June 2021| Vol. 1| Issue 2

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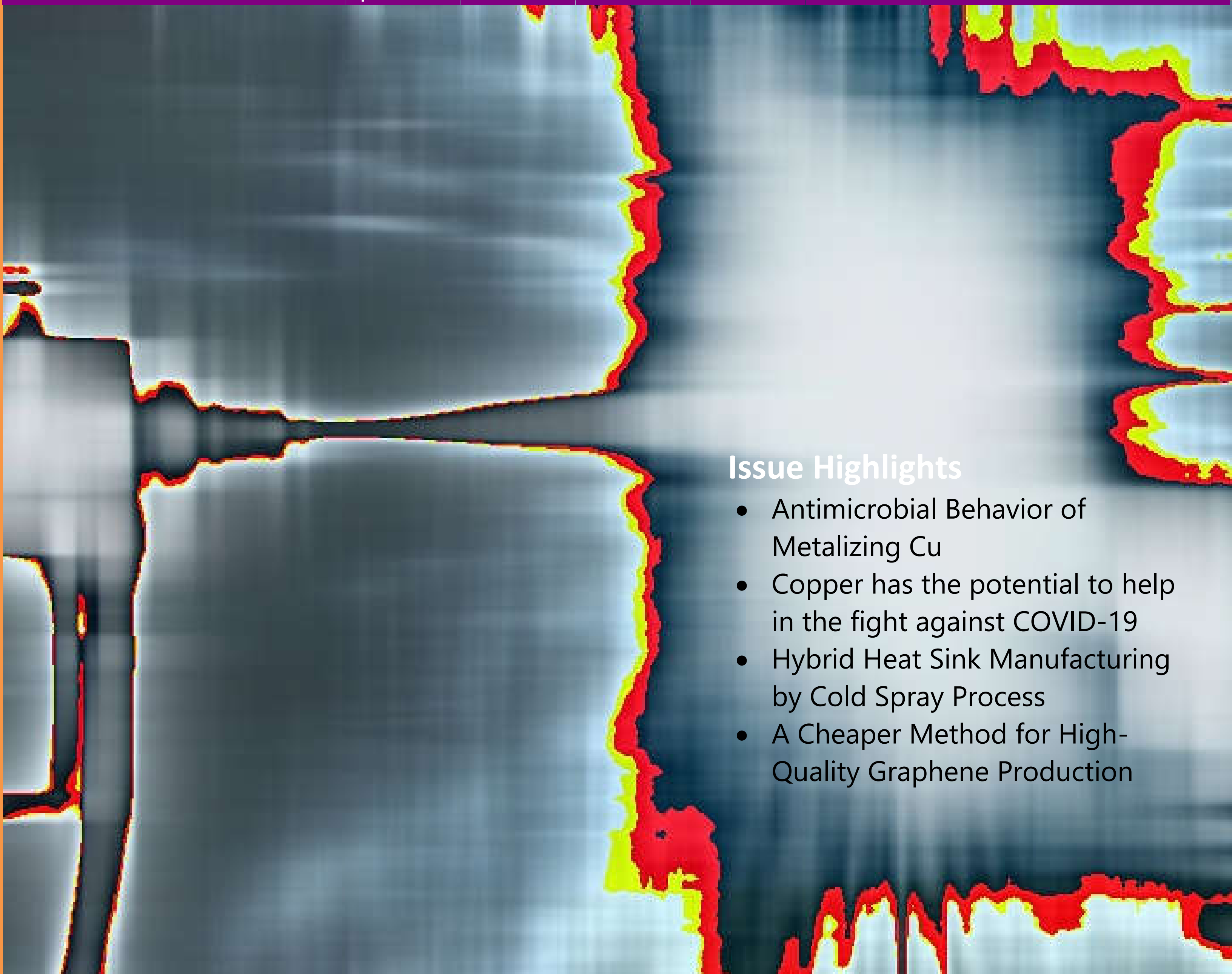

Issue Highlights

- Antimicrobial Behavior of Metalizing Cu
- Copper has the potential to help in the fight against COVID-19
- Hybrid Heat Sink Manufacturing by Cold Spray Process
- A Cheaper Method for High-Quality Graphene Production

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EROSION & CORROSION PREVENTIVE COATING ON HYDRO - TURBINE PARTS

'MEC' - HVOLF SYSTEM

XPOJET SPRAY GUN

XPOJET 5000

XPOJET 5250

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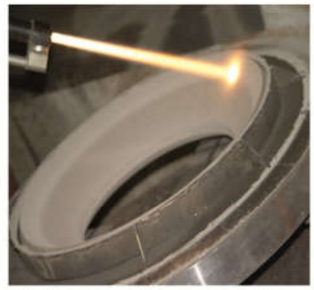
APPLICATIONS



HARD SURFACING OF SEAT RING

HARD SURFACING OF RUNNER

HARD SURFACING OF PELTON WHEEL

HARD SURFACING OF CONE

HARD SURFACING OF GUIDE VANE

HARD SURFACING OF TOP COVER

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XRD Machine

Adhesion Testing Machine

Vickers Hardness Tester

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EDITOR

Dr. Satish Tailor, MECPL Jodhpur

Mission: Our mission is to deliver the most recent thermal spray industry news and keep up to date to thermal spray community by providing company, event, people, product, research, and membership news of interest to industrial leaders, engineers, researchers, scholars, policymakers, and the public thermal spray community.

