OPTIMASI PARAMETER PROSES RF-DC PLASMA N₂-H₂ PADA NITRIDASI SELEKTIF AISI420 UNTUK FABRIKASI CETAKAN *DIE* POLA MIKRO

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UNTUK FABRIKASI CETAKAN *DIE* POLA MIKRO**

TESIS

**Untuk Memenuhi Persyaratan Memperoleh
Gelar Magister Sains Bidang Fisika**

Oleh:

**HENGKY HERDIANTO
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**PROGRAM STUDI S2 ILMU FISIKA
MINAT MATERIAL**

**PROGRAM PASCASARJANA FAKULTAS MIPA
UNIVERSITAS BRAWIJAYA
MALANG
2017**

TESIS

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Oleh:

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Telah dipertahankan di depan penguji
pada tanggal 16 Agustus 2017
dan dinyatakan lulus

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RINGKASAN

Penelitian ini mengoptimasi parameter proses RF-DC plasma N₂-H₂ pada tahap *pre-sputtering* dan nitridasi. Hasil penelitian ini menunjukkan bahwa temperatur optimasi proses nitridasi adalah 673 K dengan ketercapaian kekerasan 1328 HV. Pada suhu proses nitridasi 673 K mikrostruktur mengalami ekspansi kisi dan regangan internal *anisotropic* membentuk fase α' -Fe, σ -FeCr, α' -FeN, ε -Fe₂N, ε -Fe₃N, γ -Fe₄N, dan CrN. Spesies plasma yang paling berperan dalam proses nitridasi pada optimasi temperatur adalah N₂⁺ dan NH. Semakin besar tegangan DC dan waktu proses *pre-sputtering* RF-DC plasma N₂-H₂ semakin buruk kualitas lapisan pola mikro karbon AISI420. Tegangan DC dan waktu optimasi adalah -450 volt selama 400 sekon. Spesies plasma yang paling memberikan dampak pengikisan lapisan cetak pola mikro karbon dalam proses *pre-sputtering* pada optimasi DC *bias* adalah N₂⁺ sedangkan pada optimasi durasi adalah N₂⁺ dan N₂^{*}. Semakin besar waktu proses nitridasi RF-DC plasma N₂-H₂ semakin buruk kualitas lapisan pola mikro karbon. Waktu optimasi nitridasi adalah 5400 sekon dengan nilai kekerasan 1214 HV. Pada durasi proses nitridasi 5400 sekon mikrostruktur yang terbentuk adalah fase α' -Fe, σ -FeCr, α' -FeN, ε -Fe₂N, ε -Fe₃N, dan CrN. Spesies plasma yang paling berperan dalam proses nitridasi pada optimasi durasi adalah N₂⁺ dan NH. Nitridasi dengan optimasi parameter proses RF-DC plasma N₂-H₂ membentuk pola kekerasan yang sesuai dengan desain pola mikro yang dicetak. Kekerasan di wilayah yang tidak dicetak 1220 HV dan di wilayah tercetak 335 HV. Mikrostruktur yang terbentuk adalah fase α' -Fe, σ -FeCr, α' -FeN, ε -Fe₂N, ε -Fe₃N, dan CrN dengan dominasi fase mikrostruktur ε -Fe₃N yang bersifat superparamagnetik.

Kata Kunci: RF-DC, Plasma, N₂-H₂, AISI420, Pola Mikro

**OPTIMIZATION OF RF-DC PLASMA N₂-H₂ PROCESS
PARAMETER IN THE SELECTIVE NITRIDING AISI420
FOR FABRICATION OF MOLDS AND DIES MICRO PATTERNS**

