Hard Coating is Because of Oppositely Worked Force-Energy Behaviors of Atoms

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Abstract –Coatings of suitable materials having thickness of few atoms to several microns on the viable substrates are the basic need of society and they attend the regular attention of scientific community working in various fields of science and technology. Decorative and protective coatings, transparent and insulating coatings, coatings of medical implants and surgical instruments, coatings for drug delivery and security purposes, ultra-precision machine coatings and coatings of miscellaneous uses are in the routine demand of research and commercial objectives. Different hard coatings develop under the significant composition of differently natured atoms where their force-energy behaviors as per recovering of transition states provide the provision for electron (of outer ring) belonging to gas atom to undertake another clamp of unfilled energy knot (of outer ring) belonging to solid atom. Set process conditions switch force-energy behaviors of differently natured atoms as per set process conditions where they worked differently to the original state behaviors. Different natured atoms develop structure in the form of hard coating by locating the ground point between original points where gas atoms increase potential energy under the decreasing levitational force at electron-level while the solid atoms decrease potential energy under the decreasing

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gravitational force at electron-level. Ti-atom to Ti-atom binding is through the difference of expansion of their lattices when one atom is just landing on the already appropriately landed atom where the adhered nitrogen atoms come nearly at their interstitial sites. Under suitable set parameters, different natured atoms deposit in the form of coating at substrate surface under the given conditions depending on the source-behavior of their ejecting or dissociating associated to employed technique. In random arc-based vapor deposition system, depositing different natured atoms at substrate surface depends on the input power where involved non-conserved energies engaged the non-conservative forces to keep their structure adhered. Different properties and characteristics of hard coatings emerged as per engaged forces under the set conditions of involved energy. The present study sets new trends not only in the field of coatings but also in the diversified class of materials and their counterparts, wherever, atoms recall their roles.

Keywords: Atomic behavior; Hard coating; Expansion and contraction; Force-energy behaviors; Surface and interface

1.   Introduction

Hard coatings are the integral part of scientific research for researching and technological advances. Marketable hard coatings for different purposes are learnt routinely where their ingredients and deposition technique are in the hot topics. In this context, several materials involving different ingredients and deposition techniques are available in the literature discussing and explaining their deposition history along with the features of substrate material. In coatings, a minute deposited quantity of materials over less-important or not practically viable material solves the purpose of giving the value-added results.

A variety of techniques are involved to deposit different sorts of hard coatings at the surface of suitable substrates. Coatings are mainly employed with two targeted approaches; in the first case, the potential use of external coated part, which is not subjected to a great deal in the uncoated case and, in the second case, potential use of internal surface where inner uncoated surface of material was not the subject of great concern but, on coating, it became a great deal. Overall, coating the surface of a certain

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substrate results into deliver its different behavior of functioning, often in an astonishing way.

Solid atoms of unfilled states do not elongate and those belonging to inert gases split under the excess propagation of photons characteristic current [1]. A neutral state silicon atom transformed heat energy into photon energy as discussed elsewhere [2]. Atoms of suitable solid behavior evolve structures of different dimension and format as per the nature of built-in electronic gauge where conservative forces involved executing confined inter-state electron-dynamics [3]. The origin of atoms in some elements to be in gas state and the origin of atoms in some elements to be in solid state are discussed elsewhere [4]. A gas state carbon atom originates several different physical behaviors, which is under the involvement of non-conserved energy where non-confined inter-state dynamics of electron to attain certain state engaged non-conserved forces as well [5]. Depending on the atomic behavior of tiny-sized particles, their role for nanomedicine can either be beneficial or harmful [6].

Developing different hierarchical tiny particles under varying conditions of the process is under differently attained dynamics of gold atoms [7]. A monolayer triangular-shaped tiny particle was considered as the model system discussing the elongation behavior of gold atoms of one-dimensional arrays and their conversion into structures of smooth elements under the joint application of surface format force and travelling photons of adequate wavelength also [8]. At suitable precursor concentration, many tiny particles shape-like equilateral triangle developed [9]. Shapes of tiny-sized particles and large-sized particles were controlled under the application of different ratios of pulse OFF to ON time [10]. Particles of different anisotropic shapes developed in less than millisecond time [11]. Developing tiny-sized particles of certain shape tapped in different precursors [12]. Predictor packing while developing geometric anisotropic gold particles was envisaged [13] where controlled force-energy behaviors regulate the shape.

Different behaviors of tiny grains carbon films registered under Raman spectroscopy and energy loss spectroscopy indicated several phases of tiny grains [14]. Switching morphology-structure of grains and crystallites under a bit altered locally operating parameters in developing carbon films is discussed elsewhere [15]. Under varying

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chamber pressure, a discernible change in the morphology and growth rate of carbon films was observed [16].

While depositing TiN coatings on different substrates under varying process conditions while employing a technique known as 'cathodic arc physical vapor deposition', a different morphology-structure along with hardness, surface roughness, friction coefficient, adhesion strength and overall performance of coated tools were studied [17-28]. In addition to these studies, there are several other available studies in the literature targeting TiN coatings along with their processing techniques and analyses [29-36]. In addition to TiN coating, different types of hard coatings developed under various employed conditions have also been published extensively [37-48]. The basic idea discussed in those studies is related to the properties and characteristic of deposited coatings, which are subjected mainly to the change of process parameters, type of material and processing approach.

