THERDAM

MODERN PROTECTION AGAINST THERMAL CAMERAS

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DESCRIPTION OF THE CURRENT STATE

Our team of technologists and scientists has successfully integrated innovative materials and created a unique surface structure that provides effective protection against thermal cameras.

During development, we focused on four key criteria:
- Low material weight,
- Effective camouflage in the NWIR, SWIR, MWIR, LWIR, and VIS bands,
- Breathability of the material,
- Ease of implementation into established compositions/solutions.

Modern battlefields, characterized by **significant technological developments** such as thermal cameras and compact drones, along with the evolution of combat tactics, have motivated us to seek solutions that would enhance the protection of human life and minimize the risk of eliminating military materials, weapon systems, and logistical supplies.

The **Therdam** material, characterized by its anti-thermal vision effect, is ideal for camouflaging individuals (integrated into clothing), various solid and natural structures of different sizes and shapes, including:
- warehouses,
- air defense systems,
- command and combat vehicles,
- artillery positions, including radars and other key components,
- camouflaging of trenches, hangars, and tents,
- protection of vehicles and tanks,
- canopies over trenches,
- integration into non-standard size covers

The combined use of Therdam material and traditional camouflage nets **creates an ideal combination for effective camouflage** from detection by the human eye, night vision, and thermal cameras, with controlled heat release. Therdam material can be covered with IR fabric using a connecting system, while creating 3D structures of regular or irregular shapes, achieving the most comprehensive camouflage effect.

One of the additional advantages of Therdam material is its **ability to resist** direct fire exposure, significantly expanding its applications and providing irreplaceable protection for individuals, materials, and military facilities. The material is available in rolls with a width of 1 meter and a length customizable to customer needs, while the use of the joining technique designed by the manufacturer guarantees its unchanged functionality.

The future of advanced materials like Therdam is directed towards integration into carbon-aramid composites, which are expected to serve as structural components (such as gun turrets and other structural parts of vehicles) with combined ballistic and thermal vision protection.

DESCRIPTION OF THE ISSUE

Introduction

Constant technological progress in modern warfare, bringing new technologies and detection devices operating in the NIR, SWIR (night vision), MWIR, LWIR (thermal imaging devices), and radar detection, necessitates the camouflaging of people, objects, equipment, and other important points of interest.

However, there is no ideal and universal solution that would prevent the detection of a camouflaged object by all available technologies in the NWIR, SWIR, MWIR, LWIR, and VIS (visible spectrum) bands. For instance, solutions optimized for camouflage against thermal detectors may paradoxically facilitate detection through night vision or by the naked eye.

To achieve the desired level of camouflage against various types of detectors, compromises must be made, and unconventional, often illogical combinations of materials and their structures must be utilized. Such a composition ultimately allows us to achieve comprehensive protection against detection by the aforementioned types of devices.

Camouflage against night vision

Camouflage against night vision (NWIR, SWIR) is effectively achieved by using fabric that is impregnated on one side with pigments that have suitable reflectivity in the given band. This generally involves metal oxides, which allow for the creation of a color structure, i.e., a camouflage pattern. This approach also ensures camouflage in the visible spectrum (VIS). However, this technology does not provide sufficient effectiveness in the area of protection against radar and thermal vision detection.

Camouflage against thermal cameras

Camouflage against thermal vision detectors is also related to camouflage against radar detectors to some extent. Every object with a temperature above 0 K emits radiation, which a thermal vision detector captures and converts into information about the object's surface temperature. However, the radiation emitted by the camouflaged object is not the only radiation detected by the thermal camera; it also includes radiation reflected from the camouflaged object towards the camera. The accuracy of the thermal vision camera measurement is affected by several factors, such as air humidity, the core temperature of the camera, and the ambient temperature. In the context of thermal vision camera detection, the key for us is the temperature difference of the camouflaged object compared to its surroundings and the identification of a thermal anomaly based on its silhouette. We then evaluate the thermal zones and their intensity. Every body with a temperature above **0 K** emits radiation into its surroundings. **Each material has a specific level of emissivity and reflectivity.**

Generally, shiny metallic materials have very low emissivity, which increases with rising temperature, and this effect is individual for each metal.