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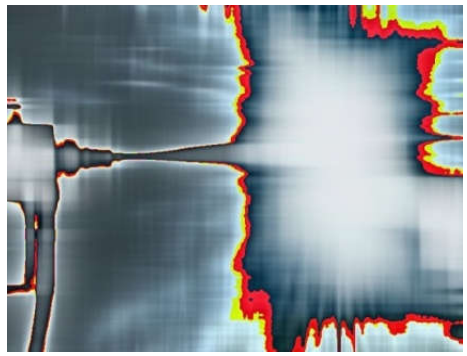

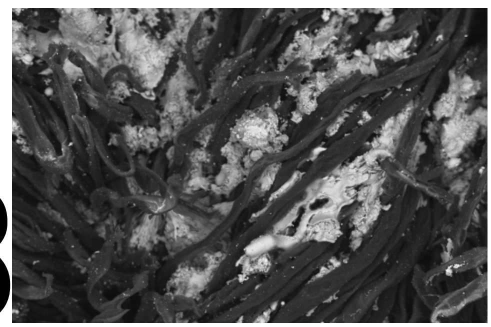

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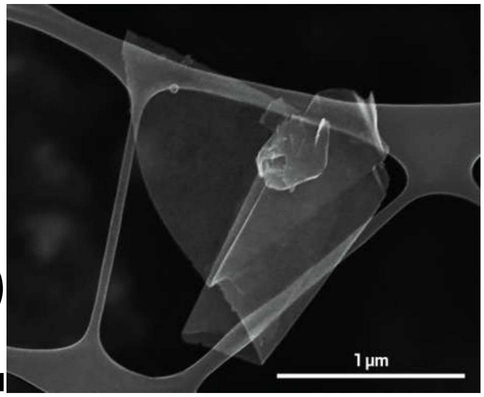
12 

Research NEWS from Academia: **A Cheaper Method for High-Quality Graphene Production**

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ABOUT THE COVER

Schoop view of metalizing

Editor's Note

Despite the fact that thermal spray technologies have been adopted by almost all major industry sectors globally, but the progress of thermal spray industry in India has been slow. However, the scenario is changing rapidly in the country now. For the past two decades, the increase in the number of job shops is reflecting the country's interest in developing the thermal spray industry in India. The demand for thermal spray coating services is historically increasing day-by-day in the country. Presently there are already more than 30 thermal spray job shops across the country. Metalizing Equipment Company Private Limited (MECPL) Jodhpur is the only OEM funded in 1967 in the country and supports all job shops in India as well as abroad by supplying indigenous thermal spray equipment, consumables and turnkey solutions. They also provide coating services for very specialized jobs. MECPL also has a world class R&D center with ISO 172025:2017 accredited Thermal Spray Laboratory and Robotic Thermal Spray Experimental Setup. Their R&D center also working on frontier areas like Cold Spray and Suspension Plasma Spraying. Many academic institutions and labs across India Now we have several state-of-the-art TS facilities in like IIT Ropar, IIT Patna, IIT Madras, IIT Kharagpur, IIT Roorkee, ISRO, ARCI, IGCAR, BARC, DRDO, NAL, IMMT, NITJamshedpur, DTU, and many other prime institutes are working on various thermal spray projects. I see a very bright future for thermal spray technologies in India.

Lastly, I would take this opportunity to invite existing and potential TS industry and academics to join ITSS. The aim of the society is to provide a common platform to facilitate interaction between industry, academia and research laboratories of the country for thermal spray development.

Looking forward to have your support and be part of this society.

Best Regards,

(Dr. Satish Tailor)

Antimicrobial Behavior of Metalizing Copper

*By **Paul McCabe**, Compositenano, 2735 e Thomas rd Good year Az, USA.*
Email: phoenixmachi112@gmail.com

Antimicrobial coating applications can be deposited onto various substrate materials at various processing temperatures and pressures, thus allowing for exceptionally high versatility in applications. Computer-generated pathways mounted on a robotic arm or as a handheld applicator, generating highly antimicrobial, or functional surfaces on preexisting parts is a highly feasible opportunity for improvement to both new and preexisting parts regardless of geometry. Reemergence of copper as an antimicrobial touch surface application developed at Battelle Columbus Laboratories. Since then, the capitalization of materials with antimicrobial properties has been further explored breaking away from strictly metallic systems to polymeric and inorganic materials. While it has been demonstrated that zinc and silver-containing systems have antimicrobial properties, copper has demonstrated significantly higher kill rates in a broader variety of bacteria and deactivation in viruses. Moreover, copper-containing implants have shown to be nontoxic in small concentrations, suggesting that antipathogenic copper-based biocompatible surfaces can be useful outside of fomite-mediated pathogen transmission prevention too.