The prosperous assembling of colloidal matter into meaningful structure will result into deal atoms and molecules as tomorrow's materials [49] and understanding in the individual dynamics of tiny sized particles formation is essential before enabling their assembling to the useful large sized particles [50].

In addition to the discussed scientific details available for hard coatings, coatings are in the way to express relation between comprised atoms. This study reports the fundamental aspects of developing hard coatings with special emphasis on depositing TiN coating at a high-speed steel (HSS) disc while employing random arc-based vapor deposition technique. This work presents the fundamental aspects of depositing hard coating, in general, and investigating mechanism of developing TiN coating, in specific.

2.   Experimental details

HSS discs were utilized as a substrate material for the deposition of TiN while employing the commercially available coating unit known as 'cathodic arc physical vapor deposition technique', which is now termed as 'random arc-based vapor deposition technique' in the present study. After the required cleaning, the samples having diameter: 10 mm and thickness: 6 mm were loaded in the coating system mark

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Hauzer Techno Coating (HTC) 625/2 ARC. The complete deposition procedure along with metallographic process of samples has been described in the earlier work [28]. Surface and interface cross-sectional views were captured by using field emission scanning microscope (FESM known as FE-SEM, Model LEO-1525). The thickness of the deposited coatings was measured under the application of field emission scanning microscope and through the captured fractured cross-sectional image of the deposited coating on HSS substrate. Prior to coat (deposit) TiN on treated HSS disc, an inter-layer of Ti-atoms was deposited for the period of 15 minutes process time. The purpose of depositing inter-layer was to enhance the adhesion strength of the following TiN coating. So, instead of nitrogen gas, an inert gas was regulated through mass flow controller to incorporate into the deposition chamber to ignite the arc. At the start of depositing inter-layer, chamber pressure was 5×10^{-6} mbar. While depositing inter-layer, 50 sccm nitrogen gas flow rate was maintained by mass flow controller meter. To deposit TiN in the form of coating, substrate temperature was maintained at 300°C where N gas flow rate was 250 sccm. The bias voltage was 50 volts where rotational speed of the substrate holder was set 60%. Input current for igniting arc to eject Ti-atoms from the target was 100 A. Total duration of the deposition process was set 90 minutes.

3.   Results and discussion

Figure 1 (a) shows surface topography of deposited TiN coating on HSS disc where coating is partially covered with macrodroplets (MDs), size ranging from few hundred of nanometers to few microns. The distribution of MDs is uniform throughout the surface of deposited coating. A large sized macrodroplet (MD) in the central vicinity of deposited coating shown in Figure 1 (a) shows mapping of the region where the concentration of both Ti and N atoms is appeared to be in different colors. Figure 1 (b) shows fractured cross-sectional view of the coating where initially deposited Ti inter-layer shows thickness less than one micron. Atoms of Ti inter-layer first adhere to surface atoms of substrate under the favorable conditions as observable in the texture of few nanometers thick deposited layer between the substrate and deposited TiN coating.

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Substrate surface comprises different elements like W, Mo, Cr, V, C and Fe, which solve the initial purpose to adhere Ti-atoms to the substrate [17, 24]. Ti-atoms bound to substrate surface under the certain conditions of depositing inter-layer as discussed in the experimental section. The nature of substrate surface dealt their atoms of different elements in the manner where certain arrested force-energy behaviors introduce their appreciable binding to the depositing few nanometers thick Ti-atoms layer. This inter-layer workout for the adhesion strength of afterward depositing coatings needs to be investigated further. Some preliminary detail regrading adhesion strength of TiN coating deposited under certain conditions in random arc-based vapor deposition system is discussed elsewhere [26, 28].
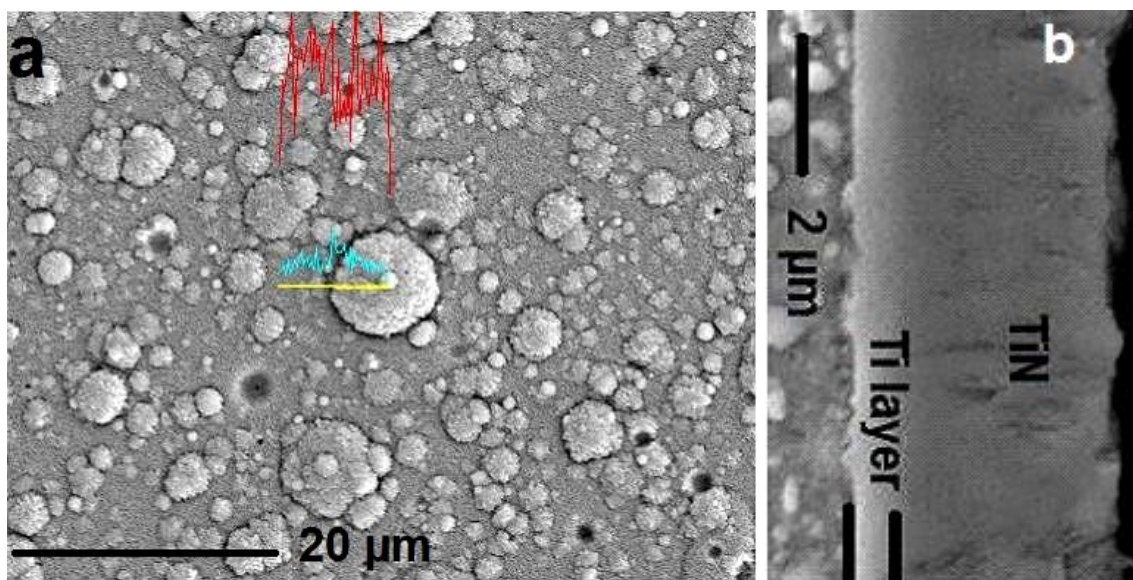
Figure 1: *(a) topographic view of TiN coating on HSS disc and (b) few hundred nanometers thick titanium inter-layer shows contrast with respect to afterward deposited TiN coating having thickness ~4 µm*

