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Investigation of Optical and Structure Properties for Nano NiO Prepared by induced Plasma Technique

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ABSTRACT

In the current study, NiO nanoparticles were made from bulk structure using the induced plasma process and various bombardment periods. These nanoparticles were created as thin layers on various thicknesses of glass substrates (prepared at different times of shelling). After that, they were analyzed with an x-ray spectrum, scanning electron microscope, atomic force microscope, and UV-visible spectrophotometer. When the optical constants and characteristics were measured, the films' energy gaps ranged from 1.85 eV to 2.1 eV depending on the bombardment periods. The AFM and SEM examination tools clearly reveal a structural change where the roughness varies with bombardment time due to the variation in the diameter of the nanoparticles. Finally, layers are completely crystalline by the x-ray spectrum

Keywords: induced Plasma; NiO; Optical properties; Structure properties; Energy gap; Roughness;

1. Introduction

Nickel is a chemical element with atomic number 28, a shiny silver-white metal with a touch of gold. Nickel is a transition metal hard and malleable[1]. However, only small amounts of nickel are found in the atmosphere[2], and within large nickel-iron meteorites that are not exposed to oxygen outside the Earth's atmosphere. It is believed that a mixture of iron and nickel forms the outer shell of the planet [3][4]. Nickel has many uses, especially in alloys. This includes the rapidly growing battery industry as a vehicle for electric vehicles [5]. Nickel has many special uses in chemical manufacturing, such as hydrogenation catalysts, battery cathodes, dyes, and metal surface treatments [6]. Nickel is an essential nutrient for some microorganisms and plants that contain enzymes that use nickel as their active site [7]. Nickel has face center cub (fcc) structure (figure 8), and it is an alloy of many metals, used in hundreds of industries in a variety of ways. It is considered one of the most famous minerals in human history. Initially, humans had great difficulty dealing with the bends of nickel because it was difficult. Nickel is found in meteorites and can usually be found only in small quantities, but the largest source of it is in some ores, the minerals composed of iron, copper, and nickel. Perhaps this raw material is the most abundant source, since it is extracted and sent to most of the industrial regions of the world. As for how to

extract it, the nickel-bearing ore is smelted in a high-temperature furnace, resulting in a fertile mixture or mixture of metals. This mixture turns into nickel by mixing it with coke and heating it in an oven at a high temperature. Nickel is known for its shiny silver color and density, which is hard and malleable under heat. This means that it can be modified in the desired way and shape.

In many disciplines, including physics, chemistry, biology, cosmetics, medicine, engineering, and polymer science, among others, the nanoscale range of materials is extensively used [8]. Among the nanoparticles of transition metal oxide (TMO), Commonly employed in a wide range of applications, NiO is one of the significant transition metal oxide materials having a cubic lattice structure [9]. This nickel oxide NPs possesses distinctive optical, thermal, electrical, chemical, and physical characteristics as well [10]. NiO nanoparticles were created using a number of different synthesis techniques, including pyrolysis [10], ball milling [11], electro deposition [12], thermal plasma [13], chemical vapour deposition [14], gas deposition [15], radiolytic reduction [16], sonochemical method [17], chemical precipitation [18], hydrolysis precipitation method [19], sol-gel method [20], and microwave assisted method. The microwave combustion process used to produce NiO NPs uses less energy and takes less time.

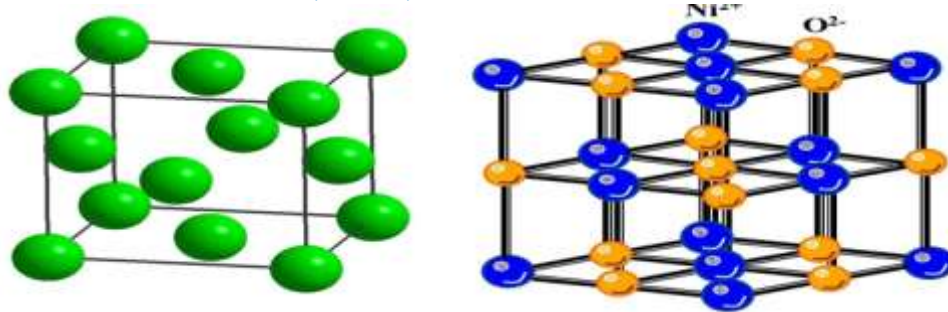


Fig. 1: a - Diagram of the crystal structure of nickel [21] b- Diagram of the crystal structure of nickel [22]

Plasma physics has played an important role in much of the development of contemporary physics, the study of problems in the fields of astrophysics, atomic physics, chemistry, life sciences, molecular physics, magnetic and dynamic energy generation, and atmospheric physics. [23].