The antimicrobial capabilities and properties of uniquely procured copper coatings manufactured by way of three thermal spray-based material processing techniques considered plasma spray processed copper coated surfaces, arc spray processed copper coated surfaces, and finally cold spray materials processed copper coated surfaces as part of research concerning antipathogenic copper coatings performance. Depositing until a thickness of approximately 1 mm was reached, the plasma sprayed, arc sprayed, and cold sprayed coatings were applied to an aluminum alloy, which was comparable with aluminum-based material systems typically affiliated with hospital and/or medical settings. Examination of various antimicrobial copper coatings produced via thermal spray techniques in general, distinctive microstructures affiliated with each of the coatings would attain different antimicrobial efficacies based upon each of the three materials unique microstructures. Upon surveying the microstructures associated with each respective copper coated surfaces, differences in microstructure are clearly evident, suggesting that differences in biological activity may also occur.

Numerable elemental metals, including Cu, Ag, and Sn, among others, have been classified as oligodynamic. These been shown to inhibit or kill microorganisms. However, Copper has been isolated as the most actionable oligodynamic elemental metal Studied by the biological community to date.

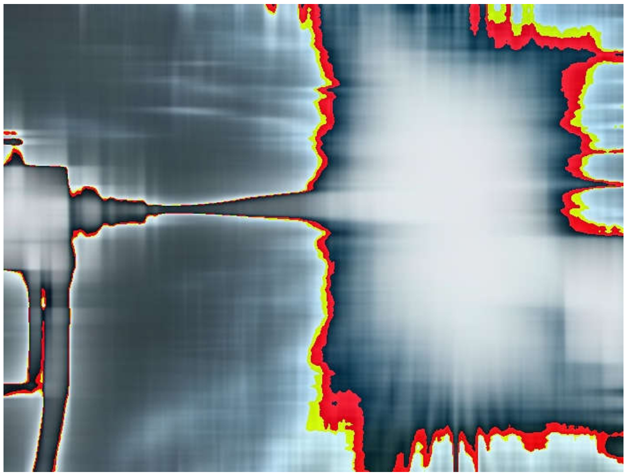
Even though Cu maintains an appreciable oligodynamic capacity, many microbial agents shown to be susceptible to copper-based contact killing, in the case of bacteria, or contact inactivation, in the case of viruses, still require trace amounts of Cu to ensure that physiological coherency and homeostasis are both maintained. More specifically, Cu acts as a critical trace metal for all aerobic organisms, wherein Cu commonly serves as an enzymatic cofactor for the catalyzation of various reactions. This is because of Cu's ability to cycle between Cu^{1+} and Cu^{2+}. An extreme example of a class of aerobic microorganism follows from the aerobic methaneoxidizing bacterium known as methanotrophs. Methanotrophs are a gram-negative and methane oxidative form of bacteria with more than thirty Cu-containing proteins. Many attempts in controlled environments to invoke methanotrophs as being a potential surrogate.

For understanding how microbes generally uptake or remove Cu in a regulated Fashion are ongoing. However, in doing so, researchers appeared to be unaware of the fact that the critical Cu-methanobactin responsible for the uptake and removal of Cu ions in methanotrophs have Been shown to be unable to be internalized by Non-methanotrophs, such As E. Coli, in contrast with the internalization of Cu-methanobactin from one Methanotroph to another. As such, one cannot consider methanotrophs as suitable surrogate microbes for garnerIng wide-ranging Cu regulation mechanisms across various pathogens.

Fenton reactions between respiration generated oxygen cold spray surfaces killed greater than 99.999% of inoculated MRSA. Two years later, in 2015, a novel nanostructured Cu cold spray surface was found to inactivate 99.3% of inoculated Influenza a virions after two hours of exposure.

Such an inactivation rate was greater than that achieved when the conventional copper cold spray consolidation was utilized, which was originally reported upon in 2013, and had reached 97.7% inactivation. These advents can be developed to be the effective action against infectious exposure as contact surfaces disinfection technology is rapidly evolving and it's mechanism is examined to help combat future pandemic prevention scenarios.

Fabricating photocatalytic materials utilizing thermal spray is a versatile surface coating technique and competitive in constructing large-scale functional coatings. The broad application of thermal spray technology is diverse and promises many opportunities to progress in capabilities and functionality.



