International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI)
An autonomous R&D Centre of Department of Science & Technology, Government of India

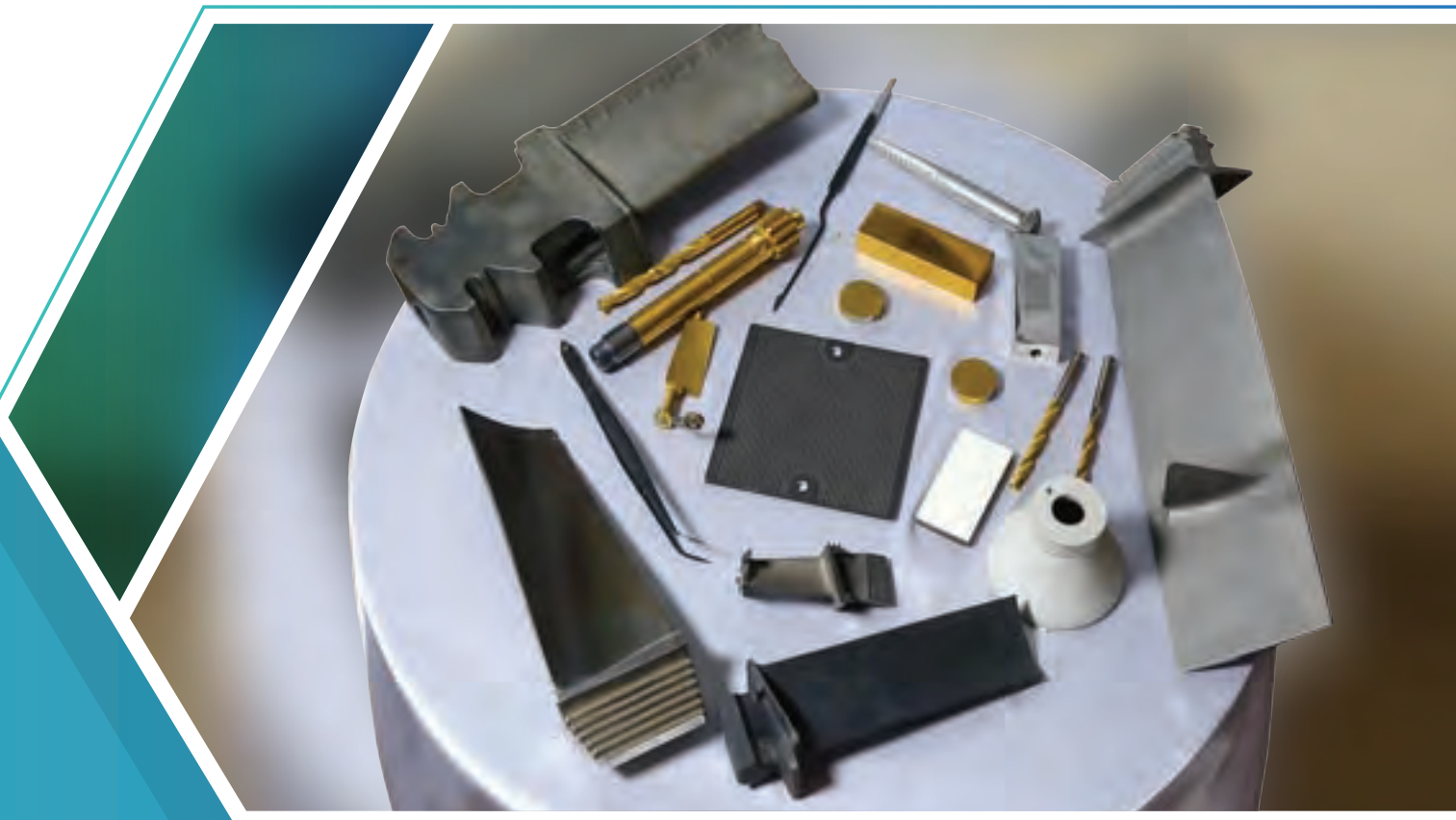
Azadi Ka Amrit Mahotsav

ONE-DAY BUSINESS OPPORTUNITY WORKSHOP ON

ADVANCED DETONATION SPRAY COATING TECHNOLOGY & COLD GAS DYNAMIC SPRAY COATING TECHNOLOGY

19th October, 2022 @ ARCI, Balapur, Hyderabad

International Advanced Research Centre for Powder Metallurgy & New Materials (ARCI) is an autonomous research and development Centre of the Department of Science and Technology, Government of India for the promotion of research as well as technology development in the area of advanced materials, including nanomaterials, energy technologies, engineered coatings, sol based coatings, laser processing of materials, ceramic processing, and powder metallurgy. ARCI has established an ensemble of the latest technologies in the above-mentioned areas and has subsequently transferred them to private industries for commercialization. Apart from this, ARCI is actively involved in the development of several advanced manufacturing technologies for a range of materials as well as components.



In the field of surface engineering, ARCI has been a globally renowned name with a rich pedigree in research and development. ARCI's Centre for Engineered Coatings (CEC) has forged ahead swiftly in the past years and maintained its pre-eminent status as an advanced surface engineering solution provider in the country by delivering on multiple fronts. In the past two decades, CEC at ARCI has significantly contributed to the science and technology in this area, which resulted in successful technology transfer of Detonation spray coating (DSC), Micro Arc Oxidation (MAO) and Electro Spark Coating (ESC) technologies to Indian entrepreneurs and academia whose success is a testimony to ARCI's excellence in this exciting field.

Thermal spray (a subset of surface engineering) has been widely used in various industrial sectors such as aerospace, industrial gas turbines, automotive, oil & gas, steel and paper-pulp industries to develop wear and corrosion resistance coating to enhance the processing capability and service life of components in harsh environments. The current world market share of thermal spay is about 11 billion USD, expected to reach 15 billion USD with an annual compound growth of 4.8% from 2022 to 2030 is an inevitable driving force for shaping up of novel research directions resulting in the development of newer technologies. Such a growth is expected to simultaneously augment the industrial demands to develop advanced processing techniques with enhanced productivity and to address the environment issues in a concurrent manner. Further, the use of thermal spray coatings is constantly increasing due to a quantum jump of aviation gas turbines in aerospace, civil and military aviation, power generation (gas and steam turbines), ships and cargo in marine and heavy machinery industries across various parts of the world.

