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Review

Metal iodide nanomaterials based thermal biological and medical systems and applications in heat transfer and therapeutics

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Abstract: Metal iodide materials as novel components of thermal biological and medical systems at the interface between heat transfer techniques and therapeutic systems. Due to their outstanding heat transfer coefficients, biocompatibility, and thermally activated sensitivity, metal iodides like silver iodide (AgI), copper iodide (CuI), and cesium iodide (CsI) are considered to be useful in improving the performance of medical instruments, thermal treatment processes, and diagnostics. They are examined for their prospective applications in controlling thermal activity, local heating therapy, and smart temperature-sensitive drug carrier systems. In particular, their application in hyperthermia therapy for cancer treatment, infrared thermal imaging for diagnosis, and nano-based drug carriers points to a place for them in precision medicine. But issues of stability of materials used, biocompatibility, and control of heat—an essential factor that would give the tools the maximum clinical value—remain a challenge. The present mini-review outlines the emerging area of metal iodides and their applications in medical technologies, with a special focus on the pivotal role of these materials in enhancing non-invasive, efficient, and personalized medicine. Over time, metal iodide-based systems scouted a new era of thermal therapies and diagnostic instrumentation along with biomedical science as a whole.

Keywords: bio-compatibility; biomedical sensors; hyperthermia therapy; metal iodides; thermal photography; thermal therapy; thermo-responsive drug system

1. Introduction

Silver iodide (AgI), copper iodide (CuI), and cesium iodide (CsI) metal iodides are now emerging at a good speed as the most preferable in thermal biological and medical systems because of their properties. These materials are famous for their thermal stability and differential scanning thermal analysis, which is important in any environment that calls for managing heat for different or unlike uses. These metal iodides also display semiconducting characteristics, thereby making them ideal for application in thermoelectric materials used in devices that are used to produce electrical energy directly from heat [1]. Bioactivity, particularly in medical applications, improves their prospects in therapeutic applications since it prompts these materials to engage with bioactive systems. The combination of thermal management performances and biological assimilation makes metal iodides unique players in various products in the healthcare industry [2,3].

Thermal management therefore plays a significant role in healthcare instruments, especially in procedures that involve higher precision instruments and tissues that have relatively high heat tolerance levels. Several metal iodides are also used as heat dissipation materials or metalized layers, which in their thoroughness tap into the additional characteristics offering heat sink or thermally conductive behavior [4]. For example, cesium iodide was investigated as a possible candidate for controlling the heat load of medical diagnostic devices. Silver iodide with its high melting point and chemical stability finds its application in the thermal management of heat exchangers in devices like laser surgery instruments where precision temperature control is critical to the sterilization process on one hand and to the health of the patients on the other. In choosing suitable metal iodides, thermal stability is not affected by stress, making them indispensable in future medical applications in thermal management [5,6].

The implications of metallo-organic compounds also found useful applications in medical diagnostics, namely in imaging systems. CsI is required in the production of scintillator crystals for the detection of *X*-rays and *Y*-rays. These crystals possess the capacity to transmute electromagnetic radiation into visible light, a feature that is fundamental in improving the quality of imaging modalities including computer axon tomography (CT) and positron emission tomography (PET). The atomic number of cesium iodide is high which is why it effectively converts photons Slag EA for diagnostic equipment of the new sample [7]. Silver iodide and copper iodide are also under consideration for use in photonic imaging systems where semiconductive properties can enhance imaging systems' sensitivity and resolution. When metal iodides are incorporated into imaging devices, clinicians have better accuracy and precision in the detection and diagnosis of different diseases, especially in minimally invasive diagnostic instruments [8].

In addition to their applications in thermal management and diagnostics, metal iodides have shown promising therapeutic properties because of their biological activity. For instance, silver iodide has been postulated due to its antimicrobial functionality, which makes it perfect for use in wound dressing and fumigation [9]. Iron-sulfur proteins share several properties of metalloids in general, which may stimulate cell proliferation, improve tissue repair, and have a positive effect on numerous therapeutic processes. Copper iodide, which has great anti-inflammatory action, has been searched as a material for the local application of inflammatory diseases. These materials' capacity not only to engage with biological systems but also to do so without resulting in toxicity poses a great benefit in therapeutic applications. Their biocompatibility coupled with intrinsic medical characteristics makes metal iodides promising materials for enhancing human-targeted therapies [10,11].