Schoop view of metalizing

Best Master Thesis and PhD Thesis Award in The Thermalmal Spray (Annually)

An initiative has been taken to promote thermhermal spray research and its application in India. Nominations are invited for Best Master Thesis and PhD Thesis, work done in the field of thermal spray in India. Please send your entries to editor@inscience.in with followiowing details

- Scholar Name and Email address
- Supervisor Name
- Supervisor's Institute and email address
- Supervisor's Contact number
- Thesis Title
- Year of completion
- Brief summary of PhD thesis, including novelty of the work (max two page) and highlight the potential applications.
- A recommendation letter from supervisor on letterhead
- A list of published research papers based on the work

Judges from Prime Educational institutes/ National Labs/Industries will evaluate the work potential and its application. Based on the evaluation report, winners will be announced.

Copper has the potential to help in the fight against COVID-19

By **Dr. Satish Tailor**, Metallizing Equipment Co. Pvt. Ltd.,
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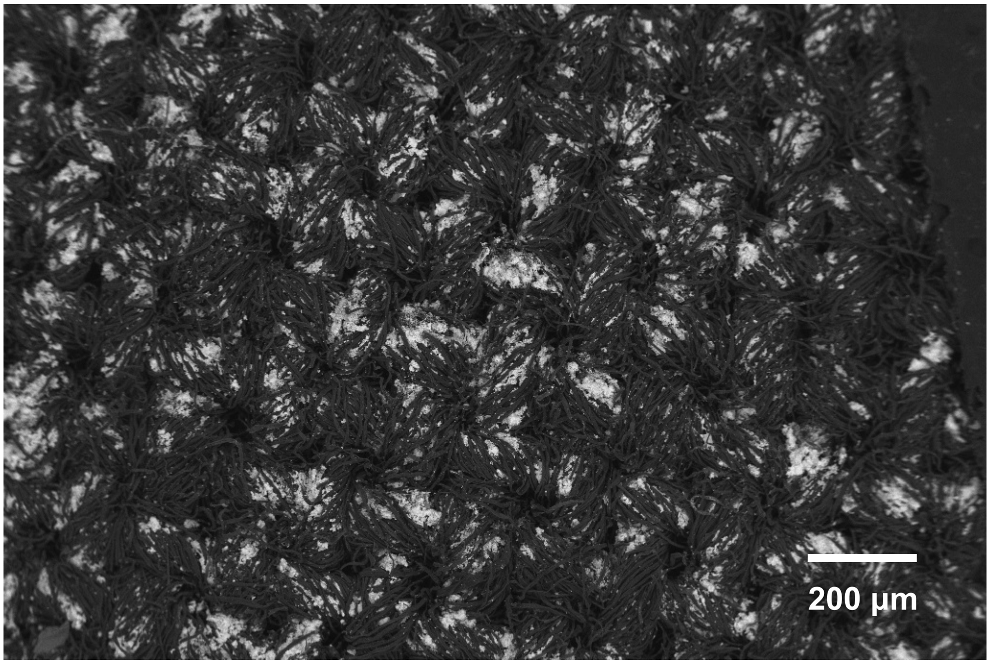
Recently Copper has been considered as antiviral material for healthcare and household applications. Copper is known for its disinfectant potential applications. Copper has the potential to help in the fight against COVID-19. A thin copper coating may help curb the spread of COVID-19 as well as other harmful bacterial infections. Also many research studies have been supported its antibacterial, antiviral and anti-fungal properties. It is reported that bacteria/virus does not stay alive longer on a copper surface than it does on fabric, plastic or metal. A recent study shows that SARS-CoV-2, the virus that causes COVID-19, was inactivated in 4 hours on 99.9% copper surfaces, but remained infective for a prolonged period on plastic and 304 stainless steel [1]. Another human corona virus knows as Hu-CoV-229E that also causes lung disorders. Six copper alloys having different Cu % (100% to 60% Cu) with Zn and Ni were tested. Study reports that rapid inactivation of Hu-CoV-229E was observed on different copper alloy surfaces within 10 minutes [2]. A very recent paper [3], published on January 2, 2021, showed that the COVID-19 causing virus, SARS-CoV-2, was inactivated by copper in as little as 1 minute. Copper is effective against both of these human corona viruses because they have very similar structures. In addition, the U.S. Environmental Protection Agency (EPA) Registers Copper Surfaces for Residual Use Against Coronavirus. On February 10, 2021, had announced that certain copper alloys provide long-term effectiveness against viruses, including SARS-CoV-2, the virus that causes COVID-19. The label of Antimicrobial Copper Alloys- Group 1 (EPA Reg. No. 82012-1), which is made of at least 95.6 percent copper. Following EPA's protocol Copper Development Association demonstrated certain high-percentage copper alloy products can continuously kill viruses that come into contact with them. EPA expects these products to eliminate 99.9 percent of SARS-CoV-2, the virus that causes COVID-19, within two hours.



