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# $Al/Al_2O_3$ direct connection using transient eutectic liquid phase

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**ABSTRACT**

In 2020, Cheng and his colleagues presented a paper entitled $Al/Al_2O_3$ direct bonding using transient eutectic liquid phase. In this research, they stated that ceramic base layers used in applications such as integrated circuit boards and diodes with high light emission. Directly bonded copper (DBC) layer is a ceramic layer that is widely used in electronic circuit boards for semiconductor modules, but the formation of $CU_2O$ at the interface causes a large deposition pressure. Therefore, the DBC layer has little strength against thermal cycling. Direct bonded aluminum (DBA), which uses aluminum as the metal circuit, used for ceramic layers. Although this combination not formed at the interface of ceramic and metal, but the bonded sample has good strength against thermal cycle. Khazaka et al. showed that in the work environment with thermal cycling, the DBA layer achieves better performance compared to the DBC layer. During thermal cycling tests from 55 to 250°C after 1500 cycles, no delamination of aluminum from the ceramic base metal plate observed. For conventional DBC technology, cracking or delamination occurs in DBC after 20 to 30 cycles. This improvement is due to the different plastic hardening behavior between aluminum and copper. To increase aluminum-ceramic bonding, the annealing temperature increased above the melting point of aluminum rather than the soaking effect. Increase and decrease the contact angle between aluminum and ceramic.

## Introduction

Ning and his co-workers used diecast joining and continuous casting joining to join aluminum and ceramics at 700-900°C and observed that a complete interface without any defects at annealing temperature of more than 750°C and in $N_2$ atmosphere can be obtained [1-3].

Lin and Tuan modeled the compact structure of $AL/AL_2O_3/AL$, which forms a direct bond at temperatures above the melting point of aluminum, and this model shows that the bonding between alumina and aluminum is a diffusion process. In addition, high annealing temperature can increase the surface strength, but increasing the temperature can lead to AL metal vaporization [4-6].

Therefore, it is necessary to establish a bonding process at a low AL melting point for the ceramic-aluminum bonding line.

Fei and his colleagues succeeded in making AL/ALN by using CUO paste with a baking temperature of 660 degrees Celsius, and the copper layer produced from the reduction of CUO. Then it spread on aluminum foil. So, they achieved a solid connection. This dispersion of copper on aluminum led to the formation of rod-like particles of $AL_2CU$ intermetallic compound in the surface reaction zone and caused deterioration of the mechanical properties of AL/ALN joints [7-9].

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Kumamoto and his colleagues used an aluminum alloy with an atomic percentage of 0.42% Mg and 0.38% Si additives, lowers the melting point of aluminum for bonding to ALN after heating in vacuum at 650°C, and They discovered the cause of the reaction of magnesium, the surface oxide of ALN ($AL_2O_3$), aluminum alloy, a single layer of MgO at the interface [10-12].

