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ACTIVE SCREEN PLASMA NITRIDING (ASPN): AN ENVIRONMENTALLY FRIENDLY PROCESS (A REVIEW PAPER).

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ABSTRACT
In times like this when the environment has become a matter of concern to all living on planet earth. It is just proper to encourage the use of technologies that will not further impact negatively on the planet. Today world leaders are battling with the problem of global warming, environmental pollution, and degradation. We need to give them our support to save planet earth. This paper has examined a relatively new technology called Active Screen Plasma Nitriding (ASPN). It is a technology which is economical and environmentally friendly. The paper has compared the technology with other existing nitriding or nitrocarburizing equipment or processes. ASPN is economically and ecologically friendly and safe. ASPN makes nitriding of stainless steels easier and more efficient and it is suitable for nitriding small articles in bulk.

KEYWORDS: Active screen, Plasma, Environment, Nitriding, Friendly process, and New technology.

INTRODUCTION

Active Screen Plasma Nitriding Furnace is still under development in Japan. Those in current use in the country were bought from Australia. Researchers in Japan are working on developing it locally and to change the colour of the products processed using this furnace [Shibata, 2008]. This same kind of approach can be adopted here in Nigeria. Active Screen Plasma Nitriding (ASPN) is a novel alternative for plasma nitriding, and J.N. Georges was the inventor of the active screen technology at plasma metal SA Luxembourg. This novel active screen technology was first presented for the first time at the International Federation of Heat treatment and Surface Engineering Congress in Melbourne November, 2000. Since then several authors like Prof. Tom Bell, Prof H. Spies and Prof. H. Biermann, and Prof. D. Doyle had both published several papers [Shibata, 2008] regarding this novel and innovating technology. Furthermore the European Community decided to allocate the CRAFT project G5ST-CT-2002-50324 to investigate on ASPN surface engineering of austenitic stainless steel components [Shibata, 2008].

The active screen, on which plasma is applied, radiates heat to the workload. The latter is brought to the desired temperature under vacuum. The active screen generates highly energized species, which are directed on the workload by gas flow and bias. The use of plasma technology in furnaces today is on the increase and one of the reasons is because less heat is generated; causing the components to retain their shape after the nitriding process. Active screen plasma nitriding is a further improvement of the plasma nitriding process. Apart from the conventional nitriding other nitriding processes include; gas carbonitriding, plasma carbonitriding , direct current plasma nitriding (DCPN), ASP nitrocarburizing, plasma nitriding, and salt bath nitriding [Kondo, 2008]

The issue of the environment has become very important, in the words of Kyazze [Umolu, 1995] ‘’we at UNESCO are convinced that the depletion of, or disrespect for the environment is one of the most crucial problems facing human kind today. We are also convinced that the global change is largely a result of man’s abuse of the environment. We know that environmental issues can only be dealt with effectively if tackled globally, and internationally. The air, the seas, oceans, and rivers are never, limited to national boundaries”. These words no doubt stress the need for processes like the ASPN which is environmentally friendly.

The objectives of this paper are to explain the principle of operation of the ASPN process and to stress the importance of using environmentally friendly processes in order to save the environment from the current state of abuse by man.

NITRIDING PROCESS

Nitriding process is a heat treatment to diffuse nitrogen into steel. By nitriding steel, steel surface hardens to form nitrides (Al_xN, Cr_xN, V_xN,…) This imparts improved abrasion resistance to the surface of the steel and also corrosion resistance and fatigue strength. The nitriding temperature is less than 873K (600ºC). This process does not need surface hardening by quenching as carburizing [INM, 2008]. Table1, shows the comparison of nitriding processes, from the table it can be seen that the plasma techniques have good characteristics. The diagram of the structure of nitrided steel is shown in figure1. The diagram illustrates the structure of a nitrided steel showing the compound layer, diffusion layer and the substrate.