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SUMMARY

This study optimises the parameters of the RF-DC plasma N₂-H₂ process at the pre-sputtering and nitriding stage. The results of this study indicate that the optimization temperature was 673 K with an acute hardness of 1328 HV. At temperature 673 K of nitriding process, micro structures occur lattice expansion and the anisotropic internal strain forming α' -Fe, σ -FeCr, α' -FeN, ϵ -Fe₂N, ϵ -Fe₃N, γ -Fe₄N, and CrN phases. The most important plasma species involved in the nitriding process at temperature optimization are N₂⁺ and NH. The greater the DC voltage and time of RF-DC plasma N₂-H₂ on the pre-sputtering process, the poorer the quality of the AISI420 micro carbon pattern layer. The DC voltage and time optimization is -450 volts for 400 seconds. The plasma species that most impacts of the micro carbon layer printing layer erosion in the pre-sputtering process on optimization of DC bias are N₂⁺ while on optimization duration is N₂⁺ and N₂^{*}. The greater of RF-DC plasma N₂-H₂ on nitriding process, the worse quality of the micro-carbon pattern coating. The optimization time is 5400 seconds with a hardness value of 1214 HV. At the duration of the nitriding process of 5400 micro-structure sequences formed are the α' -Fe, σ -FeCr, α' -FeN, ϵ -Fe₂N, ϵ -Fe₃N, and CrN phases. The most prominent plasma species in the nitriding process on duration optimization are N₂⁺ and NH. The optimization of the RF-DC plasma N₂-H₂ process parameters forms a hardness pattern corresponding to the printed micro pattern design. The hardness in unprinted areas 1220 HV and 335 HV in printed areas. The micro structures formed are the α' -Fe, σ -FeCr, α' -FeN, ϵ -Fe₂N, ϵ -Fe₃N, and CrN phases with the dominance of the ϵ -Fe₃N superparamagnetic microstructure phase.

Keywords: RF-DC, Plasma, N₂-H₂, AISI420, Micro-Patterns

DAFTAR PUSTAKA

- Aizawa, Tatsuhiko, Masahiro Tamaki, & Tatsuya Fukuda. 2014a. Large Area Micro-texture Imprinting onto Metallic Sheet Via CNC Stamping. *Journal of Procedia Engineering*. Vol. 81. pp. 1427–1432.
- Aizawa, Tatsuhiko & Tetsuya Yamagichu. 2014b. High-Density Plasma Nitriding Assisted Micro-Texturing onto Martensitic Stainless Steel Mold-Die. *Proceeding of 9th IWMMF*. pp. 1–7.
- Aizawa, Tatsuhiko, Hiroaki Suga, & Tetsuya Yamaguchi. 2015. Plasma-Nitriding Assisted Micro-texturing into Stainless Steel Molds. *Proceeding of MATEC Web of Conferences*. Vol. 21. pp. 1-6.
- Aizawa, Tatsuhiko, Tatsuya Fukuda, & Hiroshi Morita. 2016. Low Temperature High Density Plasma Nitriding of Stainless Steel Molds for Stamping of Oxide Glasses. *Journal of Manufacturing Rev.* Vol. 3. No. 5. pp. 1-6.
- Aizawa, Tatsuhiko. 2017. Functionalization of Stainless Steels via Low Temperature Plasma Nitriding. *Proceeding of The 7th Annual Basic Science International Conference*. pp. 1-4.
- Ali, A *et al.* 2012. Improvement of (004) Texturing by Slow Growth of Nd Doped TiO₂ Films. *Journal of Applied Physics*. Vol. 112. pp. 1-6.
- Almeida, Elisabete. 2001. Surface Treatments and Coatings for Metals. A General Overview. 1. Surface Treatments, Surface Preparation, and the Nature of Coatings. *Journal of Ind. Eng. Chem. Res.* Vol. 40. No. 1. pp. 3-14.
- Alphonsa, I. *et al.* 2002. A study of Martensitic Stainless Steel AISI 420 Modified Using Plasma Nitriding. *Journal of Surface and Coatings Technology*. Vol. 150. pp. 263–268.
- Armentrout, P.B. 2004. Fundamentals of Ion–Molecule Chemistry. *Journal of Anal. At. Spectrom.* Vol. 19. pp. 571-590.
- Aydin, Hakan & Ali Bayram. 2013. Effect of Different Nitriding Processes on the Friction Coefficient of 304 Austenitic and 420 Martensitic Stainless Steels. *Journal of Ind. Lub. and Tribo.* Vol. 65. No. 1. pp. 27-36.
- Babakiray, Sercan *et al.* 2015. Structural Properties of Bi_{2-x}Mn_xSe₃ Thin Films Grown via Molecular Beam Epitaxy. *Journal of Applied Physics*. Vol. 118. pp. 1-7.
- Badjuk, T.I, Kushma, G.P, and Rybajlo, O.I. 1974. Temperature and Concentration Dependence of the Unit Cell Dimensions of Fe-Cr Solid Solutions. *Proc. of Chern. Metal.* Vol. 17. pp. 126-128.
- Baldwin *et al.* 1997. The Low-Pressure RF Plasma as a Medium for Nitriding Iron and Steel. *Journal of Appl. Phys.* Vol. 36. pp. 4941-4948.