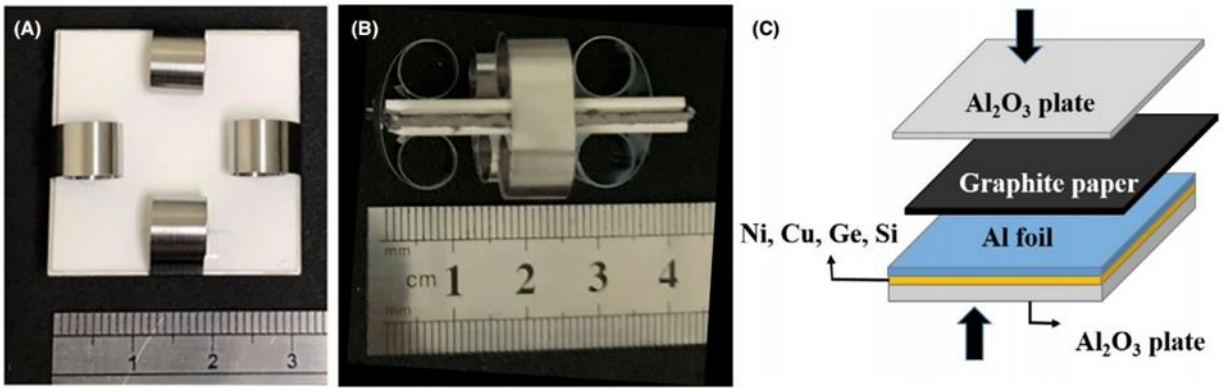



**Figure 1.** a) top view, b) cross-section, c) $Al_2O_3$ schematic with Si, Ge, Cu, Ni samples.

Kormitz et al developed a transient eutectic liquid phase formed in aluminum-X (X includes silicon, germanium, silver, and copper) for joining ceramics such as ALN. The aluminum-X liquid phase contacts the ALN layer transiently before isotherm solidification by spreading element X on the aluminum foil. During the heating process, the elements that layered on the ceramic surface cause the formation of a thin eutectic liquid phase at the interface [13-30]. Subsequently, elements diffuse on the aluminum and cause eutectic liquid strength, which leads to aluminum-ceramic bonding, but Kormitz et al did not measure interfacial bonding strength and thermal conductivity to evaluate aluminum-ceramic bonding. The TLP method is suitable for aluminum-ceramic joints because the annealing temperature reduced to the melting point of aluminum [31-35].

The goal of Cheng and his colleagues is to select the appropriate elements to create a transient eutectic liquid phase at the aluminum-ceramic interface after joining. The elements of nickel, copper, germanium and Si appear in $Al_2O_3$ layer and then join aluminum after annealing in eutectic regions. Among these elements, nickel and copper were chosen, because both can be prepared through the low-cost process of electroplating. The microstructural characteristics of $AL/AL_2O_3$ junction were performed using scanning electron micrograph and transmission electron microscope equipped with energy dispersive spectrometer. Evaluation of voidness, shear strength and thermal conductivity was done using acoustic tomography scan, ISO ۱۲۴ ۱۳ test and laser flash method, respectively. They found that using the TLP method, aluminum was successfully bonded to $AL_2O_3$, which showed nickel, copper, germanium, and Si at the interface of the $AL_2O_3$ layer after annealing at a relatively lower melting point than aluminum layer.

There is no reaction layer in the interface in any of the $AL/AL_2O_3$ samples [36-45]. Aluminum-iron intermetallic compounds such as $AL_9Fe_2$ and $AL_3Fe$ formed due to the deposition of iron in all layers, which was an impurity layer of aluminum foil and reaction with aluminum at the boundary of aluminum grains during the annealing process. The characterization of $AL/AL_2O_3$ samples, which are represented by germanium and Si layers, was relatively unsuccessful, which could be due to the fact that the amorphous layers of the represented layer easily form oxides and lead to low adhesion between aluminum and $AL_2O_3$. Therefore, the optimal choice for use in high-power devices is $AL/AL_2O_3$ with a layer of nickel film.

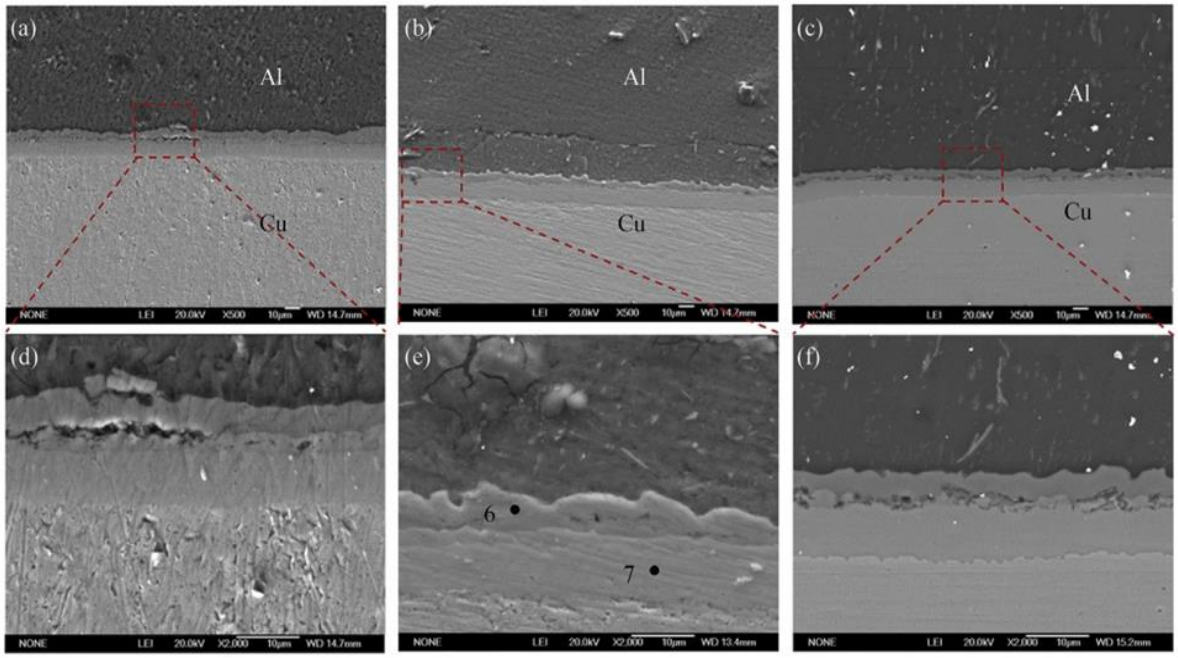
The article titled study on the microstructure and performance of the copper-aluminum junction of the transient liquid phase with an inner layer with an aluminum base.