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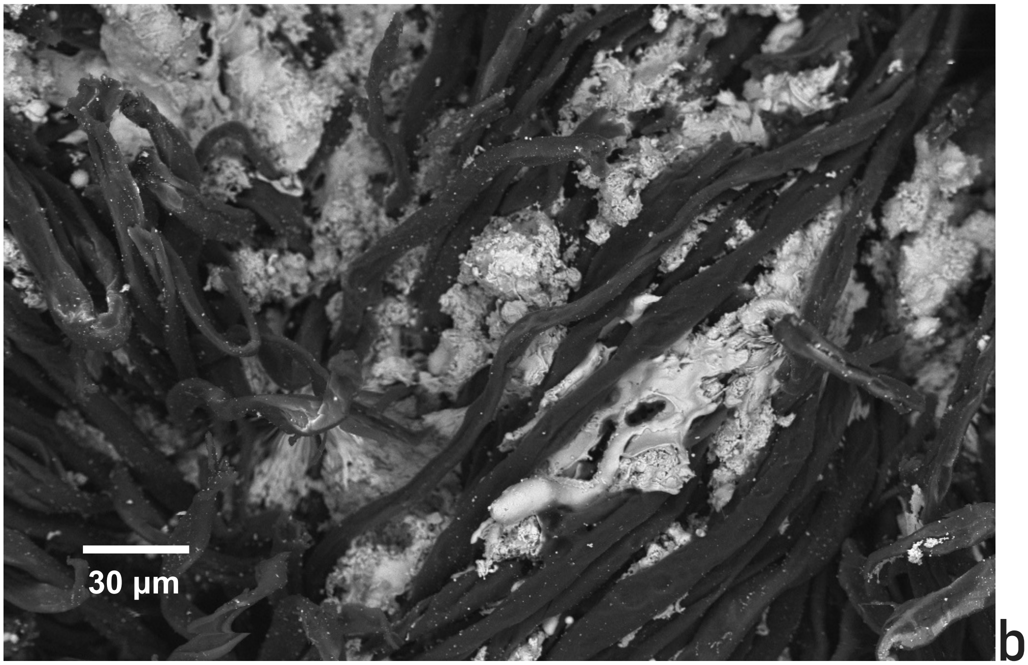

Figure 1: SEM images of Copper coated cloths
(Image Credit – MECPL R&D)

The use of antimicrobial copper alloy products supplements but does not replace standard infection control practices. Individuals should continue to follow state, and local public health guidelines, including critical precautions like mask wearing, social distancing, and ventilation.

Today, all industry sectors have demand of better, faster and cheaper methods of production of THIN copper coating <50 microns, as a result of economic or technological requirements. Thermally Sprayed THIN Copper Coating can be used for Antimicrobial, Antiviral face MASK Applications". Fig. 1 shows SEM images of a copper coated cloth. During spraying copper particles are embedded in between cloth fibers. A recent paper has discussed an effective and affordable thermal sprayed method to produce THIN copper coating [5] for wide applications such as mask, frequently touch surfaces in hospitals, schools, ships, textiles and shopping centers. A thin uniform Cu coating can be sprayed on a fabric, metal substrates by fast, easy and economical thermal spray process W-HVOF.

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Hybrid Heat Sink Manufacturing by Cold Spray Process

Hybrid heat sinks produced via cold spray technology can be a cost effective and lightweight alternative for cooling electronics.

*By **Dr. Reeti Singh**, Impact Innovations GmbH, Rattenkirchen, Germany.*
Email: info@impact-innovations.com

Electronic devices, e. g. in telecommunications and high power systems, generate heat during normal operation that must be dissipated to avoid junction temperatures exceeding tolerable limits as this can lead to performance inhibition and deterioration of reliability. It has been shown that every 10 K reduction in the junction temperature will increase the device's life and performance. Thus, maintaining the junction temperature below the maximum allowable limit is a primary issue.

The most common way to cool devices has been air/liquid cooling using a heat sink. Conventionally, copper and aluminum heat sinks are used in the combination with such cooling systems. Copper is always a preferred choice for heat sinks due to its cooling capacity superior to aluminum; however, copper's weight and cost limit the size, especially for large electronics systems. Whereas due to lower thermal conductivity, aluminum heat sinks do not spread the heat quickly enough; thus, a large surface area or taller fins are required, which is not a plausible option in many cases. Moreover, a problem arises if a heat sink is substantially larger than the integrated circuit devices it resides on. If the electronic device generates heat faster than the heat sink spreads, portions of the heat sink far away from the device do not contribute much to heat dissipation. In other words, if the base is a poor heat spreader, much its surface area is wasted. Furthermore, to connect the aluminum heat sink with electronic devices, a thermal interface material is generally used because soldering of aluminum with direct bond copper of the electronic device is difficult. Typically, this material has a very low thermal conductivity, affecting the overall aluminum heat sink's performance.