- Barbagiovanni, E.G *et al.* 2015. Influence of Interface Potential on the Effective Mass in Ge Nanostructures. *Journal of Applied Physics*. Vol. 117. pp. 1-9.
- Barton, D *et al.* 2000. The Measurement and Control of the Ion Energy Distribution Function at a Surface in an RF Plasma. *Journal of Meas. Sci. Technol.* Vol. 11. pp. 1726–1731.
- Bayliss, Peter. 1990. Revised Unit-Cell Dimensions, Space Group, and Chemical Formula of Some Metallic Minerals. *Journal of Canadian Mineralogist*. Vol. 28. pp. 751-755.
- Bhattacharyya, Sayan. 2015. Iron Nitride Family at Reduced Dimensions: A Review of Their Synthesis Protocols and Structural and Magnetic Properties. *Journal of Physical Chemistry*. Vol. 119 No. 4. pp 1601-1622.
- Botana, A.S *et al.* 2011. Electronic Structure Analysis of the Quasi-One-Dimensional Oxide $\text{Sr}_6\text{Co}_5\text{O}_{15}$ within the LDA+U Method. *Journal of Applied Physics*. Vol. 109. pp. 1-3.
- Callister, William D. Jr. 2007. *Materials Science and Engineering: An Introduction*. New York: John Wiley & Sons, Inc.
- Carrasco, E. V J Herrero, & I Tanarro. 2012. Time-Resolved Diagnostics and Kinetic Modelling of the Ignition Transient of a $\text{H}_2 + 10\% \text{N}_2$ Square Wave Modulated Hollow Cathode Discharge. *Journal of Phys. D: Appl. Phys.* Vol. 45. pp. 1-7.
- Castillo, M *et al.* 2005. Low-Pressure DC Air Plasmas. Investigation of Neutral and Ion Chemistry. *Journal of Phys. Chem. A*. Vol. 109. No. 28. pp. 6255-6263.
- Choi, Y. H. *et al.* 2005. Characteristics of Atmospheric Pressure N_2 Cold Plasma Torch Using 60 Hz AC Power and Its Application to Polymer Surface Modification. *Journal of Surf. and Coat. Tech.* Vol. 193. pp. 319-324.
- Chomoucka, Jana *et al.* 2010. Magnetic Nanoparticles and Targeted Drug Delivering. *Journal of Pharmacological Research*. Vol. 62. pp. 144-149.
- Christiansen. T, K.V. Dahl, & M.A.J. Somers. 2006. Simulation of Nitrogen Concentration Depth Profiles in Low Temperature Nitrided Stainless Steel. *Journal of Defect and Diffusion Forum*. Vols. 258-260. pp 378-383.
- Cosby, P.C. 1993. Electronimpact Dissociation of Nitrogen. *Journal of Chern. Phys.* Vol. 98. No. 12. pp. 9544-9553.
- Czerwicz, T *et al.* 2009. Austenitic Stainless Steel Patterning by Plasma Assisted Diffusion Treatments. *Proceeding of IOP Conf. Series: Materials Science and Engineering*. Vol. 5. pp. 1-8.
- Denisov, V.V *et al.* 2015. Pulsed Non-Self-Sustained Glow Discharge with a Large-Area Hollow Cathode for Nitriding of Iron-Based Alloys. *Proceeding of IOP Conf. Series: Materials Science and Engineering*. Vol. 81. pp. 1-6.