Metal iodides represent the new horizon in medical technologies since they are thermally stable, semiconducting, and biologically active materials. Their uses in thermal control, diagnosis, and treatment show how they could transform medical instruments and techniques [12]. Since many new properties and applications are being discovered, integrating metal iodides into medical systems will continue to increase as solutions for clinical and therapeutic issues arise. As continued with further development, metal iodides may bring a new revolution in the field of medical technology and patient care [13,14].

2. Properties of metal iodides in biological and medical systems

Metal iodides are chemical compounds formed by the metal cations bonded with iodide anions, some of which have the characteristics described in the work that make them indispensable in biological and medical applications. As most of them are ionic, metal iodides can chelate biological molecules and affect their respective cellular actions. Some metal iodides, potassium iodide for instance, are used in medicine to treat thyroid problems since they assist in handling the situation where there is a shortage of iodine or excessive production inside the thyroid gland. Silver iodide and other metal iodides are also bactericidal and are employed in the treatment of ulcers/lesions and controlling infection. The good solubility and reactivity of metal iodides in physiological conditions make them potential precursors for drug delivery systems and diagnostic and therapeutic tools, while their toxic effects should be controlled.

2.1. High thermal conductivity and efficient heat transfer

Other metal iodides include silver iodide (AgI), copper iodide (CuI), and cesium iodide (CsI); all of these possess high thermal conductivity, a property important in heat exchange in body and medical applications [15]. The thermal stability of metal iodides also means that for thermal management applications, their heat flux remains stable [16]. For example, in medical technologies that use materials sensitive to heat or require very precise thermal control in some applications like laser treatment systems or thermal therapy devices, metal iodides contribute by their conductivity of heat and keep the adequate operating temperature. This property is also important in biological systems where heat control is required for activities such as regulating body temperature in tissues or keeping temperature steady during treatments [17]. This fast dissipation of heat in those materials makes certain that any changes in the temperature of the structures do not jeopardize the trueness of the tissues or biologic processes. Hence, metal iodides are more and more incorporated in certain physiological applications of medical devices, such as thermostats, including thermoelectric coolers, implants, and temperature control in diagnostic instrumentation [18,19].

The uses of metal iodides in biological and medical systems can be observed in **Figure 1** below. The therapy includes metal iodides, with potassium iodide being used for iodine inadequacy and hyperthyroidism. Silver-containing compounds, for example, silver iodide, sufficiently proved antimicrobial characteristics helpful in wound treatment and the prevention of infections. Their capacity to recognize, assimilate, transform, and work at the biological molecule level as well as deliver medicine and serve as imaging agents defines their capacity in medical therapies. Nevertheless, issues of bioavailability and toxicity of metal iodides remain crucial for application in practice. Moreover, this means that they can be introduced into biological systems without any adverse effects, and the ability to prevent bacterial growth makes them suitable for use, for example, in the development of artificial limbs. The metal iodides also possess photothermal characteristics so that they can be used in the conversion of light to heat, such as in cancer treatment. The chemical stability indicated that there will be no chemical reactions between the materials and the body, hence providing durability and reliability in all circumstances. Their conductive properties support their use in modern diagnostic instruments and therapeutic instruments. Altogether these characteristics indicate that metal iodides are unique chemicals needed in contemporary biomedical networks.

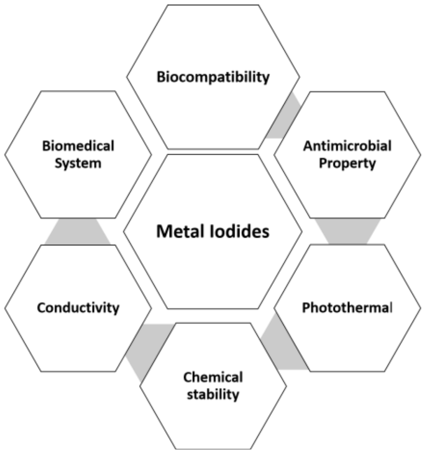

Figure 1. Represent the properties of metal iodides in biology and their application.