ARCI being the leading torchbearer in India from the mid 1990's, it has contributed a lion share towards popularizing, translating, acquiring and transferring of thermal spray processes and technologies in the country. The consistent efforts of ARCI in this direction together with the creation of business friendly environment resulted in the establishment of over 20 thermal spray job shops that clearly highlights the dominant role of ARCI in the Asia-pacific region.

It is well known that the Thermal spray is a family of spray deposition processes broadly categorized based on the temperature and velocity of the powder particle prior to its impact. Detonation spray technique is one of the thermal spray variants run on propriety basis for several years. ARCI acquired the technology from former USSR, fabricated indigenously and transfer the technology to Indian industry in the initial days of thermal spray industry setup. The design has a cam mechanism with mechanical moving parts to control the process gases and backdated control panel design. Several deposition techniques were installed/established in the recent years due to increase in demand for thermal spray market.

To enhance the old system performance, meet the market demand, an advanced process gas control system with Mass Flow Controllers, PLC based programming, high firing frequency with quality firing was developed.

The present system has great technological flexibility while it can operate at 6 Hz (increased) frequency with the doubled productivity. The quality of firing that the new system offers resulted in improved coatings.

The system can deposit metals, alloys, cermets and selected oxide coatings as well. The system can run continuously for longer duration with a suitable powder feeder to deposit coatings on medium to large size components.

Application development studies that were successfully accomplished at the time of old DSC system technology transfer period are directly translated in the case of new system as well. The presence of newly designed system in the market will definitely help to deposit various wear and corrosion resistance coatings which will enhance the component life and productivity in aerospace, power generation, chemical, paper and pulp and agricultural sectors.