Figure 2 shows the mapping of Ti-atoms found in the deposited TiN coating at the point of its MD (in Figure 1a) in the form of histogram where its content is around 70%. This indicates that the portion of coating covered by Ti-atoms in top front surface coating not only contained 70% of its content but the distribution of Ti-atoms in MD is also remained uniform. This indicates that MD contained less concentration of N-atoms.
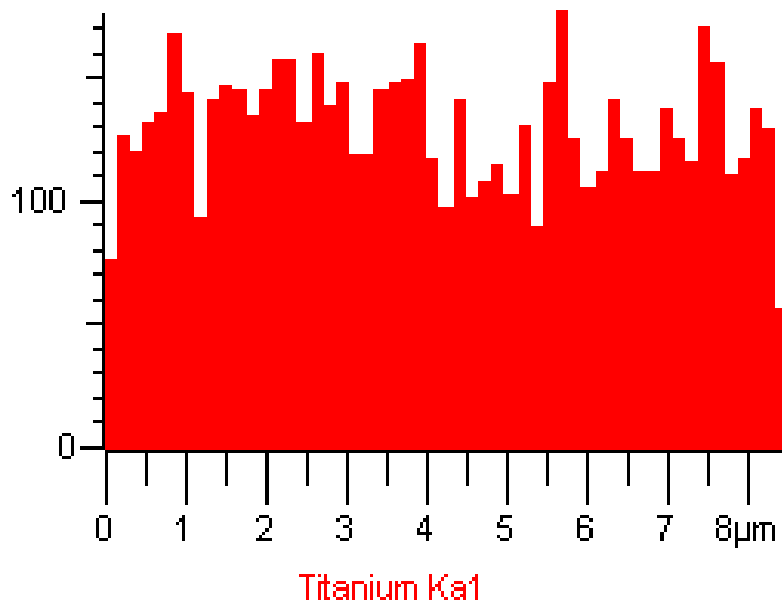
Figure 2: *Mapping of Ti-atoms distribution along with the ratio of content*

Figure 3 shows the mapping of N content in TiN coating in the form of histogram, which is around 30% at the central point of MD shown in Figure 1 (a). This indicates that the potion covered by N-atoms in top front surface of coating not only contained 30% of its content but also contained uniform distribution. However, the distribution of N-atoms in the coating is not appeared in the dense manner. This describes that MD contained approximately three times less concentration of N-atoms as compared to Ti-atoms.
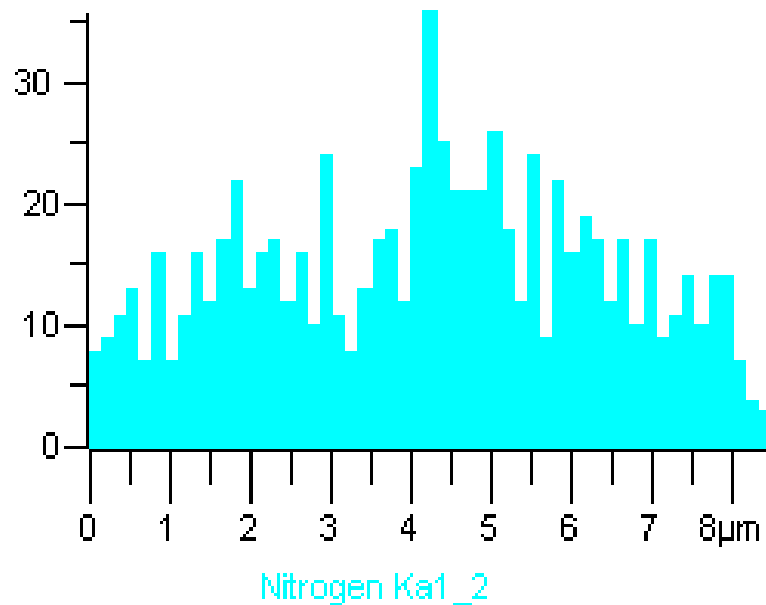
Figure 3: *Mapping of N-atoms distribution along with the ratio of content*

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There are several studies where reduction of MDs for depositing hard coatings was investigated under the different conditions of process along with impact of their tools in the ultra-precision machining [17-20, 23-25].