2.2. Biocompatibility and tunable optical and electrical properties

The fact that metal iodides have an ionic character of bonding makes them highly biocompatible, which will be important when used in medical systems. Thanks to their covalent ionic bonds, these materials are inherently biocompatible and have little chance of provoking an immune reaction or displaying toxicity—an essential feature when implanting material or using it for diagnostic or therapeutic purposes requiring direct contact with the human body [20]. These metal iodides have an affinity to biological environments while their optical and electrical properties are still adjustable. For instance, where diagnostic tools require the characterization of semiconducting materials such as copper iodide, precise electronic property control is crucial for signal amplification and imaging [21]. In addition, the ability of these crystals to selectively absorb and emit light makes them suitable for use in imaging products, for instance, scintillators, or in optoelectronics where light conversion is central to the formation of high-resolution images [22]. As a result, these tunable properties enable metal iodides to be very appropriate in modern medical applications such as bio-electronic sensors, drug delivery systems, and bioimaging. Because of their stability in various physical and biological applications, metal iodides are accurately described as critical commodities for creating future medical technologies [23].

3. Thermal regulation and management using metal iodides

This is explained by the fact that thermal regulation is very important when it comes to the homeostasis of the body, especially when the patient is receiving specific medical treatment or when receiving treatment that necessitates a specific body temperature. Materials with metal iodides have come to prominence for their effectiveness in thermal control in therapeutic devices and wearable health systems [24]. Such as silver iodide (AgI) and cesium iodide (CsI), due to their considerably higher value of k, the heat transfer rate of these materials is high. These features make them suitable for incorporation into thermal pads or wearable devices for handling hypothermia, fever, and chronic pain [25]. For example, hypothermic patients can benefit from metal iodide thermal pads to heat certain body parts without causing harm to a particular tissue while effectively raising the patient's normal body temperature. In the same way, in fever treatment, metal iodide-based materials may, for instance, be incorporated into the cooling systems to enable regulation of body temperature in a safe, non-invasive manner [26]. Biocompatibility of their molecules also allows them to be safely applied topically or incorporated into therapeutic products that will not cause irritation or negative impact on the body tissues during long-term medical therapies [27,28].

The function of metal iodides in thermal control is described in **Figure 2** to demonstrate how they can be used in future sophisticated thermal system applications. In particular, metal iodides with high thermal stability can be investigated as PCMs that heat up or cool down depending on temperature changes. The diagram highlights the use of metal iodides in thermal control, the structures of metal iodides, and the functions of heat absorption and distribution and thermal control devices, among others. Metal iodides are superior heat-conducting and heat-transfer agents and are used in complex systems with special requirements for thermal regulation. It improves the energy dispersion of thermal energy, making devices more efficient and safe, especially in medical applications in electronics and implantations. Metal iodides help enhance the performance and reliability of heat control devices, both for therapy-related fields and for complex biomedical technologies.

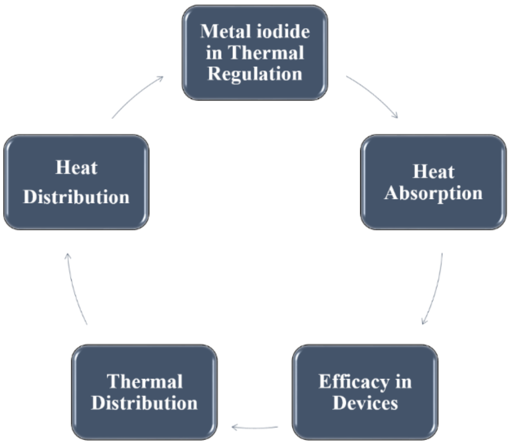

Figure 2. Role of metal iodide in thermal regulation and its application.

Thermal management in implants and high-power medical electronics

In addition, metal iodides could play an additional role in addressing heat dissipation from implanted devices like pacemakers, neurostimulators, and other high-technology medical implants. Some of them are portable while others are easily movable systems, and during operation, they produce heat and hence need proper temperature control to avoid causing danger and/or damage to the device [29]. Metal iodide materials, because of their high thermal conductivity, can be employed to control thermal load on delicate structures in implants and prevent overheating of the implanting devices. For instance, home medical devices such as pacemakers and neurostimulators, which incorporate tiny circuits that deliver electricity, can benefit from metal iodide-based coatings or composites to prevent localized heating of the circuits [30]. Due to increased heat transfer, the above-mentioned materials maintain the operating temperature necessary for the prolonged functioning of the device and thereby reduce chances of failure [31]. Furthermore, due to the miniaturization of devices and the higher density-compelled high-performance implant, metal iodides are indispensable materials to create the next generation of bioelectronic systems that need both high-temperature dissipation and reliable stability. This makes them useful in creating efficient, safe, and long-lasting medical implants to be used in several therapeutic practices [32].