As the nation commemorates Azadi Ka Amrit Mahotsav, marking the 75 glorious years of India's Independence, ARCI is organizing a series of events during the year. One of the events being organized by ARCI on 19th October, 2022 is **One-day Business Opportunity Workshop on Thermal Spray Technologies** that aims to bring together leading industry personnel and potential entrepreneurs to showcase the technology: ***Advanced Detonation Spray Coating (ADSC) System*** that is ready for adaptation and transfer. The capabilities and uniqueness of the ADSC technology will be demonstrated and the associated techno-economic business opportunities will be presented and discussed. This workshop not only provides an opportunity for existing thermal spray stakeholders to expand their repertoire but also provides a platform for aspiring and ambitious entrepreneurs.

- Another novel spray deposition technique is known as cold spray; one of the thermal spray variants is also ready for technology transfer.
- The advantage with the cold spray technique is it retains the original feedstock properties without affecting the component material properties. In addition, the deposition rate is also high.
- The uniqueness of ARCI cold spray system is process gas is air, which is very economical compared to Helium and Nitrogen gases.
- Extensive efforts on the nozzle design at ARCI has resulted in a highly competent and cost effective cold spray technology. Further, the technique is very suitable for deposition of metals and alloys.
- The technique is also very well suited for repair and refurbishment of critical components to enhance their life. 3D printing of simple shapes also possible with this technique.

Cold spray at ARCI has been developed and demonstrated for various coating deposition capabilities together with prototype job work carried out to evaluate their properties in service conditions of various industrial sectors, which has led to significant revenue generation and IP. Now the system is available for technology transfer. The technical highlights and capabilities of technology will be discussed along with possible transfer during the workshop.

In the interest of industry, there will be brief talks on other deposition techniques like Pulse Electro Deposition (PED), Cathodic Arc Physical Vapor deposition (CAPVD), High Velocity Air Fuel (HVAF), Micro Arc Oxidation (MAO) and Axial Plasma Spray (APS) techniques for possible collaboration that may eventually lead to technology/know-how transfer.

Program Schedule

09:30 - 10:00	-------	Inaugural Ceremony
10:00 - 11:00	-------	Presentation on ADSC
11:00 - 11:15	-------	Tea Break
11:15 - 12:00	-------	Presentation on cold spray
12:00 - 13:15	-------	Detonation spray/Cold spray demo
13:15 - 14:00	-------	Lunch Break
14:00 - 15:30	-------	Technical Talks on other coating deposition systems and what they can offer *Micro Arc Oxidation (MAO)* *Pulse Electro Deposition (PED)* *Cathodic Arc Physical Vapor Design (CA-PVD)* *High Velocity Air Fuel (HVAF)* *Axial Plasma Spray (APS)*
15:30 - 15:45	-------	Tea Break
15:45 - 17:00	-------	Demonstration of other coating deposition facilities
17:00 - 17:30	-------	Business Networking followed by concluding remarks