Table 1, Comparison of Nitriding Processes [INM, 2008]

		Plasma nitriding	Salt bath nitriding	Gas carbonitriding	Gas nitriding
Atmosphere		Gas(in low pressure)	Liquid	Gas (in atmospheric pressure)	Gas (in atmospheric pressure)
Adaptation for steels		All steels	All steels	All steels	SACM,SCM
Nitriding temperature		623k	823k- 873k	823k-853k	773k-803k
Heating method		Grow discharge	Heater outside chamber	Heater outside chamber	Heater outside chamber
Nitriding time		15min- 100hr	15min-3hr	15min-3hr	<100hr
Source		N_2 +H_2 mixture gas	XCN-XCNO(X= K, Na)	NH_3 gas, R_X gas	NH_3 gas
Partial nitriding		Easy	Difficult	difficult	Difficult
Control of nitriding		Discharge current and voltage. Easy	Ratio of salt and research salt difficult	Degree of separation of ammonia. commonness	Degree of separation of ammonia. commonness
Distortion of steel after nitriding		Small	Larger	Larger	Larger
Cleaning after nitriding		Unnecessary	Necessary	Necessary	Unnecessary
Assessment of the environment	Waste liquid treatment	Unnecessary	Necessary	Necessary	Unnecessary
	Cleaning of toxic wastes	Unnecessary	Necessary (salt)	Necessary	Unnecessary (exhaust gases)
Working conditions		Very good	not good	not good	Not good
Porous layer of surface		Not formed	Easy formation	Easy formation	Formation
Control of ε and ŕ layer		possible	impossible	impossible	impossible
consumption	Gases	Very small	-	large	Large
	Electricity consumption	smaller	Large	large	Large

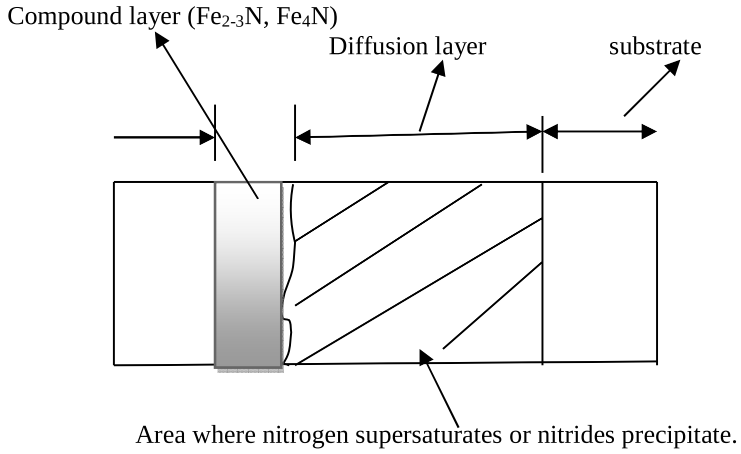


Figure1: Diagram of Nitrided Steel in Cross-section.

Plasma Nitriding

During nitriding nitrogen diffuse into the surface of steel or iron to form iron nitrides and a diffusion layer. It is possible to achieve nitride level and thickness of nitriding layer by controlling nitrogen ratio in mixture of gases the nitriding temperature is from 653K- 873K. Plasma nitriding can select the nitriding part of works easily, it can also easily nitride stainless steel and titanium. This plasma technology applies plasma of non-equilibrium state to heat treatment. The plasma of non-equilibrium state is created by abnormal glow discharge [NDK INC, 2008a].

Table 2: Surface Treatments using Direct Current Glow Discharge

Treatment	Source gases	Process temperature	Characteristic (merit)	Adaptation of steel grade
Plasma nitriding (ion nitriding)	N_2, H_2, Ar	673k-823k	*low temperature *no oxidizing treatment *easy masking *Nitriding of stainless steel *nitriding of Al, Ti, etc *pollution-free and good condition for workers. (small H_2S consumption) *Easy operation *Easy variable treating condition	SPCC, SKD11, SKD61, Ti, SCM, SKH51, SACM
Plasma carbonitriding	N_2, H_2, Ar, CH_4	773K- 853K		SPCC, SS, SC
Plasma sulf-nitriding	N_2, H_2, Ar, H_2S	773K-853K		SKD61, SCM, SACM, SUS, SK, SC, SS SUS, Ti
Plasma carburizing (using HCD)	N_2, H_2, Ar, CH_4	1073K-1273K		Ti, SUS, Cr
Radical nitriding (using external heating)	N_2, NH_3, Ar	673k-773k		SKH51, SKD11, SKD61