Figure 3 also shows the implications of thermal management in implants and high-power medical electronics devices, highlighting the capability of heat dissipation as a core factor of performance and patient safety. These biomedical applications of nanotechnology include medical implants and electronics examples such as pacemakers or high-performance diagnostic instruments; the substantially miniaturized systems, therefore, require efficient measures for thermal dissipation, lest their increased operating temperature negate the efficiency of the device or cause harm to the neighboring tissues. Elements including generative composites, metals, carbon materials, and thermally conductive polymers are utilized in creating systems that are either passively or actively cooled. Implementing such components, including heat sinks and thermal pads as well as phase change materials, into these devices will improve the flow of heat and ensure that high temperatures will not exceed their limit, thus improving the long governing factors, including longevity, reliability, and patient comfort. This new direction in thermal management is essential as medical electronics progress and constantly adapt to the growing role of miniaturization and the increasing need for high-performance functions.

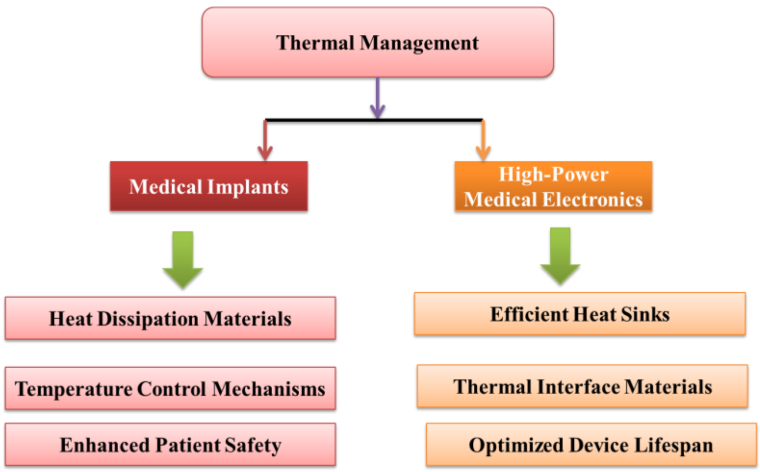

Figure 3. Characteristics of thermal management in implants and high-power medical electronics.

4. Thermal therapy and treatment enhancement with metal iodides

Therapeutic heat application with a special focus on hyperthermia has received significant attention as an adjuvant therapy to cancer treatment among other inflammatory diseases. Hyperthermia therapy uses heat on tissues to increase the outcome of other therapeutic procedures like radiation or chemotherapy. Metal iodides with [33] showing pretty good heat insurance characteristics are currently under investigation as a potential means of improving the accuracy and outcomes of thermal procedures. Different metal iodides having nanoparticles like silver iodide (AgI) and copper iodide (CuI) are being prepared for use as thermal agents effective for giving controllable local hyperthermia at tumor locations. Such nanoparticles can be stimulated externally, for example, with an electromagnetic field or laser radiation that provides targeted heating of the tumor tissue. The fact that the tumor tissue temperature rises makes the tumor cells vulnerable to the lethal effects of radiation or chemotherapy enhancing the efficiency of the two. Mainly, metals' thermal conduction characteristic also enables uniform heating so that a non-uniformity of thermal distribution which can injure the healthy surrounding tissues is avoided [34,35].

The main characteristics of thermal therapy and treatment enhancement with metal iodides in cancer treatment are shown in **Figure 4**. The metal iodides, because of thermal conductivity, have applications for thermotherapy, where heat is deliberately used on tissues of cancer cells to make the treatment of radiotherapy or chemotherapy more effective. When these compounds are used with nanoparticles, or in other words, when they are used in targeted drug delivery systems, heat can be produced only at the tumor sites, which enhances the killing of tumor cells and reduces the killing of normal cells. This property, combined with their capacity for the controlled liberation of heat, makes metal iodides a potent weapon in increasing the effectiveness of cancer treatments. Moreover, the addition of metal iodides in advanced treatment regimens is believed to be more accurate, non-harm, and highly effective than traditional cancer treatments.