You are requested to attend the workshop and make it a success

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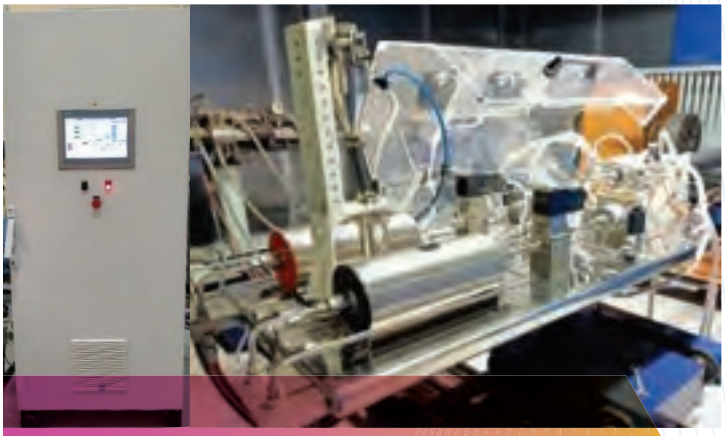
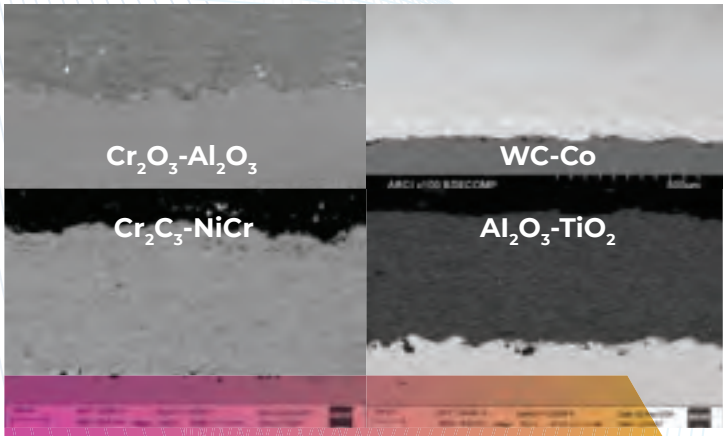
Advanced Detonation Spray Coating System (Mark II)

Detonation spray coating (DSC) technology is a popular and versatile technique to generate metallic, alloy, ceramic, and cermet based hard, dense and well-adherent coatings on the surfaces of a variety of industrial components demanding wear, corrosion, thermal, electrical and erosion resistant. In this process, the coating material, in powder form, is injected into a shock wave and propelled out from a gun barrel shot by shot.



Prototype advanced detonation spray system with control panel



Cross-sectional images of various coatings deposited by ADSC

Shaft seal drum, wire-passing pulleys, LP III blades and guide vanes coated with DSC

The series of shots/shockwaves are generated by a controlled explosion created by igniting a gaseous mixture of Oxygen and Acetylene. The high energy of the shockwave and the temperature generated by the explosion causes the powder to deposit efficiently on the desired component. By moving the component in synchronism with the powder shots, a thicker layer of the deposited powder is realized. Being a proprietary process, the Detonation spray system (Mark I) was fabricated indigenously with mechanically moving parts for gas supply in the year 1997. Subsequently the technology was transferred to various entrepreneur in India. Systems have performed exceedingly well and their contribution to the civilian and strategic sectors was outstanding. To meet the current market demand and compete with other thermal spray systems, a new version has now been developed with higher firing frequencies, longer operations, and quality firing by precise gas control.

An advanced DSC system (Mark II) equipped with PLC, HMI controls and MFCs has been designed to function at any selected frequency at 3Hz and 6Hz for a preset number of shots. The fully automated system allows the operator to select a variety of in-built recipes or design a new recipe as and when required. The integrated system is more flexible and user friendly, permits to perform a variety of user defined functions. This advanced coating system has been fully optimized, throughly tested and demonstrated in-house and is ready for technology transfer to the industries.

Salient Features:

- PLC controlled system for automation.
- Built-in feature to Import or Export recipe programs
- Display of shot number in real time
- Common Coating materials tested: Metals, alloys, cermet and oxides
- Thickness per shot: ≥ 5 µm
- Deposition efficiency: 30 – 45 %
- Low gas operating pressures: 1 to 5 bar
- Low maintenance and high safety
- Flexibility of varying process parameters
- Selectable Firing Frequency: 3 Hz and 6 Hz
- Display of consumption of gases
- Powder deposition: up to 2000 g/hr (depends on powder density)
- Porosity: less than 1%
- Good adhesion strength
- Low operational and maintenance costs

Typical Sectoral Applications:

- Power
- Textile
- Paper & Pulp
- Petrochemical
- Iron and Steel
- General manufacturing
- Cement industry
- Wire-drawing

For Further Details and RSVP, Please contact:
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Cold Gas Dynamic Spray Coating Technology