Hard coatings mainly fall in the category of refractory materials and they are no more the candidates of conductive behavior despite of the fact that their major component still involved the metallic nature atoms. On adherence of gas atoms to metallic atoms, the resulted coatings become poor in conduction and they work nearly as an insulator where field of propagating photons (having characteristic of current) is interrupted to a large extent. This is because of locking inter-state electron gaps for metallic nature atoms by means of incorporating gas atoms. These result into develop disordered structure of the resulted coating. In the case of disordered structure, it is only within the short-range order. The incorporated N-atoms built the bridges *via* their certain electrons where they undertake another clamp of unfilled energy knot belonging to outer rings of Ti-atoms. This resulted into lower the propagation of photonic current known as electric or electronic current also. A detailed study presented elsewhere [1] discussed the significance of inter-state electron gaps in atoms of different elements; propagation of photonic current (or photons having wavelengths other than that of current) requires no more the band gap between conduction band and valence band. This indicates that science of semiconductor materials or other types of materials require new and fresh thoughts to explain the origin of their different hidden phenomena.

In random arc-based vapor deposition system, atoms of Ti (or other metallic nature atoms) are ejected from the front-surface of their targets where arc (in different shape) is utilized to eject atoms under the supply of high energy depending on the strength of applied field per unit area (or volume) attached with the coating technology unit. At high concentration of N-atoms, a random arc is steered to eject Ti-atoms both in atomic form and tiny-sized cluster (droplet) depending on the nature of Ti targets along with employed conditions of vapor deposition process. The basic layout of ejecting Ti-atoms and entering N-atoms to deposit TiN coating is sketched in estimation as shown in Figure 4.

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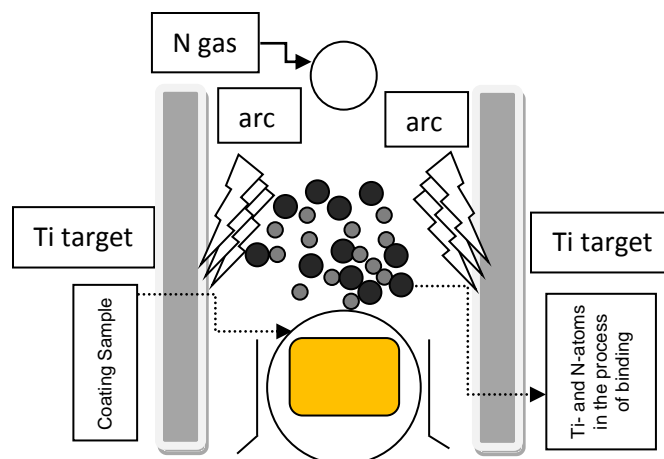
Figure 4: *The basic layout of depositing Ti-atoms and N-atoms to develop TiN coating at the surface of HSS substrate*

A newly observed atomic structure for atoms of Ti and N elements is shown in Figure 5. The tinniest sized particles called (named) electrons are filled (arrested) in the hollow space formed by the inter-crossed overt photons (with understanding of filled/unfilled states) under their certain symmetry where wavelength of those (overt) photons is in the current (conventionally known as electric or electronic current). A detailed study discussed the atomic structure of atoms belonging to different elements along with their origins to be in gas state and solid state [4]. A separate study discussed the lattice and atomic structure of different state carbon atoms [5]. In the case where electrons don't fill the inter-crossed regions of energy knots (hollow space), they are related to (termed as) the unfilled states for those atoms. For Ti-atom, total 32 states of electrons are available, but 24 states are filled by the tinniest sized particles (electrons) while 8 states are remained unfilled. In the case of inner unfilled states of the atom, they are being remained pressed by the covered filled states as indicated in Figure 5. Both filled and unfilled states of Ti-atom are formed (constructed) by the inter-crossed overt photons having their dedicated length. The required numbers of overt photons are being inter-crossed with understanding of filled and unfilled states for their atoms of each element. The wavelength of each inter-crossed overt photon to form the lattice of an atom is in the inter-state electron where their lengths are as per the number of electrons (along with unfilled states) it owns. A detailed study has been conducted discussing different types of photons and nature of the overt photons [2]. Similarly, the atomic