Ion Nitriding

Ion nitriding also has a long history; in 1920 Franz Skaupy of Germany invented a heating furnace which utilized the heat of ion discharge in inert gas. Also for nitriding, Egan of America proposed an ion nitriding method which use arc discharge or corona discharge in NH_3 gas or N_2 gas at the atmospheric pressure, but did not succeed with the method. In 1932, Bernhard Berghaus of Germany invented the ion nitriding method utilizing glow discharge. This method which causes glow discharge by putting N_2 gas or NH_3 gas in a vessel kept at low pressure was initiated by the recognition of the advantage of nitriding treatment in ionized gas [NDK, 2008b]. Table 2 shows surface treatments using DC glow discharge which is the fallout of the breakthrough by Bernhard Berghaus [NDK, 2008b].

Radical Nitriding Process

Radical nitriding was co-developed by NDK and Sumitomo metal mining co. ltd. This is plasma nitriding method based on a new idea. The process produces flat and smooth surface condition. No compound layer. It is applied to the duplex surface treatment with PVD. The specimen is nitrided with NH radical using electrical discharged energy which is small in size compared to plasma nitriding [Neturen, 2008].

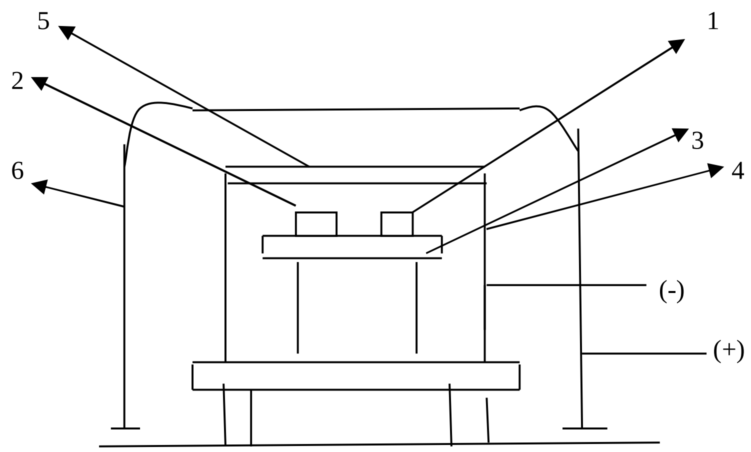
ENVIRONMENTAL CONCERNS

Man's activities and industrialization has continued to exert harmful impact on the environment and is now threatening the very existence of living things on the planet earth. A CNN documentary on the impact of man's activities on earth has it that aquatic life on the rivers, seas, and oceans is drastically reducing [CNN, 2008]. There is global warming, and polar ice is melting very fast. Recent findings about the ozone layer depletion, polar ice melting, and depletion of the polar bears are alarming. This has informed the attention being given to the environment by countries like USA and China who hitherto have been adamant and indifferent to the call by environmentalist that the earth is in peril.

Every attention is now given to actions and production activities that are eco-friendly. It is now the stand of many countries including Nigeria to eliminate processes, actions and activities that would further aggravate the damage that has already been done to the planet earth. According to Kyazze [Umolu, 1995] ''we at UNESCO are convinced that the depletion of, or disrespect for the environment is one of the most crucial problems facing humankind today. We are also convinced that the global change is largely a result of man's abuse of the environment we know that environmental issues can only be dealt with effectively if tackled globally, and internationally. The air, the seas, oceans, and rivers are never, limited to national boundaries." In the words of A.B. Boveri the balance between mankind's needs and the conservation of the natural resources of our planet depends on clean and efficient technology [Umolu, 1995]. These words therefore stress the need for uses of eco-friendly processes and technology across the globe.