A hybrid-heat sink, combining the thermal benefits of copper with lightweight aluminum presents an exciting alternative to overcome the issues associated with conventionally available copper and aluminum heat sinks. In such a concept, the portion of the heat sink that comes in contact with the electronic device is made of copper, while the other portion is made of cheaper and lighter aluminum. However, joining aluminum and copper is a difficult challenge. Soldering and brazing is commonly used to join aluminum with copper in industrial refrigeration, air conditioning, and heat exchangers. However, there are many issues associated with soldering and brazing, such as corrosion at the interfaces and solder materials with different electrical resistance and thermal expansion mismatch.

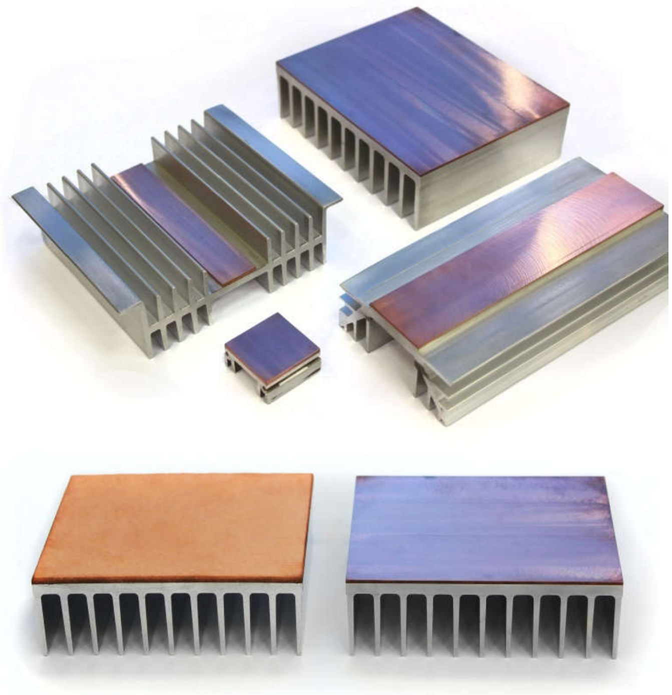


Figure 1: cold sprayed hybrid-heat sinks

The cold spray (CS) technique is an innovative solution to join copper and aluminum and overcome the issues associated with soldering and brazing. The CS-process is known to deposit the powder particles in solid-state far below the materials' melting point; thus, it can avoid common temperature-induced problems such as high-temperature oxidation, thermal stresses, and phase-transformation. Cold spray is a powder-based technology in which micron-size powder particles are accelerated in the supersonic flow of a compressed working gas through a de Laval nozzle. These powder particles impact the substrate, plastically deform, and create bonding with the substrates. CS offers short production times, virtually unlimited component size capability, and flexibility for localized deposition.

The Impact Innovations ISS 5/11 cold spray system and cold spray grade Impact's copper powder (iMatP_Cu01) were used to produce hybrid-heat sinks. A copper layer was deposited on a base plate of a commercially available extruded aluminum heat sink (as shown in Figure 1). The thickness of such a copper layer can be adjusted to the electronic devices' design and operational temperature.

When discussing a heat sink's performance, its cooling capability is typically quantified in terms of the thermal resistance, a measure of the temperature rise above ambient on the top of the device per dissipated unit of power. The lower the value of thermal resistance, the higher is the cooling ability of the heat sink. To demonstrate the performance of hybrid-heat sinks, Impact Innovations conducted experiments to compare the performance of identically structured copper, aluminum, and hybrid-heat sinks. The experiment was performed three times, each time with a different heat-sink design. Thermal impedance and thermal resistance were measured. The thermal impedance of heat sinks was evaluated by running power cycles at specific load currents heating the device until reaching the thermal equilibrium. Then the load current was switched off, and the voltage drop was recorded. When an aluminum heat sink was tested, a maximum temperature of 438 K was registered. This value corresponds to a thermal resistance of 0.7 K/W. For the copper heat sink, the maximum temperature was just 348 K, and the corresponding thermal resistance was 0.33 K/W. Testing the hybrid-heat sink, the maximum temperature was just slightly higher at 349 K, and the thermal resistance was 0.36 K/W.