Technology Highlights

Portable Cold Spray System

System Features

- Wide material spectrum (comparable to commercial available high P systems)
- AIR as process and carrier gas
- He and N_2 can also be used
- Option of portability with widest material spectrum (see table below)
- Material or application specific nozzle(s)- USP of ARCI-CS system
- Flow- max 60 CFM and Power rating- max 10 kW (single phase)
- Commercial CS systems 30kW and above (CGT, PG > 50kW)

Parameter/ Company	ARCI-CS	CGT-2000 Oerlikon Impact	SST (Dymet)	ASB/Impact Innovation	MOOG
Temp.	1000°C	400°C	550°C	300°C	----
Pressure	20 bar	20 bar	17.2	20 bar	----
Materials	Cu, Zn,Al, Ag, Ta, Nb, Ti, Sn, Ni, Ni-Cr Bronze, Brass, SS316L, MMCs#	Cu, Zn, Ag, Al	SST Powders	Al, Cu, Ti,Ta, SS316L and MMCs#	Cu, Zn, Ag, Ta, Nb, Ti, Sn, Bronze, Brass, Monel, Inconel, SS316L, Zr#
Gas	AIR	N_2	AIR/N_2	AIR/N_2	AIR/N_2
Portability	Yes	----	Yes	Yes	----

Nozzle Design

Different Sets of Nozzles

Throat Area

- Low choke flow rate
- Low power consumption at a given P,T
- Regulated rate and size of deposition

Expansion Ratio (M_G)