- Eddine, M.N, E.F. Bertaut, M. Roubin, and J. Paris. 1977. Etude Cristallographique de $\text{Cr}_{1-x}\text{V}_x\text{N}$ à Basse Temperature. *Journal of Acta Crystallographica B*. Vol. 33. pp. 3010-3013.
- Figuerola, C. A *et al.* 2006. Previous Heat Treatment Inducing Different Plasma Nitriding Behaviors in Martensitic Stainless Steels. *Journal of Vacuum Science & Technology A*. Vol. 24. No. 5. pp. 1795–1801.
- Figuerola, C. A, D. Wisnivesky, & F. Alvarez. 2002. Effect of Hydrogen and Oxygen on Stainless Steel Nitriding. *Journal of Applied Physics*. Vol. 92. No. 2. pp. 764–770.
- Filippov, A. V. *et al.* 2016. Oriented Microtexturing on the Surface of High-Speed Steel Cutting Tool. *AIP Conf. Proc.* 1783. pp. 1-4.
- Fitriani, Sukma W *et al.* 2017. Plasma Oxidation Printing Into Carbon Based Materials. *Proceeding of 11th Seatuc Symposium*. OS-06. CD ROM Series. pp. 1-5.
- Fiedl, R & U. Fantz. 2012. Spectral Intensity of the N_2 Emission in Argon Low-Pressure Arc Discharges for Lighting Purposes. *New Journal of Physics*. Vol. 14. pp. 1-23.
- Ganeshraj, C & P.N. Santhosh. 2014. First-Principles Study of Structural, Electronic, Vibrational, Dielectric and Elastic Properties of Tetragonal Ba_2YTao_6 . *Journal of Applied Physics*. Vol. 116. pp. 1-10.
- Goldsztein, Guillermo H & Oscar P. Bruno. 2004. A Fast Algorithm for the Simulation of Polycrystalline Misfits. II. Martensitic Transformations in Three Space Dimensions. *Proceeding of R. Soc. Lond. A*. Vol. 460. pp. 1613-1630.
- Gupta, Rachana & Mukul Gupta. 2005. Nanocrystallization and Amorphization Induced by Reactive Nitrogen Sputtering in Iron and Permalloy. *Journal of Physical Review B*. Vol. 72. pp. 1–12.
- Hamann, S. 2013. Spectroscopic Studies of Conventional and Active Screen $\text{N}_2\text{--H}_2$ Plasma Nitriding Processes with Admixtures of CH_4 or CO_2 . *Journal of Plasma Sources Sci. Technol.* Vol. 22. pp. 1-12.
- Hannemann, M. *et al.* 2013. Langmuir Probe and Optical Diagnostics of Active Screen $\text{N}_2\text{--H}_2$ Plasma Nitriding Processes with Admixture of CH_4 . *Journal of Surface & Coatings Technology*. Vol. 235. pp. 561–569.
- Helden, J. H. van *et al.* 2007. Production Mechanisms of NH and NH_2 Radicals in $\text{N}_2\text{--H}_2$ Plasmas. *Journal of Phys. Chem. A*. Vol. 111. No. 45. pp. 11460-11472.
- Hendricks, S.B and P.R. Kosting. 1930. The Crystal Structure of Fe_2P , Fe_2N , Fe_3N and FeB . *Internasional Journal of Crys. Geo. Crys. Phys. Chem. Crys.* Vol. 74. pp. 511-533.