ACTIVE SCREEN PLASMA NITRIDING (ASPN): AN ENVIRONMENTALLY FRIENDLY PROCESS.

The novel active screen technology was presented for the first time at the IFHTSE congress in Melbourne November, 2000. Since then authors like Prof. Tom Bell of the university of Birmingham (UK), Prof. H. Spies and Prof. H. Biermann of the Bergakademie Freiberg Demark, and Prof. D. Doyle of Swinburne university of technology , Melbourne Australia have each published several papers [Shibata, 2008] regarding this novel and innovating technology. Furthermore the European community decided to allocate the CRAFT project G5ST-CT - 2002-50324 to investigate on ASPN surface engineering of austenitic stainless steel components [Shibata, 2008]. Figure 2 shows a schematic diagram of active screen plasma nitriding equipment. The plasma is applied to the screen and no longer to the parts; in industrial equipment a bias is applied to the parts in order to direct the active species to the work-load [Shibata, 2008]. Figure 3 shows the industrial version of ASPN, while Plate 1 shows the ASPN on the workshop floor.



1. *Sample 2. Dummy shape for temperature control 3. Isolated sample table 4. Mesh cylinder cathode 5. Top lid cathode 6. Furnace wall anode*

Figure 2: Schematic Diagram of Active Screen Plasma Nitriding Equipment.

The Role of the Active Screen

Active screen plays the following important two roles:

1. The active screen, on which plasma is applied, radiates heat to the work load. The latter is brought to the desired temperature under vacuum.
2. The active screen generates highly energized species, which are directed to the workload by gas flow and bias.