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structures along with their behaviors were discussed in a separated study [4]. However, unfilled states are belonged to outer ring where electrons don't occupy the position, which are at the terminals of certain chain of states as shown in Figure 5.
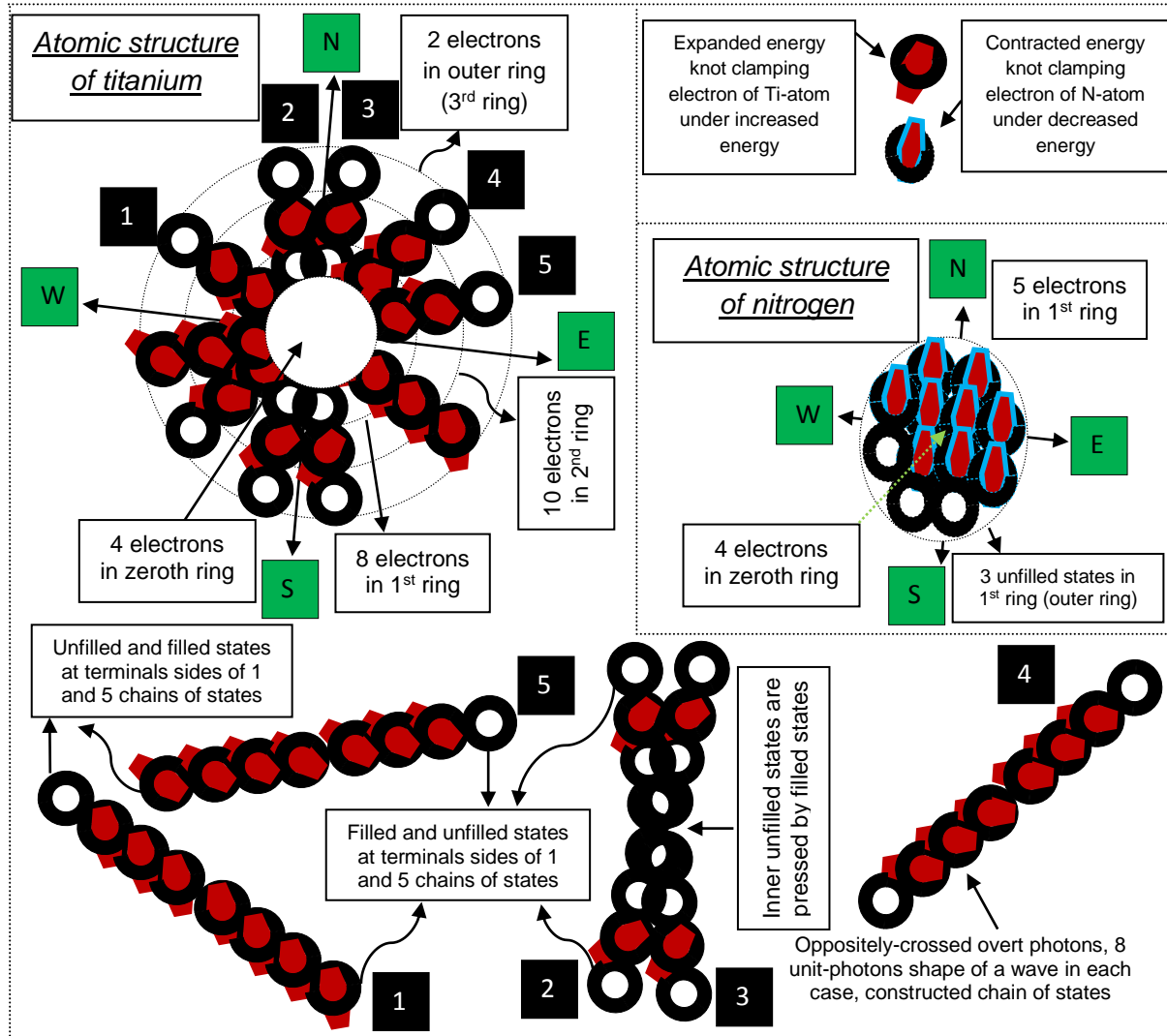
Figure 5: *newly observed atomic structure of atoms belonging to Ti and N elements; involved different chain of states are shown at bottom indicating filled, unfilled states and pressed (unused) states for Ti-atom*

Oppositely-sided crossed two overt photons comprising eight unit-photons construct a chain of filled and unfilled states of electrons. As shown in the bottom part of Figure 5 where five such shapes are drawn and their precise inter-crossing at a common centre forms the lattice of Ti-atom in which 24 states are remained filled. Expanded and contracted energy knots (in estimation) clamping electrons in Ti-atom and N-atom,

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respectively, are also shown in Figure 5. Filled states of outer ring in the atoms of solid
and gas donate the positive valency and negative valency, respectively. For the case of
Ti atom, valency is +2, so, it has '8' unfilled states. In the case of nitrogen atom, valency
is -3, so, it has '5' unfilled states. Hence, negative sign of valency in gas atoms indicates
their ground point at above average-leveled ground surface and positive sign of valency
in solid atoms indicates their ground points at below average-leveled ground surface.
Inner four electrons of atoms belonging to each element form the zeroth ring, whereas,
others are related to the available consecutive rings as discussed elsewhere [4].

In different coating technology units, regardless of that, required numbers of atoms
per unit area or volume are being deposited under set parameters of the process, their
involved energy is based on individually attained dynamics plus electron-dynamics,
which is the key to regulate their structure, and so, there is emergence of properties and
characteristics of their resulted coating. However, it appears that evolving structure of
TiN coating in the order of certain homogeneity is within the short-range order.
Therefore, the deposited coating is developed mainly under the mixed behavior of
structure evolution. Each Ti-atom only occupies two electrons in the outer ring. This low
number of filled states enables it to occupy many unfilled states of outer ring. Being a
solid atom, it should possess unfilled states at above east-west poles, both at left and
right sides of the north-pole. As the Ti element is belonged to grounded format, so,
electrons of filled states (of outer ring) in atoms are to be remained at below east-west
poles along the south-pole. On the other hand, five filled states in outer ring of N-atom
allow a smaller number of unfilled states in the outer ring. In this context, N-atom
contains several filled states of outer ring where majority of the electrons (filled states)
are expected to be at above the east-west poles along the north-pole while in each
dedicated state. This is because of the gas nature of N-atom. Further detail of the origin
of gas atoms belonging to some elements was also discussed [4]. The availability of
several unfilled states of outer ring in Ti-atom provides provision to work for electrons of
filled states of outer ring in N-atom where targeted electron (of gas atom) is being
clamped by another clamping of energy knot (of solid atom). The double-clamping of
energy knot to the electron of N-atom is by means of energy knot clamping unfilled state

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of outer ring in the Ti-atom. But the mechanism of double clamping of energy knot by the electron is by means of suitable transition state in gas and solid atoms. Atoms when are in a certain transition state adjust potential energy of their electrons as per exertion of orientationally-controlled force [4]. Therefore, two different nature atoms (Ti and N) develop affinity in terms of strong binding under a suitable reaction (fast interaction).