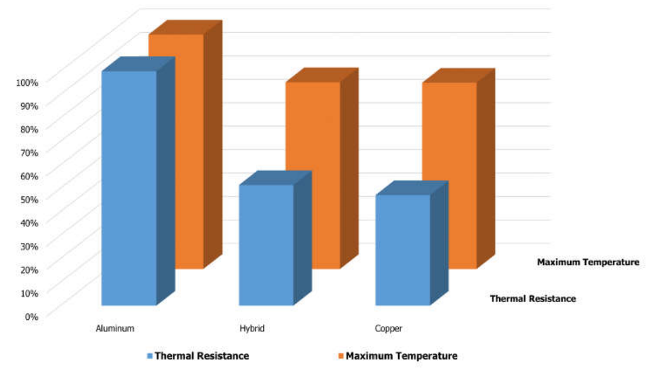
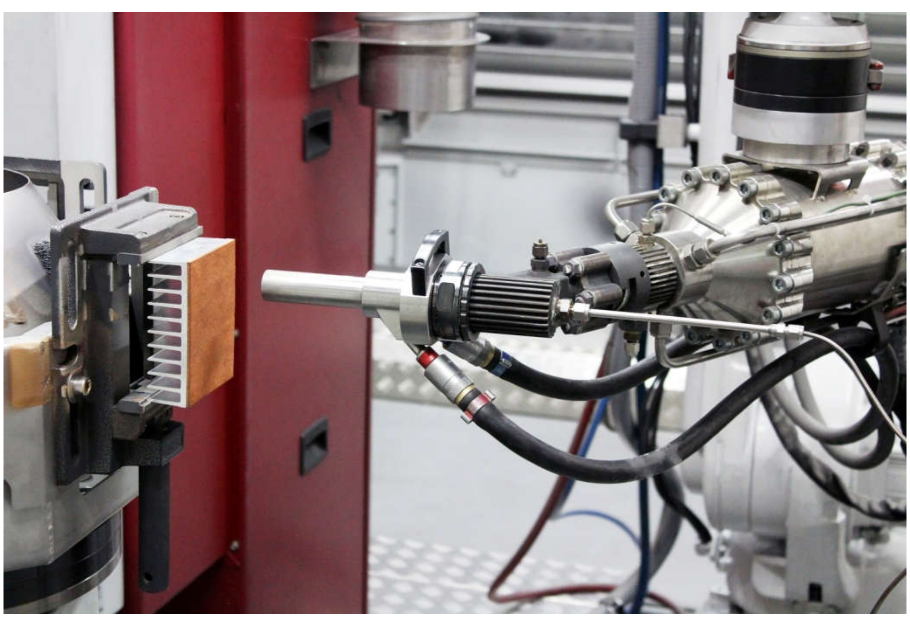


Figure 2: Thermal resistance and maximum temperature obtained at the device using aluminum, hybrid, and copper heat sinks

These results show that the copper and hybrid-heat sinks have almost identical thermal results and outperformed the aluminum heat sink in a substantial fashion, thus showing the importance of quick heat spreading along the base. At the same time, the hybrid-heat sink weighed and cost less than the copper heat sink.

Indeed, hybrid-heat sinks manufactured by cold spraying have slightly higher production cost than commercially available aluminum heat sinks; however, adding a layer of copper on an aluminum heat sink decreases its thermal resistance by 48%. This has a direct effect on the production costs since the semiconductor area can be decreased by 94%. Besides, the deposition efficiency and deposition rates of copper powder by the cold spray process are 95% (including overspray) and 10 kg/h, respectively, indicating the potential of the CS-process to realize a cost-effective large-scale industrial production.



Impact Innovations ISS 5/11 cold spray system

A Cheaper Method for High-Quality Graphene Production

The fast, low-cost method splits graphite particles into graphene flakes, showing promise for mass production

By Prof. Anup Kumar Keshri, Indian Institute of Technology Patna.
Email: anup@iitp.ac.in

Graphene has slowly made its way into sports gear, anticorrosion coatings, and even fabric face masks. But widespread use of the strong, conductive material in electronics, energy storage, and medical devices hinges on making high-quality graphene affordably and at large scale. Researchers now report an ultrafast way to peel graphene flakes a few atoms thick from graphite using a high-temperature plasma spray process (*ACS Nano* 2021, DOI: 10.1021/acsnano.0c09451).

The winners of the 2010 Nobel Prize in Physics first lifted monolayers of carbon atoms from graphite, the stuff of pencil lead, using ordinary sticky tape. That slow, painstaking method gives the highest quality graphene. Other exfoliation techniques yield very small amounts of graphene, and the material can have defects. Chemical vapor deposition (CVD), which grows materials from the bottom up, is now the leading method to make large amounts of graphene. But it requires multiple steps and remains expensive. Graphene is a compound composed of a single layer of carbon atoms linked together in a hexagonal pattern. Graphene is both extremely light and strong, and can conduct electricity, which makes it an exciting material for research in a variety of applications, such as aerospace and mobile devices. Unfortunately, it is very challenging to produce quickly and in bulk. Currently, the best way to produce graphene is to take graphite, the kind you might use in a pencil, remove a layer with regular office tape, and then separate off the single layer graphene sheets. However, this is slow and very expensive. Other methods, such as depositing vapor from a gas to form graphene or using chemical treatments of graphite, can be more efficient, but they tend to produce more impurities in the resulting graphene.