In 2018, he and his colleagues stated in an article titled Study on the microstructure and performance of transient liquid phase copper-aluminum bonding with an aluminum-based inner layer that bimetallic composite structures between pure aluminum and copper due to excellent thermal and electrical conductivity It has been widely used in the fields of electronics, refrigeration and hydrometallurgy, such as power transmission parts [45-55], heat exchangers and conductive heads. The key factor in the preparation of aluminum-copper composite structure is the connection between copper and aluminum, but the oxide film of aluminum surfaces and intermetallic compounds are inevitable problems in aluminum-copper connection in terms of their metallurgical characteristics. The oxide film in aluminum-based materials is stable and insoluble,

which prevents direct contact between copper and aluminum.

The high strength and hardness characteristics of IMGs severely reduce the joint performance. Many welding methods such as cold rolling friction welding, brazing and explosive welding have used in practical production to make copper-aluminum structure. It has suggested that friction welding and explosive welding methods can produce aluminum-copper bimetallic structure with reliable welding properties. The oxide film completely broken and destroyed by relying on severe deformation of the plastic [56-70]. The formation of IMGs effectively inhibited due to the lower thermal cycling and higher recombination rate, but the interface structures obtained by friction welding and explosion welding depend on the severe plastic deformation and very fast cooling and heating rates [71-80]. They are thermodynamically unstable and this unbalanced structure prevents the driving force for the nucleation and growth of IMGs. For example, as the main component of the hydrometallurgical cathode plate, the copper-aluminum conductive head produced by explosive welding shows an increase in resistance and interface band during use as conductive parts. The growth and failure of IMGs is the main factor of failure in the service process by reducing the connection strength. Hard and brittle IMC ALx/CUx form easily due to their strong chemical affinity when aluminum and copper are directly bonded. Therefore, adding an intermediate layer has become the most effective method. Transient liquid phase bonding has gained increasing attention since it has been able to dissolve oxide layers by the liquid phase and thus allow internal contact with the bulk metal. The metal foil pressed between the installed metal surfaces. The surface liquid layer formed depending on the interactions between the MPD and the base metal [81-90]. The TLP process includes several steps such as layer disintegration, isometric solidification and solid-state homogenization. Although extensive studies have been carried out on the formation of aluminum-copper intermetallic compound during the reactions of the internal part of the solid state and to the same extent on the reactive diffusion between the liquid and solid phases, a detailed explanation of the surface structural evolution of the TLP foil-aluminum alloy junction with Aluminum-copper base is not provided in the background [91-93].