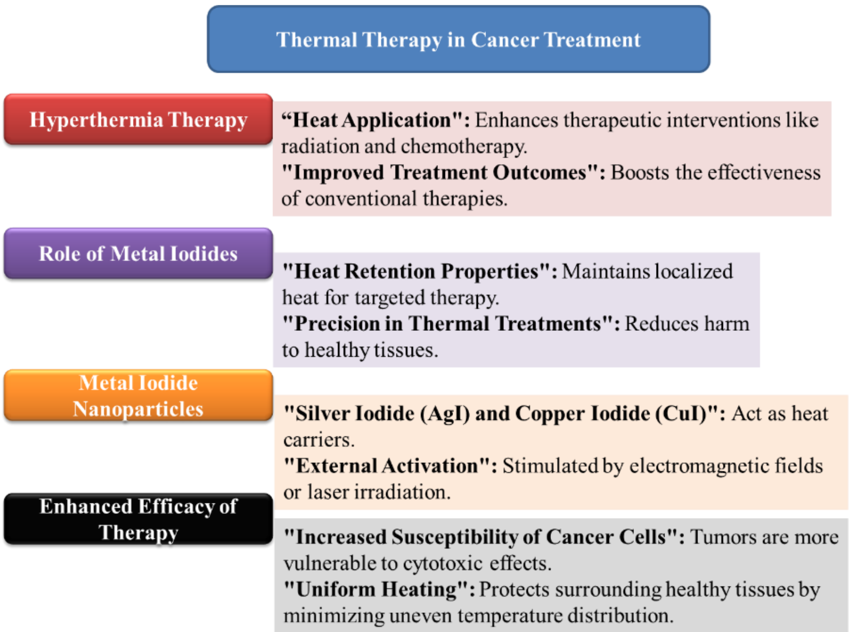

Figure 4. Important characteristics of thermal therapy and treatment enhancement with metal iodides.

Development of metal iodide-infused hydrogels for precision thermal therapy

Another promising area of thermal application relates to the creation of self-assembling metal iodide-containing hydrogels or biomaterials that can release heat as required. Heating depends on the amount of water that hydrogels can swell and absorb and their capacity to control the rate of release of this heat to the environment on a time basis. The combined metal iodide aquatic hydrogels used in this study can function both as thermal carriers and as responsive drug delivery systems. Hydrogels containing metal iodides may be used to deliver heat intermittently at the required treatment points, thus enhancing the accuracy in thermal medicinal uses [36]. These materials can then be developed to integrate responsiveness to external signals, such as temperature flaming, electromagnetic fields, or light, to achieve optional thermal release. For instance, in light irradiation, such as infrared light or laser irradiation, these kinds of materials could instantly be heated at the target site, offering immediate thermal temperature ease or treatment to regions influenced by disease or injury. The benefits of using such a system could include highly selective targeting that would increase even further the odds of leaving healthy tissues untouched and an increase in the safety and efficiency of thermal therapy. For cancer treatment, these metal iodide-containing hydrogels can be administered through an injection or applied locally at the tumor site where the heat delivered by hydrogels will improve the efficacy of the simultaneous chemo- or radiotherapy [37]. In certain cases, such as cancer or other conditions that require localized thermal delivery, this form of targeted, minimally invasive therapy shows much promise [38].

5. Metal iodide concept in thermal diagnostics and imaging.

In summary, metal iodide-based sensors introduced a new generation of thermal diagnostics, enabling multi-scaled and precise detection of temperature changes at the tissue and cellular levels. These types of sensors are usually comprised of silver iodide (AgI) or copper iodide (CuI), and are incorporated into image-capturing systems to measure even the smallest variation of thermal differentials; which are necessary for identifying an array of illnesses [39]. Therefore, sensors based on metal iodide sources are effective regarding continuous active temperature monitoring at room temperature without the utilization of expensive cooling systems or equipment. Such characteristic makes them especially suitable for clinical practice as the ability to examine a patient’s thermal state at once helps diagnose the problem more effectively [40]. In disease detection, these sensors can detect the temperature change which may not be distinguished from the normal anatomy on MRI or any conventional imaging modality thus detecting early inflammation, infection, or tumor. For instance, several tissues in the body exhibit different temperatures depending on their inflammation state, the senor has metals iodide that enables it to determine these temperatures vital in revealing the disease pathology [41].