A metallic target developed under the solidification of transition state atoms, most probably, when they were under their re-crystallization transition state. The processed ore of metallic target is at the level of ground surface but their atoms in original solid state are to be at the below level to ground surface. Similarly, gas atoms compressed in the container are in the re-crystallization transition state as well at the level of ground surface, whereas, they are in original gas state at the above level to ground surface. On ejecting of solidified nature atoms from the target and flowing of the compressed gas nature atoms from the container, they are again in transition to restore their original states. So, in the attempt of reviving their original state behaviours, they react (fast interact) just at above the substrate of their deposition. At instant of their reaction (fast interaction), different natured atoms are in their nearly opposite switched force-energy behaviours. Here, under their suitable interactions, electrons of gas atoms enter to unfilled states of solid atoms. In both cases, entering electrons of filled states and clamping energy knots of unfilled states, they are belonged to the outer ring of their atoms. Gas atoms when are in the re-crystallization state, their electrons go downward sides under infinitesimal displacements where they decreased their levitational force by gained potential energy. But, electrons of the gas atoms are still more than 50% to upward sides at mid of their clamped energy knots. Solid atoms when are in the re-crystallization state, their electrons go upward sides under infinitesimal displacements where they decreased their gravitational force by losing the potential energy. But, electrons of the solid atoms are still more than 50% to downward sides at mid of their clamped energy knots. Two different natured atoms reach in their suitable transition states where certain electron of the gas atom undertakes another clamp of certain energy knot belonging to solid atom. When gas and solid atoms just attain those transition states, electron of the gas atom undertakes one more clamping of energy knot

belonging to solid atom by visualizing the exerting force of relevant pole. Those different natured atoms remain attempting to restore their original state behaviors but under their adherence, thus, keep maintaining their hard features.

Atoms of metallic targets are already in contraction of energy knots clamped electrons and unfilled states as they are not in their original solid behavior. On the other hand, entered gas atoms to the chamber are in the expansion of energy knots clamping electrons because, they are at ground surface now instead of being at above ground surface through the given pressure for their entering to the deposition chamber. Therefore, different natured atoms switched force-energy behaviors nearly in opposite manner. Just at instant of recovering original behaviors, they reach to bind upon suitable coinciding where targeted electron of gas atom undertakes another clamp of targeted energy knot (clamping to unfilled state) of solid atom. Therefore, solid atoms of Ti have already done work negatively (arriving near to ground surface from the south-side) while gas atoms of N have already done work positively (arriving near to ground surface from the north-side). On recovering the state behaviors of two differently natured atoms to be just in suitable transition states, they switched their force-energy behaviors where work done by the gas atom is negative while work done by the solid atom is positive. So, they react to undertake double clamping of the suitable electron (of the gas atom) through suitable unfilled state (of the solid atom).

Ti metal is known in metallic character where filled state electrons of atoms remain grounded under attaining the maximum gravitational force, so, the maximum expansion of their clamped energy knots, also. Thus, electrons of Ti-atoms keep the original ground point at below ground surface under the normal condition. On the other hand, a N-atom belongs to gas behavior, which remains in the air (at above average-leveled ground surface) under the engagement of space format force exerting at electron-level. The electrons of N-atoms possess their ground point at above ground surface because of the maximum contraction of their clamped energy knots where the maximum orientating levitational force is being exerted at electron-level. Therefore, in their joint deposition while employing a suitable coating technology unit, electron of outer ring belonging to N-atom clamp by another energy knot clamping to unfilled state of outer

ring in Ti-atom. Given energy in the deposition chamber enables another clamping of the energy knot to a suitable electron of gas atom and through energy knot of a suitable unfilled state of solid atom where energy is involved to engage the force. This results into attain their ground point neither at above ground surface nor at below ground surface. To attain their common ground point, they mutually get ready at above or just at the surface of depositing substrate. Under the tailored process parameters of deposition, structure of hard coating exhibits high hardness because of the maximum ordering of different nature transition state atoms where their attained mid-points remained ordered to a large extent.