**Figure 2.** Aluminum-copper connection cross-section presented by him and his colleagues.




He and colleagues have designed two types of aluminum-based alloy foils and considered sandwich assemblies such as aluminum-copper-based aluminum-foil alloy [94-99], TLP bonding at different temperatures in vacuum environment. The structure and composition of the bonding surface area determined by SEM and X-ray energy dispersive spectroscopy. The bonding strength of aluminum-foil alloy structures with aluminum-copper TLP base determined by tensile shear test and predicted strength [100-110]. Three types of aluminum-copper TLP junction lines were TLP junctions in sandwich-like coupon assemblies at different temperatures in vacuum environment. The structure and composition of the binding interface region were determined. The strength and resistance of the connection was tested. They obtained the following results:

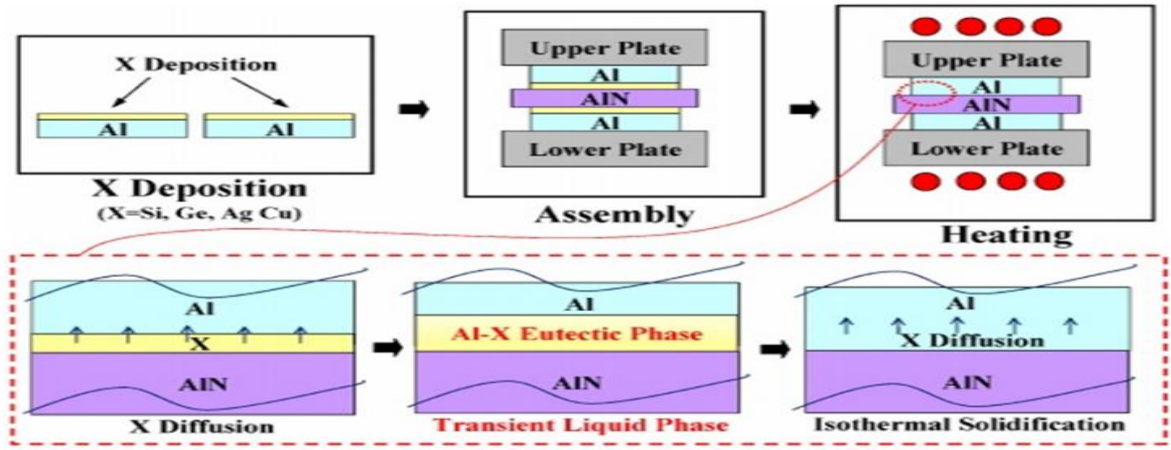
- ✓ Two layers of compounds formed in three types of connection lines. A typical eutectic structure without an inner layer found at the junction. The main difference between the three bonding lines, which uses different inner layer, is the microstructure of $Al_2Cu$/Al and $Al_2Cu$ interfacial structures.
- ✓ The thickness of the $Al_4Cu_9$ layer near the copper side has no obvious change. The formation of compounds near the aluminum side inhibited by the use of the inner layer. This shows that the presence of Si elements significantly inhibits the formation of $Al_2Cu$ phase [111-113].
- ✓ The cutting power of the connecting line without an inner layer is significantly lower than that in the connecting line with an inner layer [114-122]. The cutting strength of the connection lines used in the Al-11Si-4Cu-2Mg foil has reached 77 MPa at a temperature of 575 degrees Celsius. The aluminum-copper composite structure fabricated by TLP using Al-11Si-4Cu-2Mg foil, which has good conductivity. Because its resistance is almost equal to the theoretical resistance.

The article titled direct bonding of aluminum-on-aluminum nitride plates by transient liquid phase bonding.

In 2017, Kormitzo et al. stated that aluminum nitride (ALN) was used as a ceramic for DBC layers especially for its high thermal conductivity to extract heat from silicon chips. Direct bonding aluminum layers using ALN have been developed to replace DBC layers and also practically used in IGBT modules for hybrid electronic vehicles that require very high reliability under extreme thermal stress. Is. Finite Element Method (FEM) analysis showed that the higher tensile strength of DBA layers compared to DBC layers under high thermal stress conditions is due to the different plastic deformation behaviors of aluminum and copper. Two different methods are used to bond aluminum to ALN in practical applications. One involves adding a solder film between the aluminum and ALN layers and then melting the solder film. Another method requires direct melting of aluminum on the ALN layers without using a solder film.

Kurmitz et al developed a new process for bonding aluminum to ALN that uses transient liquid phase (TLP). DBA layers are fabricated by this new method and these properties have been evaluated. They developed a new binding process to generate DBA layers by TLP binding. DBA layers were prepared by this process with suitable heating conditions which were very stable and showed no surface fracture. TEM observations for the model samples using crystalline ALN layers showed that these DBA layers were transformed between aluminum and ALN.