In practical terms, this means that at normal temperatures, they emit only a small percentage of radiation.

The emissivity of a perfect black body = 1,
The emissivity of an ideal mirror = 0.

Here, a simple solution presents itself: camouflage the object using a shiny metallic material, such as foil. This shiny metallic material will assume the temperature of the radiation source, but due to its very low emissivity, it cannot emit enough energy for successful detection by a thermal camera. It is important to use pure metal because using metal oxides would significantly increase the material's emissivity.

This property of metallic material is advantageous, but it must be used in a different way, to eliminate drawbacks such as:

- fatal demasking effect in the VIS (visible radiation spectrum),
- fatal demasking effect in the NWIR, SWIR (night vision),
- rapid increase in emissivity due to metal contamination or oxidation.

If a foreign radiation source approaches such a camouflaged object, or it is exposed to sunlight or moonlight, the radiation is reflected into the surroundings, thereby also towards the thermal camera, leading to the successful detection of the object. Another disadvantage of such foils is their insufficient flexibility and, most importantly, insufficient breathability.

Here, a solution arises: cover the metallic foil with fabric that is impregnated on one side with IR pigments having suitable emissivity and reflectivity. In such an arrangement, the camouflage in the MWIR and LWIR bands will function at an insufficient level and only for a limited period of time.

The reason is that the heat from the shiny metal, which has a low ability to emit energy, is transferred to the outer material by conduction (direct contact of materials). However, this outer material has significantly higher emissivity, due to effective camouflage in the VIS, NIR, and SWIR bands, and begins to emit energy. This occurs despite the fact that the temperature of the outer layer is lower due to heat transfer losses (conduction). The emitted energy will be reduced by losses caused by the transfer of energy from the radiation source to the surface of the camouflaged object, and this process has a certain time delay.

Losses caused by energy transfer and their minimization are key factors for successful camouflage against thermal cameras. For the effective functioning of complex camouflage technology, it is essential to minimize the heat transfer from the source to the outer layer. This way, the amount of energy that can be detected by the thermal camera is reduced, thereby increasing the effectiveness of the camouflage.

Reflectivity, emissivity, specific heat capacity, and the thickness of the pigment layer must be chosen so that while maintaining the camouflage effect in the VIS, NIR, and SWIR bands, they are able to best absorb and transfer heat to the surrounding environment and mimic the ambient temperature.

Underneath the outer, cool layer (D) is a material (C), whose function is to prevent direct contact of this cool layer with the Therdam material (A+B). In this way, the transfer of heat by conduction towards the outer cool layer (D) is minimized as much as possible.

The next layer is made of Therdam material. The main role of this layer is to limit the amount of energy transferred from the heat source towards the material (C), while also ensuring the breathability of the composition.

In scientific circles, it's often suggested that glass is ideal for "shielding" thermal signatures, but this isn't entirely true. This myth likely originated from observing buildings through thermal cameras, where sheet glass appears cold in the images. This phenomenon is associated with its thermal conductivity, reflectivity, and placement. However, glass has an emissivity of up to 0.92, making it a very effective emitter. Its glossy surface reflects incoming energy. The reflectivity of glass can be demonstrated by standing in front of glass with a thermal camera and observing your thermal reflection. You can verify the emissivity of glass by placing your hand on its surface for 30 seconds, removing it, and then observing the thermal trace with a thermal camera. While sheet glass is unsuitable for this purpose, it may be appropriate in other structures.