The electrons of N-atoms undertake double clamps of energy knots while visualizing to unfilled states of Ti-atoms where gas state atoms are being uplifted while solid ones are being grounded. Suitable transition state atoms undertake double clamps of targeted energy knots (belonging to solid atoms) to targeted electrons (belonging to gas atoms) under their favorable coinciding. The mechanism of double clamping of suitable energy knots to suitable electrons of N-atoms is grounded forcefully by the Ti-atoms (through suitable energy knots clamping unfilled states) as shown in Figure 6. Binding of Ti-atom to Ti-atom under the application of an electron (belonging to less expanded Ti-atom just landing) to undertake another (double) clamp of energy knot (belonging to more expanded Ti-atom already landed) is also shown in Figure 6 where N-atoms mainly position at interstitial sites of Ti-atoms. Under the action of tailored force-energy behaviors of N-atoms and Ti-atoms, they react, which results into their binding to develop TiN coating at surface of the substrate. Because, solid atoms in their original state behavior undertook fully orientated gravitational force, which is due to their grounded ground points under fully gravitized behavior exerting at electron-level, thus, their electrons gained the maximum potential energy where clamped energy knots also undertook the maximum expansion. So, energy knots constructing unfilled states in those atoms also expanded maximally. But, gas atoms in their original state behavior undertook fully orientated levitational force, which is due to their ground points at above ground surface under fully levitized behavior exerting at electron-level, thus, their electrons gained the minimum potential energy where clamped energy knots also

undertook the maximum contraction. So, energy knots constructing unfilled states in those atoms also contracted maximally.
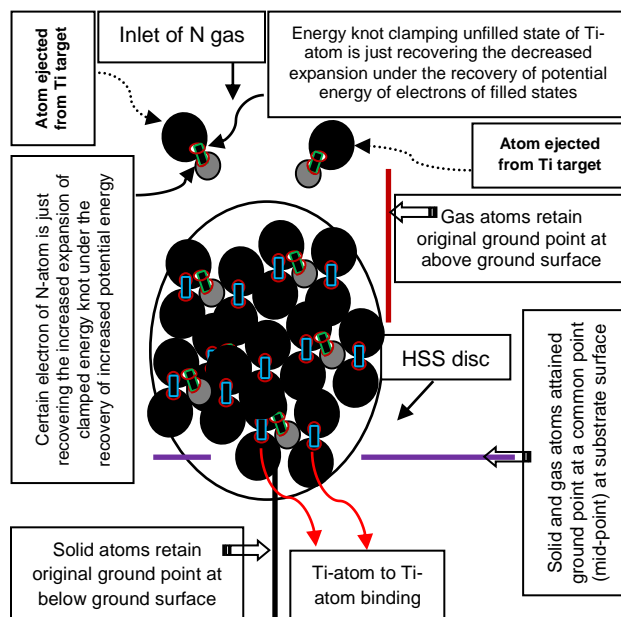
Figure 6: *Mechanism of double clamping of suitable energy knots to suitable electrons of gas atoms through suitable energy knots clamping unfilled states of solid atoms along with Ti-atom to Ti-atom binding*

On landing a Ti-atom at substrate, it recovers transition state into original solid behavior where electrons start to gravitize. But prior to fully gravitize, an adequate expansion of the lattice under increased (gained) potential energy is taken place. However, Ti-atom after landing attains ground point at the surface of previously landed atom due to its lattice of less expansion. Therefore, a certain electron of less expanded landed Ti-atom (where it is pointing toward the downward-side) enters to a suitable vacant energy knot of a more expanded landed Ti-atom (where it is pointing toward the upward-side). This results into bind the two identical atoms. Now, forcefully grounded nitrogen atoms tend to recover state to go into original gas behavior where their certain electrons are entered to certain vacant energy knots of Ti-atoms from the back-side (rearward-side). In this way, nitrogen atoms are trapped at interstitial position of the Ti-atoms. Binding of nitrogen atoms at interstitial positions of bound Ti-atoms is also shown in Figure 6. Atoms of nitrogen (or other suitable gas elements) and titanium (or other suitable solid elements) engage energy under the exerting forces of fixed poles of

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electrons when they are in their original states. But, the situation becomes different when they undertake certain transition (liquid) state where, in the solid atoms, energy is directly proportional to the exerting gravitational force exerting at electron levels, whereas, in the gas atoms, energy is inversely proportional to the levitational force exerting at electron levels. Further detail of energy-force (or force-energy) relationship in the case of gaseous state atoms and solidus state atoms is given elsewhere [4].

The similar sort of mechanism is being anticipated in bi-metallic composition with gas behavior atoms, for example, TiAlN. Again, low measured-hardness coating of chromium nitride (compared to TiN) involves the mechanism of binding their different nature atoms under similar lines where high probability of binding is involved as Cr-atom contains many unfilled states in the outer ring (compared to Ti-atom). That's why CrN coating exhibits low surface roughness as compared to TiN coating [28] and, also, because of greater level of homogeneity of binding atoms while evolving structure. A similar approach may be validated to explore the science of other hard, moderate hard and even less hard (soft and porous) coating materials. A different originating scientific mechanism may be anticipated in the case of TiCN coating and because of involving the carbon atoms, which requires additional lines to express the science of their synthesizing materials. Reaction of gas atoms and solid atoms endorse engaging of force exerting by their electrons under the adjustment of expansion and contraction of clamped energy knots, respectively. In this case, the energy is being involved. Therefore, developing hard coating is related to non-conserved energy where non-conservative (frictional) forces are engaged to sustain the structure of coating. However, where the force element is involved first, the energy is being engaged as for the case of silicon atoms [2]; conservative forces are involved to configure the energy in the form of forcing energy (photon). A photon wavelength in the characteristic current is discussed elsewhere [1]. A unit-photon and an overt photon are discussed elsewhere [2]. The origin of atoms of different elements to be in gas state and to be in solid atoms is discussed elsewhere [4]. Conversion of gas state carbon atom into its different states along with the binding of identical state carbon atoms is also discussed [5].