**Figure 3.** The new connection process presented by Kormitz and his colleagues.




The article titled Transient Liquid Phase Diffusion Bonding of Aluminum Metal Matrix Composite Using Copper-Nickel Mixed Powder Intermediate Layer.

In 2011, in a paper titled Transient Liquid Phase Diffusion Bonding of Aluminum Metal Matrix Composite Using Copper-Nickel Mixed Powder Interlayer, they stated that aluminum-based metal matrix composites reinforced with silicon carbide have better properties compared to the integrated aluminum alloy is shown to make these composites useful for industrial aerospace and transportation applications. Despite the potential advantages of using AIMMCs, it has not achieved widespread industrial applications. One of the main reasons for limiting the use of AIMMC is the problem of connecting them. Mechanical fastening requires drilling of the composite, which can damage the reinforcement and also cause stress concentration, which leads to catastrophic failure. Fusion welding of Sci-reinforced AIMMC is associated with a number of problems such as high melt viscosity,

segregation effects on restrengthening, trapped gas evolution causing extensive cracking in the heat-affected zone, weld porosity, and particle/matrix reactions that combine Metal creates harm, turns. The presence of small $Al_4C_3$ plates reduces the fracture toughness of the weld and causes corrosion in a humid environment. The main problem associated with AIMMC solid state diffusion bonding is the presence of a hard and stable aluminum oxide layer on the plate, which prevents metal-to-metal contact. To overcome this problem, a program of high pressure is required, which deforms the plastic by more than 40% to disrupt the oxide film on the mounted plates. Another alternative is to remove the oxide layer before bonding by vacuum ion beam cleaning. Both approaches are difficult to implement in industrial applications. The transient liquid phase (TLP) diffusion bonding process has been reported by several researchers as a promising technology for bonding AIMMCs. The TLP diffusion bonding process is an attractive bonding approach used to bond internal layers between components, where internal diffusion of the layer and base material results in the formation of a low-melt composite that expands, contracts, and solidifies at a constant melt joint temperature. will be This process has advantages such as low junction temperature, low junction pressure, presence of heat affected zone, breakdown of the plate oxide film by TLP and low probability of adverse reactions.

The TLP release coupling process was first introduced and patented by Paolonis and his colleagues in 1972. This process was introduced for joining heat-resistant alloys such as nickel-based superalloys. During this period, this process was introduced to join heat-resistant alloys such as nickel-based superalloys. Later, along with nickel-based superalloy, it has been used for other materials such as magnesium alloy, dola stainless steel, titanium aluminide, joining different materials and MMCs. In the TLP process, the bonding temperature keeps the eutectic temperature of the layer-based material system slightly high and the solid temperature of the base material low. The most widely used inner layer in TLP release junction for AIMMCs is copper. This is because this element requires a low joining temperature that is significantly lower than the solidification temperature of the base material to avoid distortion and melting.

The initial attempt by Bashby and Scott to bond Sic fiber reinforced AIMMC with inner layer of copper foil and Ag-Cu foil at $550^{oC}$ in air environment resulted in poor bond strength due to transient liquid oxidation.

Len Weiger achieved better bonding quality during TLP diffusion bonding of $Al_2O_3$ 6061-15vol with internal layers of Ag foil and copper foil in vacuum environment. Although the different stages of the TLP bonding process were not studied for the composite system, the separation of $Al_2O_3$ reinforcement at the bonding interface up to a maximum holding time of 2 hours at $566^{oC}$ has been reported. Generally, during TLP diffusion bonding for AIMMCs containing alumina and copper reinforced with Sic particles and when ODS alloy is bonded to yttria, segregation of particles in the bonding medium has been observed. Especially for the connection of TLP Sic or AIMMCs reinforced with $Al_2O_3$, the application of the inner layer of pure copper leads to the strengthening of the separation of particles at the connection interface. The weak zone created by particle separation in the joint area is found, which leads to increased failure during the tensile test. On the other hand, the use of the inner layer of pure nickel has not shown any fracture from the dispersion of particle reinforcement, but the joining temperature is usually more than 60 degrees Celsius, which is close to or higher than most aluminum matrix alloys and causes melting or severe distortion of the base material. and connection becomes impossible.