Recently, Prof. (Dr.) Anup Kumar Keshri, a materials scientist and engineer at the Indian Institute of Technology Patna, and his team developed a way to produce graphene using a plasma gun that they hope is scalable while still producing high quality material. Plasma spraying is a well-established technique for depositing metal or ceramic coatings. The method involves melting powdered coating materials in a jet of plasma—a high-temperature gas of ions—and spraying them on a surface. Plasma guns take gas-phase ions, which are charged particles, and spray them at a surface. In the case of graphene, when the ions hit the surface at a high temperature, single layers of graphene are separated from the 3-D graphite structure. A centrifuge, which spins samples quickly to separate them based on density, can then be used to separate the remaining graphite from the graphene produced and ensure high purity. This method is attractive because it can produce single-layer graphene 85% of the time without dangerous chemicals or expensive solvents.

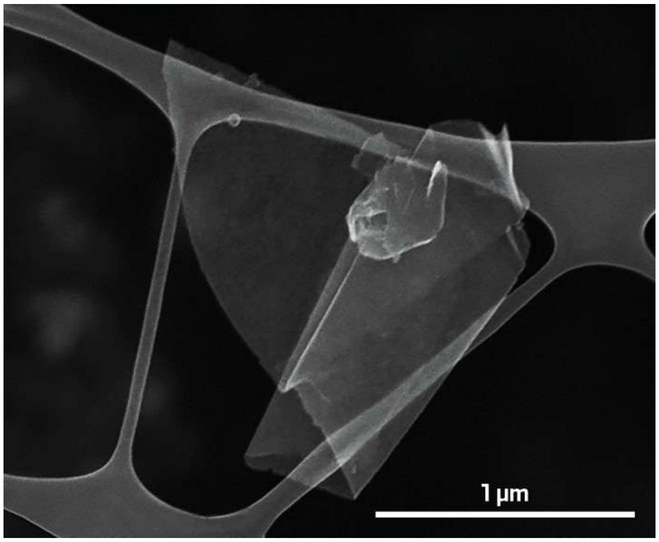


Figure 1: Scanning electron micrograph shows a flake of graphene deposited onto a carbon grid (Credit: ACS Nano)

The engineers loaded graphite particles in a plasma spray gun. The thermal shock from the 3,000 K temperature and the turbulent eddies in the resulting plume rip apart the graphite into graphene flakes. The researchers collected the sprayed powder, put it in deionized water, and spun it in a centrifuge to remove unexfoliated clumps of graphite.

Figure 2: Graphite can be split into high-quality graphene (black powder in bottles) with a plasma spray technique used to make ceramic coatings (Credit: ACS Nano)

Analysis with a variety of microscopy and spectroscopy methods showed that the graphene flakes were up to 3 µm in diameter, with 85% being a single atomic layer and the rest having a few layers. The material was free of defects and had a high carbon-to-oxygen ratio of 21, comparable to graphene made using CVD—both of which are signs of good quality. Films made with the graphene flakes were strong and had a lower electrical resistance than films prepared using graphene made with other exfoliation techniques.

The simple new method does not require any solvents, intercalants, or purification steps, Keshri says. It yields 48 g of graphene in 1 h and should be easy to scale up. The cost of the lab-made graphene is $1.12 per gram, which "is competitive or even lower than commercially available graphene," he adds, and it should go down further when mass-produced and hope to be able to scale that up to produce more of the compound in the future.

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2. Science in the News, Harvard University Blog
3. Scientific Article: Ultra-Fast, Chemical-Free, Mass Production of High Quality Exfoliated Graphene

Mr. Suresh Chand Modi

1950-2021

With profound grief & sorrow we inform that Mr. S. C. Modi, 71, Managing Director of Metallizing Equipment Company, India has passed away on 28th May, 2021. Born in Jodhpur, India. He graduated in mechanical engineering in 1971 from the University of Jodhpur. Next year 1972, he joined his family business with his elder brother Mr. M. D. Modi. He developed Surface engineering technology, in particular Thermal Spraying, Shot peening and Abrasive blasting. He has been a fellow member of American Society of Materials (ASM). He contributed several technical papers which were published in National and international magazines. He was main sponsor of Asian Thermal spray conference held in Hyderabad, India in 2014. Mr. Modi promoted a world-class thermal spray laboratory accredited to ISO 172025:2017. He attended almost all International Thermal Spray Conferences held in the past 40 years and developed close relations with the Thermal Spray fraternity worldwide. Mr. Adam Wintle, TSASA Acting Chairman said that Mr. Modi was considered as the "*Father of the Thermal Spray Industry in India*" and a mentor to many within the industry worldwide.

An obedient son of parent, Mr. S. C. Modi imbibed personal attributes of life such as noble character, integrity and truthfulness. He breathed his last at holy place of his Guru Ashram. He is survived by his wife Vandana, daughter Anubha and Son Ankur. ankur@mecpl.com

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