The application of metal iodide-based sensors in thermal diagnostics and imaging is explained in **Figure 5** in context with their contribution toward improving the temperature measurement and monitoring capacity in medical applications. Some of the uses of metal iodide-based sensors have been represented on the diagram, including diagnostic imaging and thermal diagnostics. These sensors play a critical role in acquiring high-resolution patterns and supporting advanced medical imaging techniques. Mercuric iodide (HgI_2) and other metal iodides feature in sensitive *X*-ray detectors, enhancing the level of imaging accuracy and solidity. In the same way, thermal imaging can help in the screening of temperature differences, which can help in the detection of inflammation, growth of new tissues, or infections. These applications prove that metal iodides play important roles in the variety and precision of diagnostic applications.

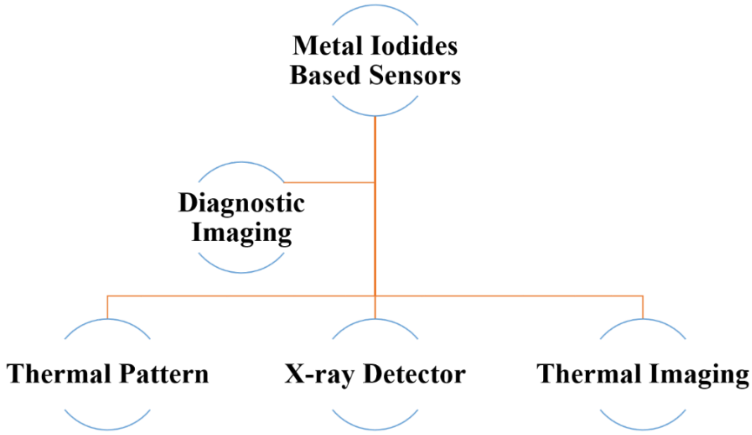

Figure 5. Metal iodide-based sensors in thermal diagnostics and imaging.

5.1. Infrared thermography with metal iodide sensors for real-time monitoring

They are most useful when combined with a non-invasive diagnostic technology called infrared thermography, which records temperature changes on the skin surface of the body. In infrared thermography, the sensitivity of metal iodide sensors, when combined with the ability to read temperature changes over the body, allows the immediate assessment of physiological conditions [42]. Such a combination is highly effective when observing conditions characterized by atypical temperature processes, including chronic inflammation, infections, or circulation disorders. For example, in patients diagnosed with diseases such as arthritis or cardiovascular diseases, the abnormal distribution of temperature in some regions of the body is associated with inflammation or insufficient blood supply sufficient to evaluate the severity of the disease or the efficacy of therapy. Metal iodide-based sensors combined with infrared thermography allow clinicians to achieve high-resolution thermal images that deliver important diagnostic information without the use of invasive treatments or radiation [43]. These sensors can also be used for always-on applications for patients in ways that range from admission assessments before surgery to post-surgery monitoring, in addition to being safer than invasive diagnostic procedures. Moreover, there are great benefits if the signals can show the subtle change of temperature—the early-stage diseases may be undiagnosed because symptoms are invisible, and subtle changes in body temperature may become indicative of certain diseases when noticed early enough and can significantly extend the patient's lifespan [44].

5.2. Employments of chronic disease management and early identification

The recent incorporation of metal iodide-based sensors into infrared thermography has already been successful in the field of treatment of chronic diseases. For instance, with such illnesses as rheumatoid arthritis, in which inflammation significantly contributes to the general pathology of the sickness, evaluation of the temperature can go a long way in revealing the activity of the sickness. Electrochemical sensors that utilize metal iodides can monitor the evolution of inflammatory changes in joints; it is possible to make corrections straight away [45]. Likewise, in cardiovascular diseases, when temperature regulation is impaired due to poor blood supply, these sensors are valuable in measuring changes in blood flow, which may not be observed through other techniques. Providing constant, instantaneous temperature readings, metal iodide sensors allow for better decision-making by doctors regarding treatments and patients' well-being, thus increasing disease control and the patient's quality of life. While the study of these materials is still in its infancy, metal iodide-based sensors are set to become ever more prevalent, opening the door to the next generation of precise diagnostics and patient-specific treatment [45,46].