- Henrion, Gerard *et al.* 1992. Spectroscopic Investigation of a Temporal Post Discharge Plasma for Iron Nitriding. *Journal of Plasma Sources Sci. Technol.* Vol. 1. pp. 117-121.
- Istiroyah, I.N.G Wardana, & D.J Santjojo. 2014a. Comparison of AISI 316L Plasma Nitriding Behavior at Low and Medium Temperature. *Journal of Applied Mechanics and Materials*. Vol. 493. pp 755-760.
- Istiroyah, I.N.G Wardana, & D.J Santjojo. 2014b. Effect of Hydrogen Addition on the Characteristics of Nitrided Martensitic Stainless Steel AISI 420. *Journal of Applied Mechanics and Materials*. Vol. 836. pp 214-218.
- Itagaki, Hirotomo *et al.* 2016. A Low-Power Nitriding Technique Utilizing a Microwave-Excited Radical Flow. *Japanese Journal of Applied Physics*. Vol. 55. pp. 1-5.
- Izumi, Fujio & Koichi Momma. 2007. Three-Dimensional Visualization in Powder Diffraction. *Journal of Solid State Phenomena*. Vol. 130. pp. 15-20.
- Jack, K. H. 1951. The Occurrence and the Crystal Structure of α'' -Iron Nitride: a New Type of Interstitial Alloy Formed During the Tempering of Nitrogen-Martensite. *Proceeding of Royal Society of London. Series. Mathematical & Physical Sciences*. Vol. 208. No. 1093. pp. 216-224.
- Katajarinne, Tuomas & Seppo Kivivuori. 2013. Material Property Evolution in Incremental Sheet Forming – A Review and Comparison. *Journal of Key Engineering Materials*. Vols. 554-557. pp 1338-1350.
- Katoh, Takahisa, Tatsuhiko Aizawa, & Tetsuya Yamaguchi. 2015. Plasma Assisted Nitriding for Micro-Texturing onto Martensitic Stainless Steels. *Journal of Manufacturing Rev.* Vol. 2. No. 2. pp. 1–7.
- Keddam, M, M.E. Djeghlal, & L. Barrallier. 2004. A Diffusion Model for Simulation of Bilayer Growth (ϵ/γ') of Nitrided Pure Iron. *Journal of Materials Science and Engineering A*. Vol. 378. pp. 475-478.
- Keddam, M, M.E. Djeghlal, & L. Barrallier. 2005. A Simple Diffusion Model for the Growth Kinetics of γ' Iron Nitride on the Pure Iron substrate. *Journal of Applied Surface Science*. Vol. 242. pp. 369-374.
- Keddam, M. *et al.* 2004. Computer Simulation of Nitrided Layers Growth for Pure Iron. *Journal of Computational Materials Science*. Vol. 29. pp. 43-48.
- Kishimoto, Kengo *et al.* 2012. Crystal Structure and Thermoelectric Properties of $K_xBa_{8-x}Zn_yGe_{46-y}$ Clathrates. *Journal of Applied Physics*. Vol. 111. pp. 1-8.
- Kitahara, Hiromoto, Masato Ueda, Nobuhiro Tsuji. 2006. Variant Selection of Plate Martensite in Fe-28.5at.%Ni Alloy. *Journal of Materials Science Forum*. Vol. 512. pp 117-122.