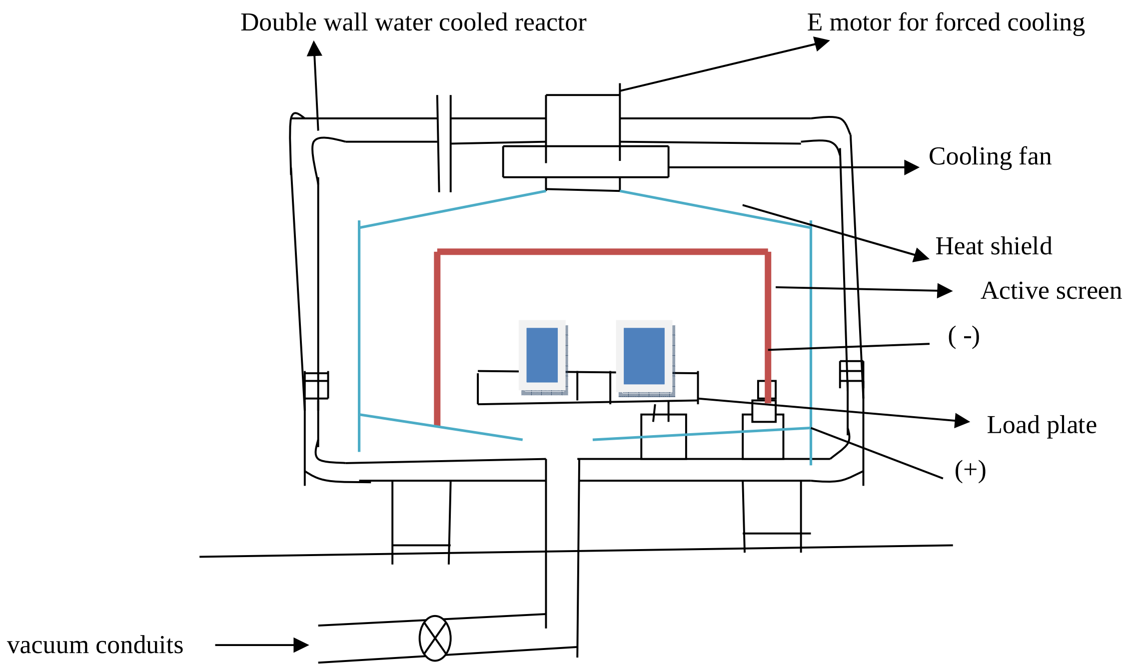


Figure 3: Shows the Industrial Version of ASPN

Plate 1: Shows the ASPN on the Workshop Floor

Comparing DC Plasma Nitriding and ASPN

In a study conducted by C.X. Li, Tom Bell, and H. Dong they both discovered that ASPN has a slightly bigger compound layer than DC Plasma nitriding. This is shown in figure 4. The studies also showed that nitrogen in-take is higher in ASPN, which confirms the correctness of figure 4. This is illustrated in figure 5, which is the plot of nitrogen (wt.%) versus depth (чm). ASPN curve is higher than that of DCPN [Shibata, 2008]

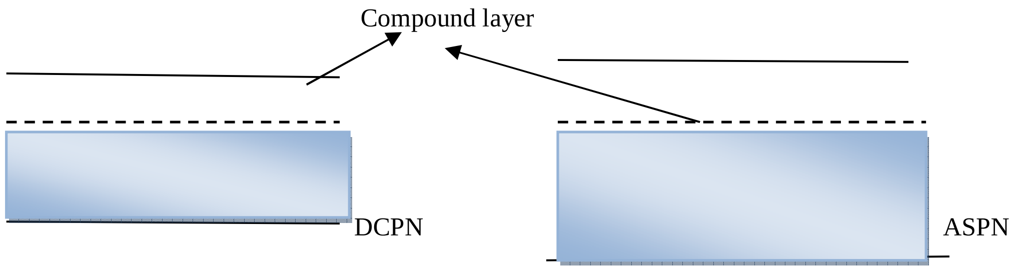


Figure 4: Comparing the Compound Layer of DCPN with that of ASPN

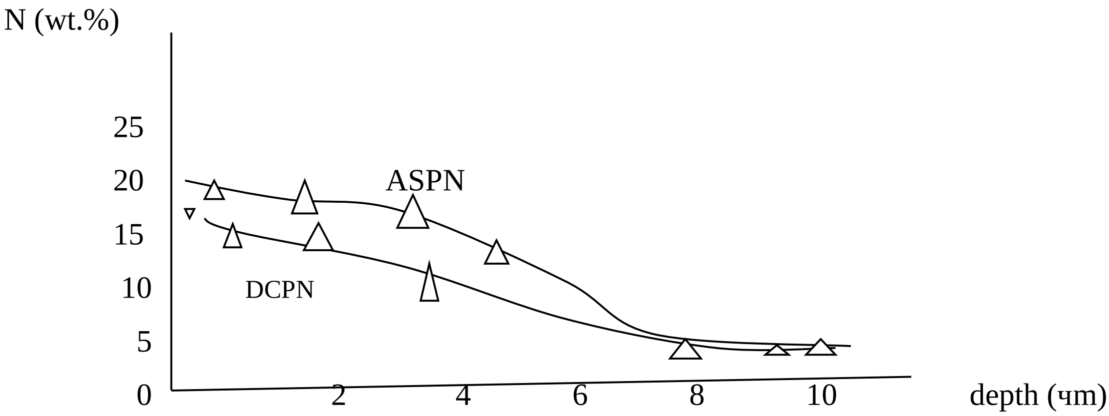


Figure 5: Nitrogen Distribution in New Surface of AS and DC Plasma Nitrided 722M24 Steel

X- ray diffraction patterns of a DC and AS Plasma nitrided 722M24 sample surface showed that both consist of a mixed structure of gamma prime and epsilon, however it seem that ASPN facilitates the formation of epsilon layer. Hardness profiles of both DCPN and ASPN are identical in test conducted [Shibata, 2008]. ASPN may replace any other plasma assisted nitriding or nitrocarburizing equipment.

ASPN Mix Load Examples

Different items can be nitrided using ASPN this include: small size gears the system can take about 23,000 piston rings at the same time, hydraulic parts, and other parts are nitrided with no edge effects and no decolouration of the parts. It is possible to also mask parts in areas where nitriding is not required.