Laser-induced plasma technology uses an ionized gas consisting of approximately equal numbers of positively charged ions and negatively charged electrons. [24]. Plasma may contain neutral atoms. In this case, the plasma is said to be partially or incompletely ionized. Otherwise, plasma is considered fully or completely ionized [25].

2. Experimental procedure

Using the induced plasma deposition approach, solutions containing NiO nanoparticles were created for various preparation times 4, 6, 8, and 10 min. The Nano- NiO has been obtained from 99% pure metal foils. The foils were cleaned with polishing paper and then washed with ethanol alcohol to get rid of any impurities on the metal's surface.

Where the Ni metal before placing it in the glass beaker had dimensions of length and width of about 5 cm², after that, a part of the Ni metal was cut to about 1.5 cm². It will be submerged in a 10 ml beaker with 7 ml of distilled water, where the nozzle of the needle is directed in the middle of the metal. The metal foil will be linked to the positive electrode, while the negative electrode will be connected to the needle nozzle. if a needle nozzle is 7 cm from the target in order to produce a spark in the shape of a scattered blue flame. The process was carried out in the presence of argon gas that flows at a constant rate (3 L/sec), then applying high voltage about 16 KV to produce nano NiO. Where it was dissolved in distilled water to form a light blue solution containing nano NiO, a centrifuge was used to precipitate nano NiO at the bottom of the tube, then placed on glass slides in a regular manner to form a thin film, and a thickness measurement was taken through a

spectrometer for each period of time, as shown in the table 1.

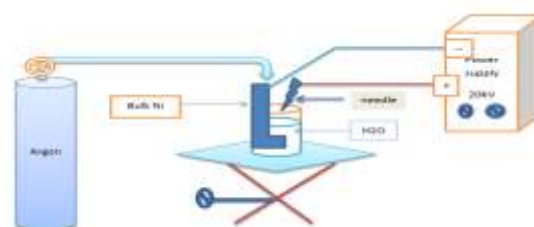


Fig. 2: Explain the operation of the induced plasma -get

3. Results and Discussion

The induced plasma technique has been used to bombardment the nickel oxide particles for varying preparation times (bombardment) ranging at 4, 6, 8 and 10 minutes. Each solution's NiO particles' optical characteristics were recorded. The optical characteristics and constants for the solution created at various times are shown in Figure 6. Over the wavelength range of 300–400 nm, the transmittance, absorbance, and reflectance rapidly changed before becoming extremely saturated for the longer wave lengths. The refractive index and the extinction coefficient both decline with wavelength in the range of 300–400 nm and then become remarkably stable for the other longer wavelengths.

This change also occurs similarly in the optical constants for the same wavelength range. For each option, the predicted band gap in Figure.6 (f) altered significantly. The band gap was 2 eV for the particles prepared at 4 min, 1.85 eV at 6 min, and subsequently increased to 1.88 eV and 2.1 eV for the particles prepared at 8 and 10 min, respectively. Figure 2. (a). The variation in particle size is what causes the band gap to fluctuate, Figure 2 (b) we can see that the energy gap widens as the grain size gets closer to the nano scale. Table .2 shows the change of the grain size with time and Table. 3 energy gap with time.

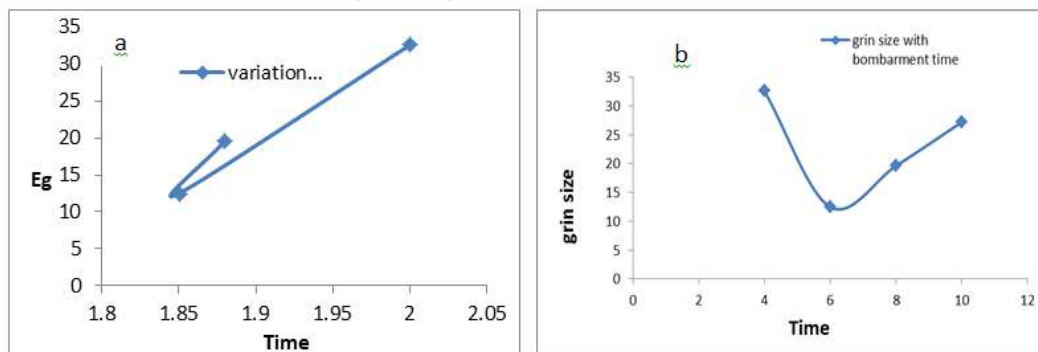


Fig. 3: (a) Variation of NiO E_g with bombardment time, (b) Variation of grain size with bombardment time for NiO.