- Gas Mach number increase
- Gas Velocity increase
- Particle acceleration more

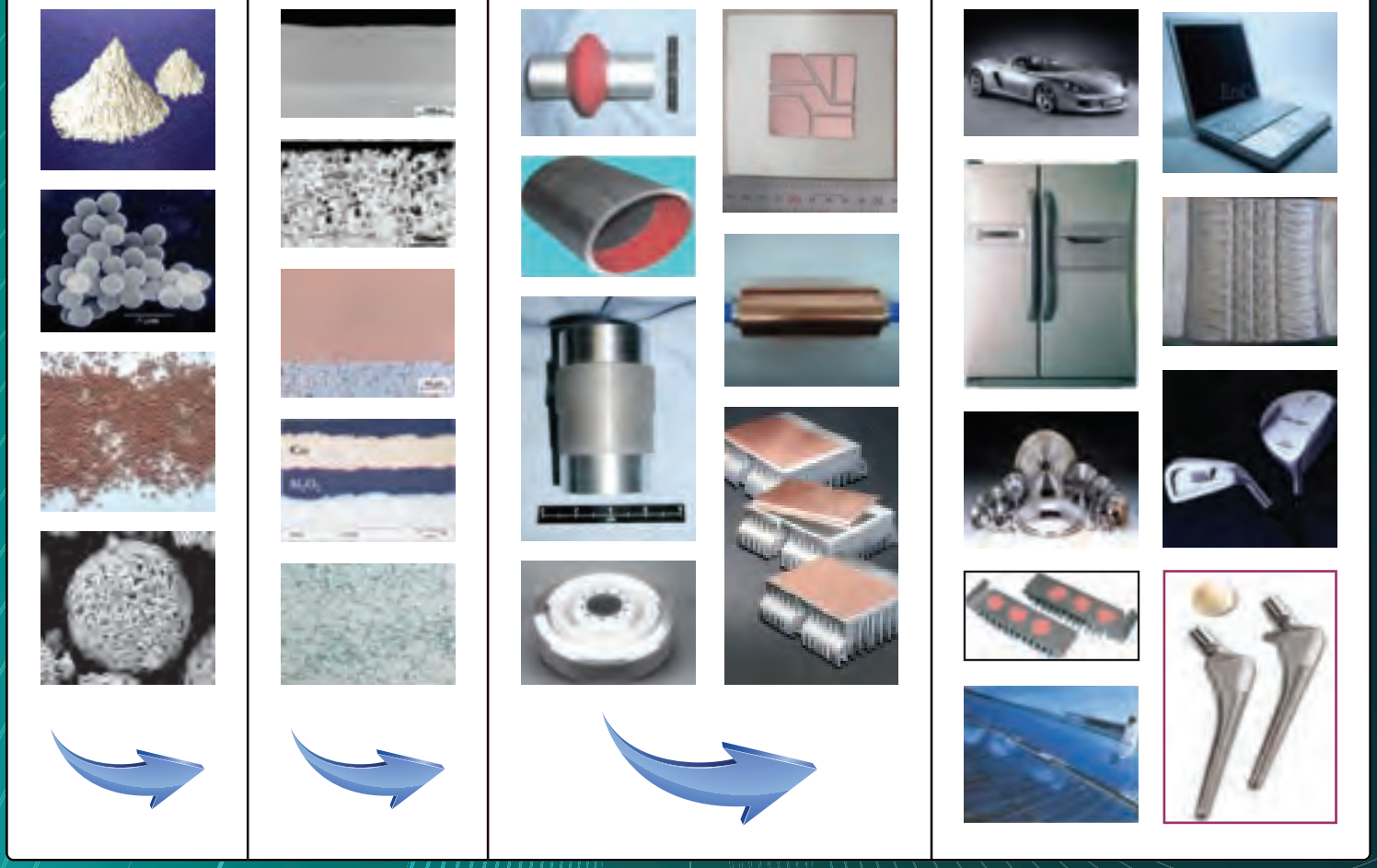
Convergent Length

- Higher particle residence time
- Deposition of high 'm' materials (Ni, Ni-Cr, In 625)

A combination of all three features enables deposition of Ni, Ni-Cr, steels and superalloys by attaining parameters of 20 bar , 500-1000°C

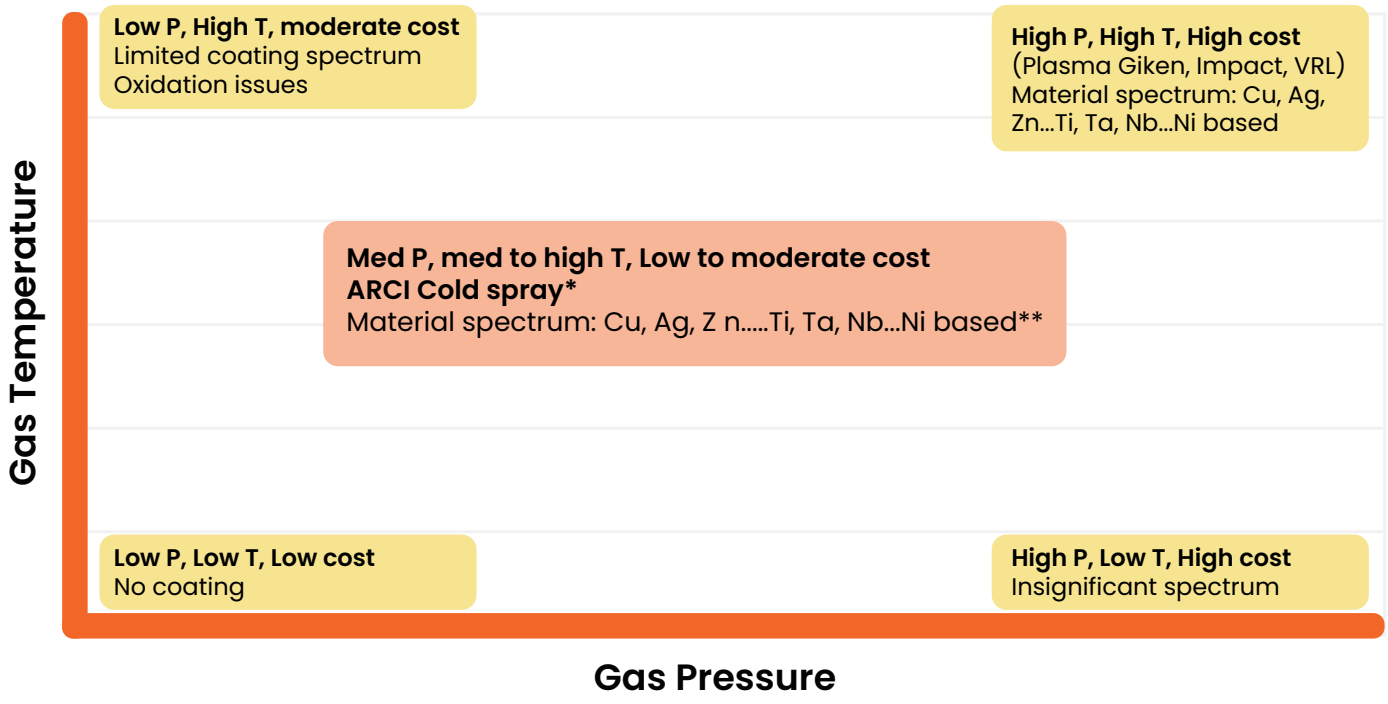
Polymer and C based nozzles for Aluminum and other low melting materials