ASPN Nitriding of Stainless Steels

ASPN nitriding of stainless steels can result in the formation of an S-phase, this is a solid solution of nitrogen. It is essential not to form CrN as in this case the steel will no longer remain stainless. S-phase layers have a thickness of up to 10 microns and a hardness of up to 1000HV0.1. S-Phase is a good solution for problems, where corrosion resistant steels also need to be wear resistant. The fields of application are numerous, e.g. medical, food, chemistry, aviation, space, etc. Tests have proven that the S-Phase treated austenitic steels have a better corrosion resistance than untreated steels. The work done under the CRAFT project G5ST-CT-2002-50324 [Shibata, 2008] has clearly proven that the ASPN technology is actually the sole technology which gave the best results compared to all today known nitriding technologies.

S- Phase can be realized not only with nitrogen, but it is also possible to do s-phase with carbon and nitrogen. Furthermore it is possible to do carbon S-Phase. The nitro-carbon s-phase is a duplex layer having excellent wear and corrosion properties this process is patented by NITRUVID, France. This very process ASPN carburizing can be used for carburizing of medical implants [Shibata,2008].

ASPN Bulk Nitriding of Small Articles

As there is nearly no plasma applied to the parts, logically no severe (damage) arcing, hollow cathode, etc can occur. It is therefore obvious to imagine a tumbling system, able to slowly move small articles, in the highly energized species atmosphere of an ASPN. Indeed the bulk nitriding system is suitable for parts of all kinds of steels. The nitriding can be achieved with or without compound layer. Stainless steel parts, nitralloy, 4140 steel parts etc can all be bulk nitrided using ASPN [Shibata, 2008].

ASPN and Economy

The process is economical for the following reasons:

- ASPN needs only 60 to 200L/ h gas mix
- ASPN needs no ammonia
- ASPN allows mixed loads
- ASPN allows very dense charges
- ASPN allows mechanical masking
- ASPN needs no skilled operator
- ASPN works fully automatically
- ASPN is equipped with forced cooling
- ASPN accepts steam cleaned parts.

ASPN as an Environmentally Friendly Process (Eco-friendly)

One can claim that ASPN does no harm to the environment. Indeed ASPN only uses pure gases like nitrogen, Hydrogen, methane, oxygen, argon. The unused gases are released to the atmosphere through the vacuum pumping system. ASPN further needs no effluent burning systems. ASPN nitriding uses only 10% gas as compared to gas nitro-carburizing equipment.

Table 3 Comparing Effluent Emissions of Gaseous Nitrocarburizing and ASPN Nitrocarburizing.

	Plasma	Gaseous	Reduction (%)
Amount of gas used, m^3/ h	0.6	6.0	90.00
Total carbon emission via CO/CO_2, mg/m^3	504	137253	99.63
Total amount of NOx gas, mg/m^3	1.2	664	99.82
Output of residual C-bearing gas, mg/h	302	823518	99.96
Output of residual NOx gas mg/h	0.72	3984	99.98

Table 3 clearly shows that effluent emissions from ASPN nitrocarburizing are far less low than emissions from gaseous nitrocarburizing equipment. The process is therefore environmentally friendly and it is recommended for a world like ours which is already experiencing the effects of global warming [Imevbore, 1995]

ASPN is Safe

The plasma reactor is not considered as a pressurized chamber. The top of the chamber only rests on the bottom part and is kept closed by vacuum. No ammonia reservoirs are needed. The system is computer controlled and a possible failure of a component is immediately detected and a safe shut- down takes place.

CONCLUSION

The issue of environmental degradation, pollution, and global warming has become a very serious problem to the entire world. This calls for the use of technology that is environmentally friendly to cut-down on the harm already done to the earth. ASPN is one of such technology, after analyzing it we have safely drawn the following conclusions:

- ASPN may replace any other plasma assisted nitriding or nitrocarburizing equipment.
- ASPN is economically and ecologically friendly and safe.
- ASPN makes nitriding of stainless steels easy and more efficient
- ASPN is suitable for nitriding small articles in bulk

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