Atomic force microscope AFM photos demonstrate how grain size varies with preparation time and decreases with deposition time, which is consistent with an x-ray spectrum in which the peaks have

shifted to the blue region. Additionally, the roughness of the surface diminishes with the bombardment time. table (1).

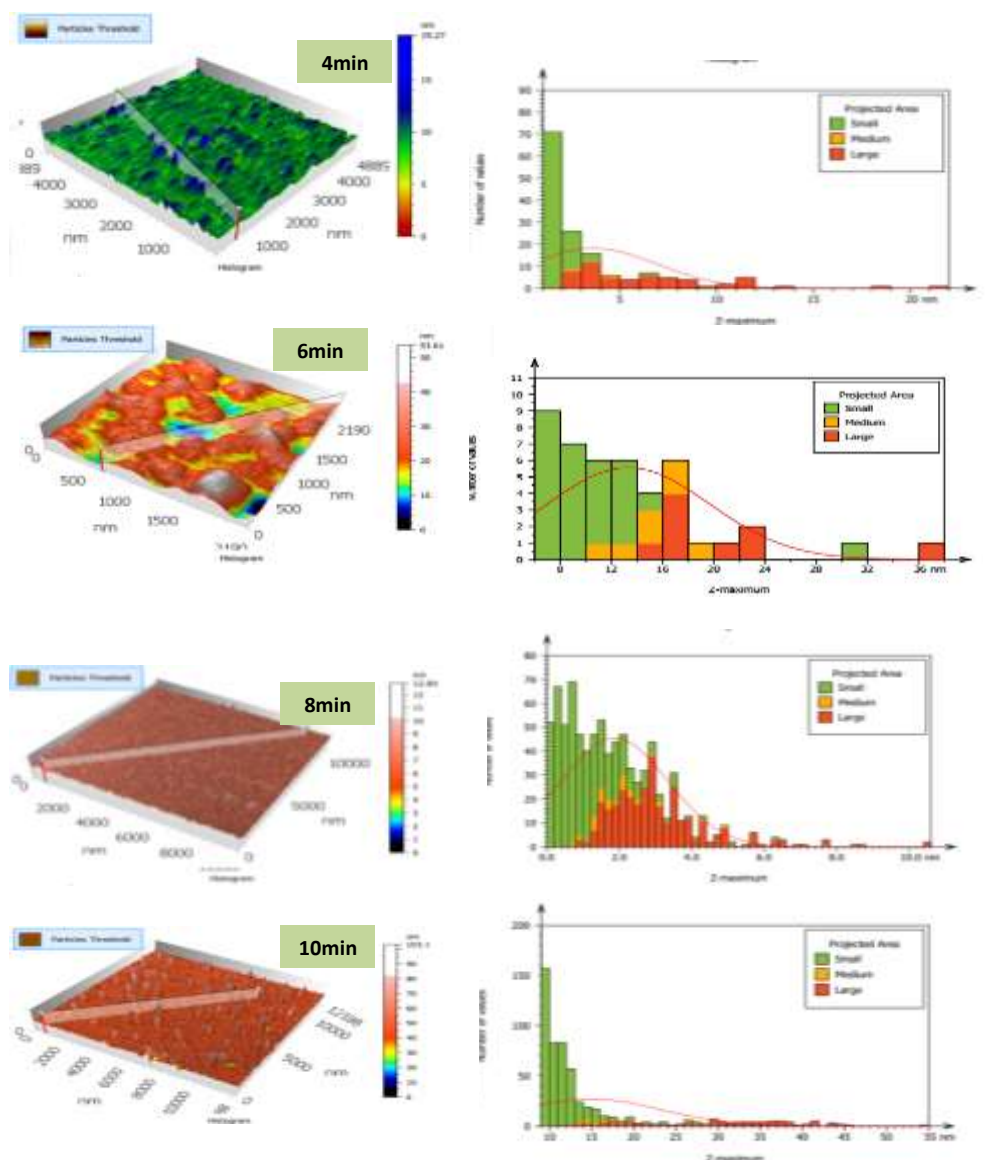


Fig. 3: Structural properties of NiO after induced Plasma bombardment for different bombardment periods (4, 6, 8 and 10 min).