- Kleijnjohann, Keila Christina *et al.* 2016. Characterization of AISI 316L Stainless Steel Pattern via DC Plasma Nitriding. *Journal of Materials Science Forum*. Vol. 869. pp. 675-679.
- Kolhatkar, Arati G *et al.* 2013. Tuning the Magnetic Properties of Nanoparticles. *Journal of Molecular Sciences*. Vol. 14. pp. 15977-16009.
- Kossyi, I.A *et al.* 1992. Kinetic Scheme of the Non-Equilibrium Discharge in Nitrogen-Oxygen Mixtures. *Journal of Plasma Sources Sci. Technol.* Vol. 1. pp. 207-220.
- Kouba, Ramdhane & Mourad Keddami. 2015. Numerical Prediction of the Compound Layer Growth During the Gas Nitriding of Fe-M Binary Alloys. *Journal of MTAEC9*. Vol. 49 No. 1. pp. 43-53.
- Krishnakumar, E & S K Srivastava. 1990. Cross Sections for the Production of N_2^+ , N^+ + N_2^{2+} and N^{2+} by Electron Impact on N_2 . *Journal of Phys. B: At. Mol. Opt. Phys.* Vol. 23. pp. 1893-1903.
- Kumar, Vikash *et al.* 2015. Structural Analysis by Rietveld Method and Its Correlation with Optical Properties of Nanocrystalline Zinc Oxide. *Journal of Advanced Materials Letters*. Vol. 6. pp. 139-147.
- Lee, T.-H, S.-J. Kim, E. Shin, and S. Takaki. 2006. On the Crystal Structure of Cr_2N Precipitates in High-Nitrogen Austenitic Stainless Steel. III. Neutron Diffraction Study on the Ordered Cr_2N Superstructure. *Journal of Acta Crystallographica B*. Vol. 62. pp. 979-986.
- Leskovšek, Vojteh, Matjaž Godec, & Peter Kogej. 2016. Influence of Low Temperature Nitriding on the Strain-Induced Martensite and Laser-Quenched Austenite in a Magnetic Encoder Made from 304L Stainless Steel. *Journal of Sci. Rep.* Vol. 6. pp. 1-10.
- McCusker, L. B *et al.* 1999. Rietveld Refinement Guidelines. *Journal of Applied Crystallography*. Vol. 32. pp. 36-50.
- Me´ndez, I *et al.* 2006. Atom and Ion Chemistry in Low Pressure Hydrogen DC Plasmas. *Journal of Phys. Chem. A*. Vol. 110. No. 18. pp. 6060-6066.
- Mizuguchi, Y. *et al.* 2016. Compositional and Temperature Evolution of Crystal Structure of New Thermoelectric Compound $LaOBiS_{2-x}Se_x$. *Journal of Applied Physics*. Vol. 119. pp. 1-6.
- Momma, Koichi & Fujio Izumi. 2011. VESTA 3 for Three-Dimensional Visualization of Crystal, Volumetric and Morphology Data. *Journal of Applied Crystallography*. Vol. 44. pp. 1272-1276.
- Monteiro, Sergio Neves *et al.* 2016. Influence of Martensitic Transformation on the Fatigue of Low Temperature Metastable Stainless Steel. *Journal of Materials Science Forum*. Vol. 869. pp. 405-410.
- Murayama, Chisato *et al.* 2016. Crystallographic Features Related to a Van der Waals Coupling in the Layered Chalcogenide $FePS_3$. *Journal of Applied Physics*. Vol. 120. pp. 1-4.