6. Temperature stimuli sensitive controlled release systems based on metal iodides

One of the most exciting innovations in present-day healthcare is thermosensitive delivery systems, which are otherwise known as smart drug delivery systems. Among the metal reagents, metal iodides as sensitive to thermal conditions and thus become promising candidates for the given innovative technology. These materials fine at the nanoscale level can be programmed to incorporate cytotoxic agents or other bioactive substances and deliver them when exposed to certain temperatures [47]. By proper synthesis, it is possible to design the metal iodide nanoparticles to encapsulate the therapeutic agents and remain stable at lower temperatures; however, at a certain temperature, the particles undergo a change of phase or structure, which leads to the release of the drug. This specific requirement in turn provides the ability to deliver a drug molecule only to the region of interest, for instance, in proximity to a tumor or inflammation site, without affecting the rest of the surrounding tissue. This reduces the probability of side effects affecting the whole system, a problem typical of other methods of drug delivery; particularly in cancer treatment, chemotherapy drugs have a magnitude of damage to the healthy cells [48].

Drug delivery systems involving thermo-responsive metal iodides take advantage of the properties of the given metal iodides for achieving site-specific and stimuli-responsive drug release. Potassium iodide (KI) is used in thermo-sensitive systems to allow for the timely delivery of an agent based on the alterations in heat environments. To achieve local action at elevated temperatures, the payload of silver iodide (AgI) is incorporated into nanocarriers for thermally activated release. Thermal-triggered drug delivery systems are promoted by copper(I) iodide (CuI) for improved therapeutic specificity. Mercuric Iodide (HgI_2) is used in targeted therapy due to its property to respond to temperature changes selectively on treatment sites. The nanoencapsulated form of lead iodide (PbI_2), which is used in drug delivery systems, allows the localized release of the drug at the target site in response to heat, thus reducing side effects and enhancing treatment response. In combination, these metal iodides constitute unique strategies in the development of new drug delivery systems. The complete flow is shown in the below **Figure 6**.

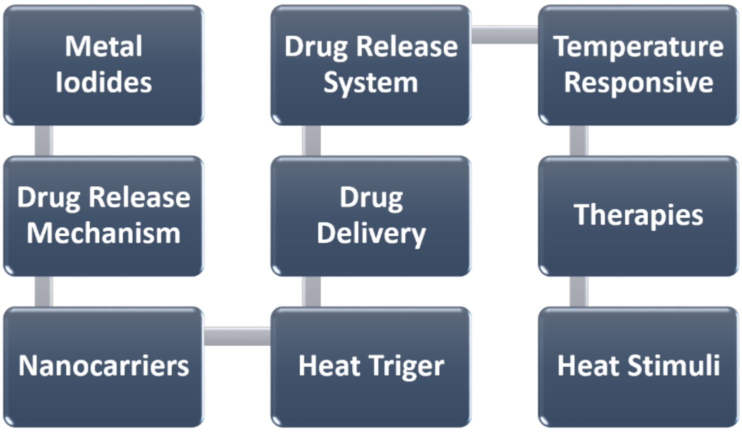

Figure 6. Thermo-responsive drug delivery systems using metal iodides.

The incorporation of metal iodides into thermo-sensitive drug delivery systems could dramatically change the way that a range of diseases are managed, especially in cancer treatments. These systems allow for the activation of drug release at the desired time and area through the application of non-invasive techniques, which include ultrasound or light of an infrared wavelength. Because metal iodides respond to heat, it is possible to control the time and place of delivery and thereby design a treatment plan to suit a given patient [49]. For instance, the infrared light can be directed at the tumor site; the metal iodide nanoparticles, which are selectively delivered at the tumor site, heat up and release the chemotherapy drug at the tumor microenvironment only. Such an approach is beneficial in the enhancement of the effectiveness of the drug, in addition to the reduction of the required amount leading to a reduction of side effects. Moreover, the characterized behavior withstanding the release of drugs by external non-invasive stimuli increases the degree of control of treatment regimens, adding a potential perspective to individualized pharmacology. Thus, as the investigation into the metal iodide-based drug delivery systems is progressing, this technology holds the promise of amplified improved patient encounters in the development of other chronic diseases, including cancer and other systemic diseases, through more efficient therapeutic plans for the delivery of medicines.