Table 1: Surface Thickness and Roughness Average from AFM for the nano NiO at different bombardment times

bombardment time (min)	Surface Thickness (nm)	Roughness Average (nm)
4	1.095	1.317
6	2.75	7
8	0.47	0.122
10	4.322	9.17

The layers are very crystalline have a cubic structure according to the X-ray spectrum .The calculated grain size indicates that the grain size decreases with bombardment period as shown in table (2), which is consistent with the AFM images. The peaks for all bombardment periods appear with small differences in 2θ and small differences in intensities.

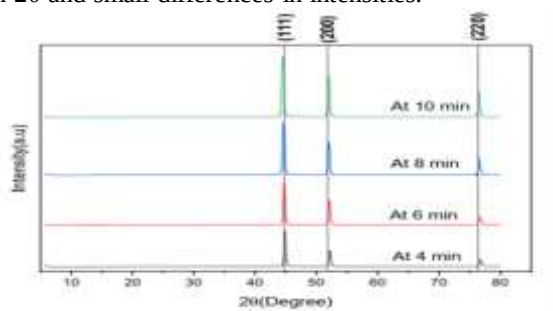


Fig. 4: Shows the X-ray diffraction of NiO after preparing it with induced plasma bombardment with different times.

Table 2: show the average grain size at different bombardment time

Bombardment time	Average grain size nm
4min	3.36
6min	3.3
8min	3.3
10min	3.37

SEM images show that the grain size decreases with bombardment time as shown in figure (5), and this agree with x-ray and AFM measurements.

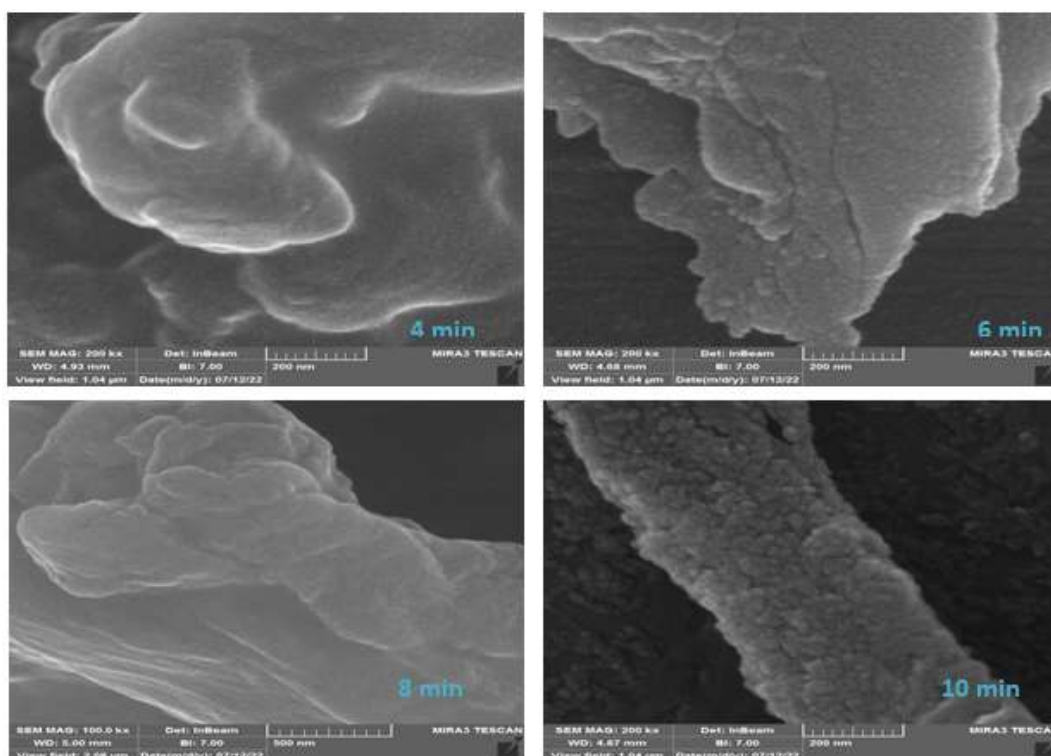


Fig. 5: show SEM images of NiO prepared at different bombardment periods (4,6,8,10)min.