- Nair, Vidhya G *et al.* 2014. Structural, Magnetic, and Magnetodielectric Studies of Metamagnetic $\text{DyFe}_{0.5}\text{Cr}_{0.5}\text{O}_3$. *Journal of Applied Physics*. Vol. 115. pp. 1-3.
- Oddershede, Jette, Thomas L. Christiansen, Kenny Ståhl, Marcel A. J. Somers. 2008. EXAFS Investigation of Low Temperature Nitrided Stainless Steel. *Journal of Materials Science*. Vol. 43. pp. 5358-5367.
- Oliveira, R.R.L. De *et al.* 2012. *Measurement of the Nanoscale Roughness by Atomic Force Microscopy: Basic Principles and Applications*. Federal University of São Carlos. Campus Sorocaba. Brazil.
- Ondrej, Pilch & Hruby Vojtech. 2016. The Influence of Plasma Nitriding Period on Nitrided Layers Thickness. *Journal of Solid State Phenomena*. Vol. 258. pp. 395-398.
- Ortiz, A.L *et al.* 2000. Fundamental Parameters Approach in the Rietveld Method: a Study of the Stability of Results Versus the Accuracy of the Instrumental Profile. *Journal of the European Ceramic Society*. Vol. 20. pp. 1845-1851.
- Petitjean, L & A. Ricard. 1984. Emission Spectroscopy Study of $\text{N}_2\text{-H}_2$ Glow Discharge for Metal Surface Nitriding. *Journal of Phys. D: Appl. Phys.* Vol. 17. pp. 919-929.
- Pindeo, C.E. *et al.* 1999. Solid State Alloying by Plasma Nitriding and Diffusion Annealing Treatment for Austenitic Stainless Steels. *Journal of Materials forum*. Vols. 318-320. pp. 233-240.
- Pinedoa, Carlos E & Waldemar A. Monteirob. 2004. On the Kinetics of Plasma Nitriding a Martensitic Stainless Steel Type AISI 420. *Journal of Surface and Coatings Technology*. Vol. 179. pp. 119–123.
- Pokorny, Z *et al.* 2016. Increasing of Durability of Surfaces by Plasma Nitriding Process. *Journal of Solid State Phenomena*. Vol. 258. pp 583-586.
- Rahinov, I., A. Goldman, S. Cheskis. 2005. Intracavity Laser Absorption Spectroscopy and Cavity Ring-Down Spectroscopy in Low-Pressure Flames. *Journal of Appl. Phys. B*. Vol. 81. pp. 143–149.
- Roisnel, T & J. Rodriguez Carvajal. 2001. WinPLOTR: A Windows Tool for Powder Diffraction Patterns Analysis. *Journal of Materials Science Forum*. Vols. 378-381. pp. 118-123.
- Rouffet, B., F. Gaboriau, & J.P. Sarrette. 2010. Pressure Dependence of the Nitrogen Atom Recombination Probability in Late Afterglows. *Journal Phys. D: Appl. Phys.* Vol. 43. pp. 1-7.
- Rusnak, K & J Vicek. 1993. Emission Spectroscopy of the Plasma in the Cathode Region of $\text{N}_2\text{-H}_2$ Abnormal Glow Discharges for Steel Surface Nitriding. *Journal of Phys. D: Appl. Phys.* Vol. 26. pp. 585-589.
- Saeed, A *et al.* 2014. Optimization Study of Pulsed DC Nitrogen-Hydrogen Plasma in the Presence of an Active Screen Cage. *Journal of Plasma Science and Technology*. Vol. 16. No. 5. pp. 460-464.