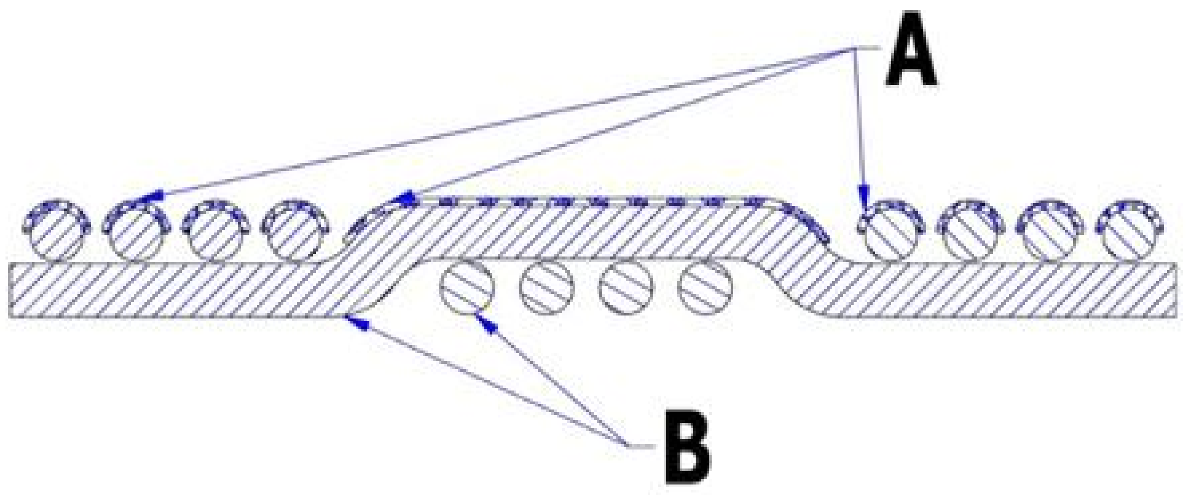
Therdam material consists of fabric woven from glass fibers (B), with the side away from the heat source being metal-coated (A) with an emissivity of 0.07 or less. The mechanism of heat transfer through this material is diametrically different from that of sheet glass. The fabric is woven from filaments composed of 204 elementary E-type glass fibers. Heat transferred from the radiation source moves through individual fibers, predominantly perpendicularly to their longitudinal axis. Since the fibers have a circular cross-section, thereby minimizing the contact area between them, heat transfer by conduction from fiber to fiber is significantly limited. Some heat is also transferred through the material by radiation. Despite glass being an effective emitter, its high reflectivity reflects a significant portion of the radiation back.

Energy passing through the Therdam material must transition between interfaces more than 100 times. Each transition from one interface to another is accompanied by a temperature loss. At the end of this barrier is the aforementioned metallic layer. This metallic layer (A) is directly applied to the glass fibers (B), and therefore, heat is transferred to the metallic layer by conduction. Thanks to the low emissivity of the metallic layer, the amount of energy radiated towards material 2 is minimized. Heat transfer by conduction from the metallic layer to material 2 is also minimized due to the complex structure. If, instead of a thin metal-coated layer, we used a metal foil or metal-coated polymer foil, the heat transfer by conduction would increase.

The unique property of metal-coated fibers lies in their ability to meet two seemingly contradictory material requirements:

- The surface must have low emissivity, which in practice means a smooth and polished surface.
- The surface must have low reflectivity, which in practice means an oxidized or sandblasted, roughened surface.
- The surface must be complex to minimize the contact area with the adjacent material.
- The complexity of the surface must be designed with the understanding that metals are **not isotropic emitters**.

Imagine the Therdam material detail as a system of circular bodies, on one side of which a metallic layer is applied. The shape of this metallic layer forms a system of semicircles, which are cyclically overlapped by other semicircles of the metallic layer at a 90-degree angle (Fig. 1). This arrangement allows for achieving a complex surface with low emissivity, low reflectivity, and high effective area. The final layer of the composition is made of fabric, which seals the composition and, in the case of camouflaging a person, also provides comfort.



Breathability is a key factor for successful complex camouflage. The material composition must have a certain breathability to allow the heat accumulated in the Therdam thermal barrier to be controlled and gradually released into the surroundings. If the heat were maximally retained under the camouflage material, it would lead to an increase in temperature, overheating of the object, and consequently overheating of the outer cool layer, resulting in a demasking effect. Thanks to its fibrous and flexible construction, the Therdam material allows for the movement of fibers among themselves, which significantly facilitates the release of accumulated heat. The value of breathability depends on the specific use and is chosen individually. The recommended range of breathability is from 0.2 to 3 m^3/min.