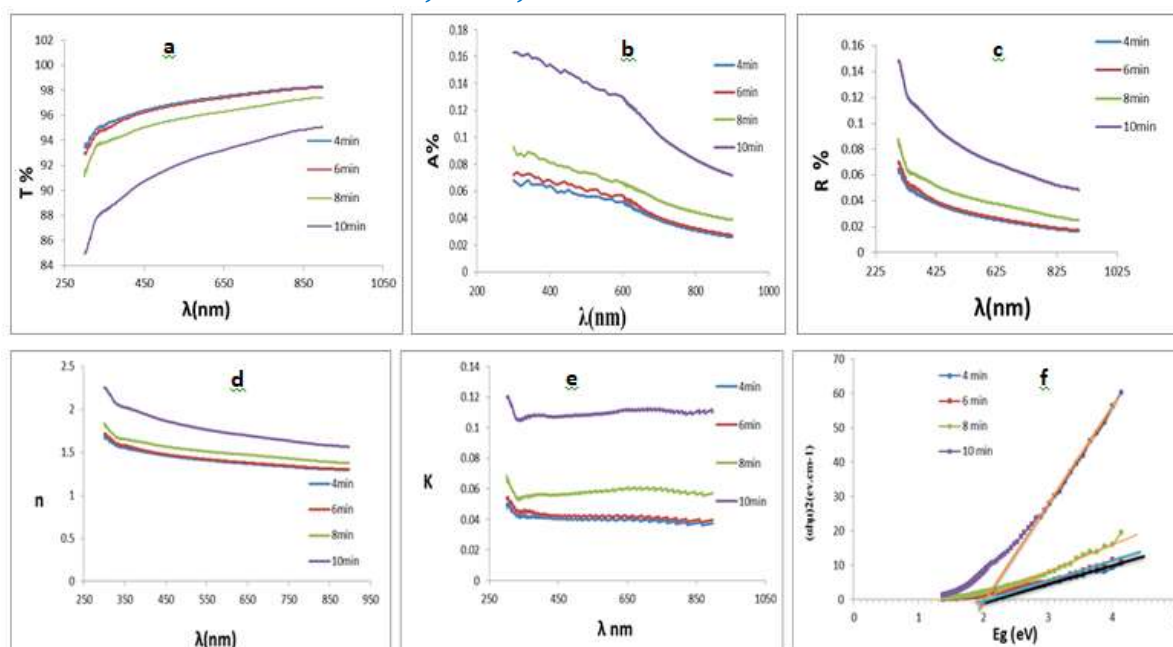


Fig. 6: effect of bombardment time on the optical properties a. transition b. absorption c. reflective d. refractive index e. extinction coefficient f. energy gap.

Table 3: band gap of the NiO prepared at different bombardment periods

bombardment time (min)	Energy gap (eV)
4	2
6	1.85
8	1.88
10	2.1

4. Conclusions

Using the induced plasma method, Nickel oxide nanoparticles have been created for various

bombardment times. The surface roughness and thickness are seen to decrease with bombardment periods in AFM images, which is consistent with SEM images and the X-ray spectrum. The peaks for all periods emerge at the same 2θ with varying intensities in the X-ray spectra, demonstrating the entire crystalline nature of the layers. The predicted grain size also gets smaller with time, from 3.36 to 3.37 nm. The energy gap and optical characteristics visibly changed with the duration of the bombardment.

References

- [1] Nickel: Nickel Metal Information and Data". Mindat.org . Archived from the original on March 3, 2016. Retrieved March 3, 2016. Retrieved March 2, (2016)
- [2] Sticksrud, Lars; Wasserman, Yevgeny; Cohen, Ronald (November 1997). Composition and temperature of the Earth's inner core. *Journal of Geophysical Research*. 102 (B11): 24729 - 24740. Bibcode: (1997) JGR... 10224729S. doi: 10.1029/97JB02125.
- [3] Coy, J. M.D.; Skomerev, F.; Gallagher, K.; (1999). "Rare Earth Metals: Is Gadolinium Really Magnetic?". *nature* . 401 (6748): 35-36. Bibcode: 1999Natur.401...35C. doi: 10.1038/43363. S2CID 4383791 .
- [4] "Nickel use in society". Nickel Institute. Archived from the original on September 21, (2017)
- [5] Treadgold, Tim. "Gold is hot but nickel is even hotter as demand for batteries in electric vehicles increases". *Forbes*. Retrieved October 14, (2020).
- [6] "Nickel Compounds - The Inside Story". Nickel Institute.
- [7] Fabiano CC, Tezotto T, Favarin JL, Polacco JC, Mazzafera P. Essentiality of nickel in plants: a role in plant stresses. *Front Plant Sci*. 2015 Sep 23;6:754. doi: 10.3389/fpls.2015.00754. PMID: 26442067; PMCID: PMC4585283.
- [8] S.C. Jeyaseelan *et al.*, (2019), Spectroscopic, quantum chemical, molecular docking and in vitro anticancer activity studies on 5-Methoxyindole-3-carboxaldehyde, **J Mol Struct**
- [9] I. Sondi *et al.* (2014), *Silver nanoparticles as antimicrobial agent: a case study on E. coli as a model for gram-negative bacteria*, *J. Colloid Interface Sci*
- [9] S.K. Jesudoss *et al.* (2018), *In-vitro anti-cancer activity of organic template-free hierarchical M (Cu, Ni)-modified ZSM-5 zeolites synthesized using silica source waste material* *Journal of Photochemistry and Photobiology B: Biology*
- [10] S.A. Cumberland *et al.* (2009) Particle size distributions of silver nanoparticles at environmentally relevant conditions, *J. Chromatogr. A*