- Sahin, Mumin & Ceyhun Sevil. 2011. Investigation of Properties of Ion-Nitrided AISI 304 Austenitic-Stainless Steel. *Journal of Industrial Lubrication and Tribology*. Vol. 63. No. 5. pp. 359-366.
- Sansonetti J. E. & W. C. Martin. 2003. NIST Handbook Basic Atomic Spectroscopic Data. *Journal of Phys. Chem. Ref. Data*. Vol. 34. No. 4. pp. 1559-2559.
- Santofimia, M. J. *et al.* 2011. Model for the Annealing of Partial Martensite-Austenite Microstructures in Steels. *Journal of Solid State Phenomena*. Vols. 172-174. pp 567-572.
- Shabadi, V *et al.* 2014. Origin of Superstructures in (Double) Perovskite Thin Films. *Journal of Applied Physics*. Vol. 116. pp. 1-8.
- Sherby, O.D. *et al.* 2010. Structure and Hardness of Martensite in Quenched Fe-C Steels. *Journal of Materials Science Forum*. Vols. 638-642. pp 160-167.
- Shinno, H, M. Uehara, & K. Saito. 1997. Synthesis of α'' -Fe₁₆N₂ Iron Nitride by Means of Nitrogen-Ion Implantation into Iron Thin Films. *Journal of Materials Science*. Vol. 32. pp. 2255-2261.
- Singh, Harmeet, J. W. Coburn, & David B. Graves. 2000. Recombination Coefficients of O and N Radicals on Stainless Steel. *Journal of Appl. Phys.* Vol. 88. No. 88. pp. 3748-3755.
- Smith, A.C.H *et al.* 1962. Electron Impact Ionization of Atomic Nitrogen. *Journal of Phys. Rev.* Vol. 127. No. 5. pp. 1647-1649.
- Sodipo, Bashiru Kayode. 2016. Recent Advances in Synthesis and Surface modification of Superparamagnetic Iron Oxide Nanoparticles with Silica. *Journal of Magnetism and Magnetic Materials*. Vol. 416. pp. 275-291.
- Sun, Y. & T. Bell. 1997. A Numerical Model of Plasma Nitriding of Low Alloy Steels. *Journal of Materials Science and Engineering A*. Vol. 224. pp. 33-47.
- Suraj, K.S. *et al.* 2007. Near Cathode Optical Emission Spectroscopy in N₂-H₂ Glow Discharge Plasma. *Journal of Surf. And Coat. Tech.* Vol. 202. pp. 301-309.
- Tefera, Anteneh G *et al.* 2014. Optimal Packing Size of Non-Ligated CdSe Nanoclusters for Microstructure Synthesis. *Journal of Applied Physics*. Vol. 116. pp. 1-9.
- Valasamudram, V. *et al.* 2008. Experimental Studies of Thermo-Mechanical Treatment on Conventionally Melted High Nitrogen Martensitic Stainless Steel. *Journal of Anti-Corrosion Methods & Materials*. Vol. 55. No. 2. pp. 73-78.
- Wang, V *et al.* 2014. Structural, Electronic, and Optical Properties of GaInO₃: A Hybrid Density Functional Study. *Journal of Applied Physics*. Vol. 115. pp. 1-8.

- Wolten, Gerard M. 1960. Martensite Transformations and the Phase Rule. *Journal of Chemical Education*. Vol. 37. No. 5. pp. 237-239.
- Wu, Yun-Xia *et al.* 2014. Research Progress of Plasma Nitriding in Low Temperature for Austenitic Stainless Steel. *Journal of Applied Mechanics and Materials*. Vol. 456. pp 486-489.
- Xi, Yun-tao, Dao-xin Liu, & Dong Han. 2008. Improvement of Corrosion and Wear Resistances of AISI 420 Martensitic Stainless Steel Using Plasma Nitriding at Low Temperature. *Journal of Surface & Coatings Technology*. Vol. 202. pp. 2577–2583.
- Yang, Xu-Sheng *et al.* 2014. Dissecting the Mechanism of Martensitic Transformation via Atomic-Scale Observations. *Journal of Sci. Rep.* Vol. 4. pp. 1-7.
- Ye, Shuai and Yujie Cao. 2016. Structure of Iron Nitrides Under Different Nitridation Temperatures. *Proceeding of 4th AMITP*. pp. 6-9.
- Young, Hugh D & Roger A. Freedman. 2012. *University Physics with Modern Physics*. New York: Addison-Wesley.
- Young, R.A. 2002. *The Rietveld Method*. USA: Oxford University Press.
- Zheng, Jie *et al.* 2009. Iron Nitride Thin Films Deposited by Chloride Assisted Plasma Enhanced Chemical Vapour Deposition: Facile Stoichiometry Control and Mechanism Study. *Journal of Physics D: Applied Physics*. Vol. 42. pp. 185209: 1-9.
- Zhong, Li & Xi Han. 2011. Influence of Hydrogen on the Plasmas Nitriding Process of 35CrMo Steel. *Journal of Advanced Materials Research*. Vols. 295-297. pp. 1004-1009.

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