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This is the provision of solid atom just recovering the transition state which allocates energy knot belonging to suitable unfilled state of outer ring to clamp certain filled state electron of gas atom when just recovering the transition state also. The reacting of gas atom while ground point is just at ground surface (instead of at above ground surface) is because of increased orientating gravitational force of its electrons where their potential energy is increased resulting into increase the expansion of clamped energy knots. The reacting of metallic atom while the ground point is just at ground surface (instead of at below ground surface) is because of decreased orientating gravitational force of its electrons where their potential energy is decreased resulting into decrease the expansion of clamped energy knots. This results into the binding of two different natured atoms at a common ground point, which is the mid of ground points of gas atom and solid atom when they were in their original state behavior, thus, engaging force as per involved energy to work out for their binding, which is a hard coating.

Certain transition metals govern hard features of coating under affinity to gas atoms because, one is undertaking the force of grounded format and other is undertaking the force of space format resulting into locate their common ground points having mid-points at the level of ground surface. The electron of outer ring belonging to gas atom (N-atom) reacts to develop TiN by having another clamp of energy knot clamped by the unfilled state of outer ring belonging to solid atom (Ti-atom). At the time of recovering transition state of Ti-atoms, they are just at the substrate surface, thus, they react to N-atoms, which are also just at substrate surface at the instant of recovering transition state. Ti-atoms just on landing undertake less expansion of their lattice as compared to Ti-atoms already landed resulting into devise the unit (primitive) cell of hard coating when under their appropriate coinciding where N-atoms are incorporated in their interstitial sites. This is the cause that hard coating presents the increased elastic behavior and the decreased plastic behavior, which is also known since antiquity.

Appropriate vacuum conditions and high power enhance the hardness level of deposited coatings. Hard coatings introduce certain properties and applications due to the developing of non-regular structure where they involved the non-conserved energy, thus, engaging the non-conservative forces to work for their structure. But, they are not

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overwhelming forever where their force-energy behaviors may be affected. So, the lifetime of hard coatings depends on their developing strategies along with nature of application. Not only hard coatings enable one to explore different phenomena of materials and their counterparts, but they also open many new areas of research.

4.   Conclusions

Suitable gas and solid atoms under their certain transition state behaviors, which are being controlled by the process parameters, bind (adhere) by introducing the mechanism of double clamping of their certain filled state electrons (in gas atoms) through certain energy knots of unfilled states (in solid atoms).

In mechanism of double clamping, a gas atom (N-atom), when in suitable transition state, partially handovers the certain electron of outer ring to certain unfilled state (energy knot) of outer ring belonging to a solid atom (Ti-atom), when in suitable transition state also. Gas atom (N-atom) binds to solid atom (Ti-atom) from the rearward-side while in the attempt to evacuate. Here, solid atom (Ti-atom) is in attempt to attain grounded level. Due to increase in its grounded behavior, bound gas atom (N-atom) is also grounded with it in the form of deposition to substrate surface located in the suitable location of the deposition chamber. Depositing bound solid atoms and gas atoms are not in their original behavior of states. They are in certain transition behavior of their states suitable (require) for their binding, so, they switch force-energy behavior under the set parameters nearly in the opposite manner to their original ones at the instant of binding, which, in fact, governs and controls the hard features along with others of their coating.

The underlying science of developing hard coatings is in the manner that atoms of solid behavior perform negative work when undertaking the certain transition state as they attain ground points at the levels above to their original levels and atoms of gas behavior perform positive work when undertaking the certain transition state as they attain ground points at the levels below to their original levels. Performing negative work in the case of solid atoms is to be taken also positive in the sense as their developed coatings are utilized at the level of ground surface where they, together with gas atoms,

always remain in the attempt to return for the original behaviors resulting into provide such a beneficial feature to the users. For developing hard coating, gas atoms when just recovering transition state of increased orientating gravitational force react to solid atoms when just recovering transition state of decreased orientating gravitational force. Two differently natured atoms bind (adhere) to each other when they are just in their transition states where certain electron (of gas atom) visualizes the exerting force to its north-sided tip through certain unfilled energy knot (of solid atom) under their appropriate coinciding.

This fundamental study describing the origin of hard coatings and others as an outlook suggests ways and means to develop smart chamber-systems of deposition controlling pressure and temperature along with other parameters in the appreciable ranges having high localized precisions. This is very much possible through the automation in addition to semi-automated deposition systems. This study suggests briefly which component is required to put more effort and which to put less effort to control and obtain planned results of materials' properties and characteristics. This really comes up with not only getting the unique benefits of coatings but sustainable and controllable utilization of resources also.

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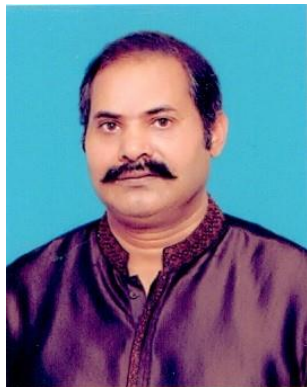
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