- [11] A. Raja, K. Selvakumar, P. Rajasekaran, M. Arunpandian, S. Ashokkumar, K. Kaviyarasu, S. Asath Bahadur, M. Swaminathan, 2019, Visible active reduced graphene oxide loaded titania for photodecomposition of ciprofloxacin and its antibacterial activity, *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, Volume 564, Pages 23-30,
- [12] Saritha Valsalam et al., (2019), Rapid biosynthesis and characterization of silver nanoparticles from the leaf extract of *Tropaeolum majus* L. and its enhanced in-vitro antibacterial, antifungal, antioxidant and anticancer properties, *Journal of Photochemistry and Photobiology B: Biology*
- [13] J. Judith Vijaya et al., 2017, Bioreduction potentials of dried root of *Zingiber officinale* for a simple green synthesis of silver nanoparticles: antibacterial studies, *Journal of Photochemistry and Photobiology B: Biology*.
- [14] K. Kaviyarasu et al. , 2016, Synthesis and characterization studies of NiO nanorods for enhancing solar cell efficiency using photon upconversion materials *Ceram Int*
- [15] Q.L. Li et al., 2008, Antimicrobial nanomaterials for water disinfection and microbial control: potential applications and implications, *Water Res*
- [16] V. Helan et al., 2016, Neem leaves mediated preparation of NiO nanoparticles and its magnetization, coercivity and antibacterial analysis *Results in Physics*
- [17] M. Kundu et al., 2017, Green synthesis of NiO nanostructured materials using *hydrangea paniculata* flower extracts and their efficient application as supercapacitor electrodes, *Powder Technol*
- [18] A. Ezhilarasi et al., 2016, Green synthesis of NiO nanoparticles using *moringa oleifera* extract and their biomedical applications: cytotoxicity effect of nanoparticles against HT-29 cancer cells, *J. Photochem. Photobiol. B*.
- [21] J.K. Sharma et al., 2015, Biosynthesized NiO nanoparticles: potential catalyst for ammonium perchlorate and composite solid propellants, *Ceram Int*
- [19] J.K. Sharma et al., 2015, Biosynthesized NiO nanoparticles: potential catalyst for ammonium perchlorate and composite solid propellants, *Ceram Int*.
- [20] Liu, P., Chen, D., Wang, Q., Xu, P., Long, M., & Duan, H. (2019). Crystal structure and mechanical properties of nickel–cobalt alloys with different compositions: A first-principles study. *Journal of Physics and Chemistry of Solids*, 109194. doi:10.1016/j.jpcs.2019.109194.
- [21] Diao, Chien-Chen, Chun-Yuan Huang, Cheng-Fu Yang, and Chia-Ching Wu. 2020. "Morphological, Optical, and Electrical Properties of p-Type Nickel Oxide Thin Films by Nonvacuum Deposition" *Nanomaterials* 10, no. 4: 636. <https://doi.org/10.3390/nano10040636>
- [22] J. Diedrich, "Laser-Induced Breakdown Spectroscopy on Bacterial Samples", M.Sc. thesis, Wayne State University USA, (2007).
- [23] N. Braithwaite, "Introduction to gas discharges" *Plasma Sources Sci. Technol.* 9 517–527,(2000).
- [24] A. Dinklage, T. Klinger, G. Marx, L. Schweikhard, " Plasma physics confinement transport and collective effects ", *Lect. Notes in phys.* 670, Springer, Berlin Heidelberg, Chap. 1, 2005.