Process to Application Map



Coating Materials	Potential Applications
Cu	Electrical contacts, lugs, EMI shielding
Ag	Electrical Conductivity, Corrosion, High T oxidation resistance/Cu lugs, contacts (high current), decorative
Zn	Galvanic protection/ cathodic protection of steels
Ta	High Temp Corrosion resistance, Bio medical, Sputter Target
Nb	High Temp Corrosion resistance, Bio medical, Sputter Target
Ti	Corrosion resistance, Bio medical
Sn	Electrical Contacts
Steel	Structural and Corrosion resistance
Ni, Ni-Cr, Inconel	Hot Oxidation
W / Cu	Heat Sink applications.
Brass	Strength, Conductivity (thermal and electrical), Corrosion resistance Architectural fascias,, Electrical Terminals, Anti Microbial surfaces
Bronze	Oxidation, corrosion resistance (sea water), Low coefficient of friction/Bearing, Bushings and electrical connectors
Aluminium	Repair & Refurbishment, Corrosion resistance
High Entropy Alloys	High Temperature Applications

Technology Capability Map



* Possible due to extensive work on nozzle design and AIR as process gas
** Details of property comparison given below

Comparison of Properties

S No	Coating	Substrate	Gas	Pressure	Temp.	System	Standard	Bond strength (MPa)	Remarks
1	Aluminum	Al2O3 Si3N4 SiC AlN	Nitrogen	28	350	CGT 3000	DIN EN 582	12, 18 26 , 42	HTK - -Ultrabond 100 UTM
2	Copper	Copper Aluminum Mild Steel SS	Nitrogen	25 30	200 250 300	---	H8664 Japan Standard	15-25	Nitrogen
3	7075 Al alloy	7075	Nitrogen	---	400	Kinetic Metallization	ASTM C-633	5-10	Thickness effect
4	Al alloy Al-SiC Mg alloy	---	Nitrogen	30	500	CGT 3000	ASTM C-633	14 18	---
5	Zinc	Mg alloy	Nitrogen	25 30	260 290 260	Home made Beijing Univ.	ASTM C-633	25 30 27	100-300 micron
6	Al	7075	Nitrogen/Air	6	400	SST	ASTM C-633	45	100-200 mic.
7	Al	Al	Air	20	400	ARCI	ASTM C-633	23	~ 500 mic
8	Zinc	Steel	Air	20	350	ARCI	ASTM C-633	22	~800 mic

- Ni-Cr and Ni-WC with ARCI system gave 22 MPa and 55 MPa respectively
- Cu coating with ARCI system gave ~80%IACS conductivity at 20 bar 600 C as compared to 50 bar and 600 C developed using a competing system.

