal heights are used to select the sensitivity and which detector should preferably be used. The less hot the ignition source, the more the signal height shifts towards PbS-based detectors.

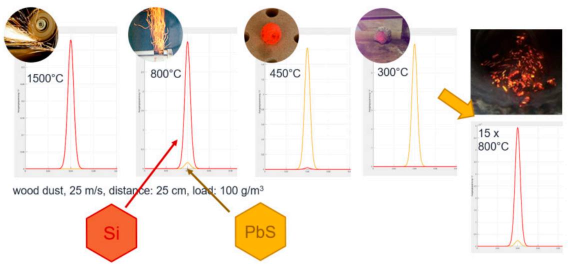

Fig. 4. Example of modeled signal characteristics on Si- und PbS-based detectors for the different types of ignition sources.

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