Factors affecting detection by thermal cameras:

- Ambient temperature
- Relative humidity
- Blood alcohol - increase in person's temperature
- Medications, e.g., Paracetamol - increase in person's temperature
- Skin color - emissivity 0.97 - 0.99 – minimal impact
- Atmosphere - consists of several gases such as nitrogen, oxygen, argon, helium, or carbon dioxide. It also contains a variable amount of water vapor. Diatomic gases consisting of the same element cannot absorb IR radiation. Gases consisting of multiple atoms of different types, on the other hand, do absorb IR radiation. Gases capable of absorbing IR radiation include **water vapor, carbon dioxide, methane**. The attenuation of the atmosphere largely depends on the concentration of gases.

Description of the individual layers of the composition and their arrangement

1. **The outermost layer** of the final composition (furthest from the heat source) is made of material **(D)**, which is a fabric with a camouflage pattern using IR pigments to ensure camouflage effectiveness in the VIS, NWIR, SWIR bands. The transfer of heat to the outer layer from the heat source must be minimized, but not completely stopped.
2. **The second layer** of the final composition **(C)** is made of a fibrous non-woven material, 100% polyester, hollow fibers, white in color. Trade name Vatelin 60g/m2, Freudenberg.
3. **The third layer** of the final composition **(A+B)** consists of Therdam material, with the metal-coated side facing the outer cool layer, i.e., away from the heat source.
4. **The fourth layer** of the final composition **(C)** is identical to the second layer. This layer can be omitted from the composition, resulting in a reduction in weight per square meter but also decreasing the effectiveness of camouflage against thermal cameras.
5. **The fifth layer** of the final composition **(E)** is made of fabric from wood pulp (100% viscose), weight 90-130g/m2, color black.

Joining individual layers into the final composition

When joining the individual layers of the final composition, it is undesirable to use gluing, as it would significantly affect breathability, increase weight, and most importantly, it would promote the transfer of heat towards the cool-outer layer.

Therefore, we carry out joining by sewing, using a standard stitch, such as Lockstitch 301. Individual stitches are spaced from 5 to 150 mm apart, thus creating a grid. It is recommended to avoid regular shapes, such as a grid, and to lead stitches along curves, chaotically intersecting, which create various shapes. By sewing in this way, we create a 3D structure that increases the camouflage effect in all the above-mentioned spectral bands. When choosing the density of stitching, it is necessary to consider that there is an increased heat transfer around the stitches, which can reduce the masking ability. The minimum recommended area of the shape is 20 cm², and the maximum recommended area of the shape is 80 cm².

Detailed description of Therdam material, physical and technological requirements

Weight	290 g/m2, tolerance ± 5%
Type of weave	2x2 Twill , iso 2113
Standard width	1000 mm, ± 2,5%
Fabric thickness	0,29, ± 5%
Type of warp fiber, E glass EC 9	3x68 tex
Type of weft fiber, E glass EC 11	204 tex
Number of filaments per cm	7
Tensile strength of fiber	3300 MPa
Chemical composition of fiber	SiO_2 52-56%, Al_2O_3 12-16%, B_2O_3 5-10%, CaO 16-25%, MgO 1-5%
Trace amounts	Na_2O+K_2O,TiO_2,Fe_2O_3,F_2
Type of metal applied	aluminium (AL)
Thickness of applied layer	10μm, ± 8%
Method of application	vacuum metal vapor deposition

Notes:

Reflectivity - the ability of a body's surface to reflect electromagnetic radiation

Emissivity - the ability of a body's surface to emit electromagnetic radiation

Conduction - the transfer of thermal energy from areas of higher temperature to areas of lower temperature through direct molecular contact

IR (Infrared) - radiation moving in the infrared range

LWIR (Long Wave Infrared) - long-wave infrared radiation

NWIR (Near Wave Infrared) - near infrared radiation

MWIR (Medium Wave Infrared) - medium-wave infrared radiation

SWIR (Short Wave Infrared) - short-wave infrared radiation

VIS (Visible) - visible

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