ARCI CS Powder Spectrum

S No	Coating Material	Process Parameters	Electrical Conductivity (MS/m)	Corrosion Rate (MPY)	Modulus (GPa)	Porosity (%)	Wear Rate	Hardness (HV)
1	Copper (Pometon)	10-22 bar 250-450 C	7-21	---	---	0.05-3	---	73-118
2	Copper (Ecka granules)	10-20 bar 400-600 C	19-45	1.76-5.05	71-117	0.05	---	102-156
3	Cu-2.2Al (Valimet)	20 bar 400-450	7.5	---	---	0.9	---	175
4	Cu-7.5Al (PAC)	20 bar 450 C	3.25	---	---	1.2	---	185
5	Cu9Al1Fe (PAC)	20 bar 600-800 C	---	---	---	---	---	224-311
6	Cu-Al2O3 (Thermo)	20 bar 450 C	19	---	---	0.09	---	200
7	Cu-W (Potmixed)	20 bar 450 C	16-21	---	---	---	3.7-9.2 e-4	135-165
8	Cu-Ta (Potmixed)	20 bar 450 C	13-15	---	---	0.09	3.7-9.2 e-4	160-200
9	Cu-Mo (Potmixed)	20 bar 450 C	6-9	---	---	---	3.7-9.2 e-4	130-155
10	Zinc (Innomet)	20 bar 350 C	---	16.8	62	0.47	---	56
11	Zinc (Grillo)	20 bar 250-350 C	---	2.36-4.06	78-89	0.25	---	37-43
12	Silver (Innomet)	10-20 bar 250-450 C	35-44	---	35-44	0.09-0.34	---	110-130
13	Tin (SRL)	---	---	---	---	---	---	---
14	Aluminum (Valimet)	20 bar 450 C	---	---	37	---	---	---
15	Aluminium (Ecka)	20 bar 450 C	---	---	42	0.3-0.9	---	40-68
16	Al-Si (Ecka)	20 bar 450 C	---	---	---	0.87-1.06	---	126-142
17	Al-10MgSi (Gururaj)	20 bar 450 C	---	---	---	0.9-1.2	---	125-139
18	Al-2024 (Valimet)	20 bar 450 C	---	---	---	0.42	---	174
19	Al-6061 (Ecka)	20 bar 450 C	---	---	---	0.16	---	116
20	Al-7075 (Valimet)	20 bar 450 C	---	---	---	0.89	---	152
21	Al-SiC	20 bar 350 C	---	---	57-75	---	23-37.5 e-4	58-88
22	Nickel (Sandvik)	15-20 bar 600 C	---	0.92-1.37	113-152	0.11-0.84	---	178-206
23	Nickel (Praxair)	15-20 bar 600 C	---	0.92-1.37	113-152	0.11-0.84	---	178-206
24	Nickel (Amperit)	15-20 bar 600 C	---	0.92-1.37	113-152	0.11-0.84	---	178-206
25	Ni-20Cr (Amperit)	20 bar 600-800 C	---	---	---	0.43-1.13	---	241-287
26	IN-625 (ARCI)	20 bar 600-800 C	---	0.43-0.87	92-127	0.38-0.80	---	322-361
27	IN-718 (ARCI)	20 bar 600-800 C	---	0.39-0.94	104-128	0.17-0.32	---	297-393
28	SS316 (Praxair)	20 bar 475 C	---	4.55	98	0.8	---	292
29	Ni-WC (Amperit)	20 bar 600 C	---	5.974	165-205	---	19 e-4	480-620
30	Ni-B4C (Mixed)	20 bar 600 C	---	6.25	---	---	3-16 e-4	298
31	Titanium (Medicoat)	10-20 bar 450 C	---	0.22-9.54 Dense-porous	51.5	0.12	---	132
32	Ti-6Al(Hoganas)	20 bar 450 C	---	---	---	---	---	---
33	Tantalum (Inframat)	20 bar 450 C	---	10.10	102	0.28	---	376
34	Niobium (Amperit)	20 bar 450 C	---	0.72-2.45	75	0.23	---	147

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