7. Issues and directions for development

Despite the exciting potential of metal iodides for thermal, biological, and medical applications, several issues have to be solved to optimize the materials. A major consideration is the ability of metal iodides to withstand the rigors of the biological environment to which it would be exposed and whether factors such as high humidity, fluctuating pH levels, or oxidative conditions would degrade the material over time. The consequent concerns pertain to the sturdiness of metal iodide-based systems especially for implantable or therapeutically devices that may be applied for decades. Furthermore, the possibility of metal iodide toxicity, especially when in nanoparticle form, is also a factor that has to be considered [50]. Although numerous metal iodides demonstrated the potential for biocompatibility, the impact of these salts on cells and tissues at different concentrations or using long-term exposure has not been completely investigated. Before these metal iodides can be included in clinical practice, they mustn't cause any deleterious biological effects. Moreover, precise heat delivery is important, especially in such processes as tumor treatment or tissue healing when high or non-focal temperature increases might cause various undesired effects. These issues are still present and call for further research that would address the problem of optimization of metal iodide-based materials synthesis, their stabilization, and the improvement of the control over thermal properties [51].

The future advancement in the applications of metal iodides in medical and biological systems could therefore involve using other biocompatible materials to enhance the properties as well as the stability of the metal iodides. When metal iodides are impregnated into polymers, hydrogels, or other bioactive materials, the resulting composite materials exhibit improved mechanical properties, thermal stability, and biocompatibility that can be exploited in long-term medical applications. Also, improvements in nanotechnology can pave the way to synthesize micro- and nanoscale metal iodide devices for enhanced and less invasive thermal treatment and diagnosis [52]. These nanoscale devices could be designed to adapt their functions to external stimuli, such as light, magnetic fields, or ultrasound, for example, to deliver drugs or to apply controlled heat at the nanoscale volume. These advances, meanwhile, and underlying innovations hold the potential to bring new therapeutic opportunities in their wake in the future and increase the prospects of recovering patterns, real-time, minimally invasive diagnosis, and treatment, significantly enhancing the patient's prognosis and shifting the paradigm of contemporary medicine [53].

8. Conclusion

Metal iodide-based materials reflect a new generation and flexibility in improving thermal biological and medical systems because of their extraordinary characteristics in accommodating various important medical functions. Because of their relatively high thermal conductivity, they can regulate heat in most medical equipment; this is important for guaranteeing that delicate procedural devices like implants, pacemakers, and therapeutic instruments maintain optimum temperatures. Further, metal iodides are biocompatible; therefore, they can interact with living tissues safely and are thus suitable for use in implants, sensors, and drug delivery systems. Responses to light, magnetic fields, or ultrasound added to their applicability for smart, responsive, localized therapies add to their versatility. These materials have the potential to enhance the performance and safety of many clinical and diagnostic technologies, whether in thermal regulation, as a means of diagnostics, or as an enzyme supportive of biomolecular identification.

Healing properties of metal iodides in medicine can be only expected when more research is conducted, and these compounds may create a revolution in the medical field. Future improvements can open the possibility of designing composites that would incorporate the advantages of metal iodides with other biocompatible compounds, increasing their stability and use as much as possible. The additional development of nanotechnology and microfabrication techniques may bring even more interesting possibilities: miniature, invasive-free devices that enable constant monitoring and deliver precise therapy. Because of the properties of thermal control, diagnostics, and therapy, metal iodides can significantly improve future medical technology and provide increased chances for the creation of safer, more efficient, and individualized systems for improving patient treatment.

- High Thermal Conductivity—Ensures effective heat regulation in medical devices like implants and pacemakers.
- Biocompatibility—They can, without much harm, come into contact with living tissues, which makes them suitable in cases of implants, sensors, or drug delivery.
- Smartness—Reacts to light, magnetic fields, and ultrasound, thus allowing smart localized therapy.
- Incremental Improvements—This is due to the fact that further research could lead to improvements of this concept and the possibility of expansion of its use.
- Nanotechnology Integration—Could be majorly beneficial for improving the invasive, or using high-precision, medical instruments.
- Revolutionary significances—Reduces hazards and potential dangers for both the patient and the medical product development company involved in the manufacturing process of the medical technology in question, thus providing efficient and personalized medical care to the patients.

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