Yan and his colleagues used 10% vol 6061-6061 $Al_2O_3$ composite bonding by TLP diffusion bonding process at 580°C temperature and with 30-90 minutes holding time in vacuum from the inner layer of Cu/Ni/Cu composite foil instead of pure copper or They use pure nickel with a thickness of 10/30/10 micrometers. A maximum bond strength of 102 MPa was obtained for the maximum bond time used, which is 68% of the strength of the parent composite. The use of the inner layer of the composite foil creates a very layered (heterogeneous) structure with the presence of Al0/9O1/1 intermetallic brittle phase, which prevents the achievement of proper efficiency, but the use of a uniform mixture of the inner layer of copper-nickel powder so far for the bonding of AIMMCs by the TLP diffusion bonding process has not been studied. Therefore, in current research studies, the inner layer of mixed copper-nickel powder is thought of as something that provides more uniformity in the microstructure by diffusion in the TLP process. Based on this, sic 6061-15 wt% composite is bonded with the inner layer of nickel-copper mixed powder in argon environment with different holding time up to 6 hours. The microstructural evolution with joint time has been fully investigated in relation to joint line shear strength and failure mode.

They obtained the following results:

- ✓ In TLP phase diffusion bonding for composite SiCp 6061-15 wt at 560 degrees Celsius, 0.2 MPa using the inner layer of copper-nickel weft, the bonding area mainly includes two areas. One is the central binding region and the other is the isothermal stabilization region.

- ✓ The microstructure of the isothermal stabilized region includes $CuAl_2$ chemical precipitation and $Al_9Ni_2$ low-stable precipitation in the alpha solid solution matrix along with Sic reinforced particles.
- ✓ The microstructure of the central bonding region is highly heterogeneous at lower bonding times. Equilibrium phases such as $NiAl_3$, $Al_7Cu_4Ni$, and alpha-reinforced solution are present along with Sic-reinforced particles. In contrast to the connection with the inner layer of pure copper, the separation of Sic particles is prevented, but fine dust has been observed.
- ✓ As the bonding time increases, it grows due to the continuous diffusion of the $NiAl_3$ phase, and gradually the structural heterogeneity decreases with the disappearance of the $Al_7Cu_4Ni$ phase and the microparticles in the central bonding region are eliminated. After 6 hours of storage, the microstructure of the central bonding region consisted of $NiAl_3$ without any visible microparticles.
- ✓ During a shorter connection time, during the shear test, the crack originates from the fine particles and spreads during the interphase interfaces, which leads to weak connection strength, but the laboratory sample with 6 hours of storage causes structural homogeneity and the presence of porosity. It shows the highest bond strength where the initial failure occurs through the destruction of the matrix/Sic particle interface.

**Internal background**

The article titled similar bonding of titanium by transient liquid phase bonding process.

In 2016, Moradi et al., in an article entitled Titanium/titanium like joining by transient liquid phase joining process, stated that titanium is widely used in aircraft manufacturing, aerospace, weapons, and also in structural materials due to its favorable characteristics such as low It has high density, high strength, excellent corrosion resistance, and a good strength to weight ratio. Also, this alloy has the ability to obtain a wide range of mechanical properties by using thermomechanical processes. Titanium's excellent corrosion resistance makes it ideal for a large number of engineering applications. Some industries choose titanium as a structural material for piping, pressure vessels, heat exchangers and autoclaves. With the increase in the use of light metals such as titanium alloys in various industries, titanium joining itself has become an important matter. Penetration welding has succeeded in joining titanium to itself or steel alloys. We need great care in the preparation of base metal surfaces and the impractical method for bulk products is the limitation of using this method. This hard connection of titanium with other metals can be solved by using soldering. As a result, soldering is useful for such cases. Because it only involves melting the filler metal. Also, soldering is able to connect all types of metals without severe distortion in them and is widely used for this type of application. Unfortunately, commercially available solder alloys require a high temperature, which can cause a decrease in the properties of titanium. However, using transient liquid phase penetration bonding, TLP maintains the structure of the base alloy in the bonding region. In the TLP method, a filler metal is placed between the joint parts and a thin molten layer is formed by heating. Because the temperature exceeds the melting point of the intermediate layer or the reaction of the intermediate layer with the base metal leads to the creation of a melt with a low melting point. The created melt fills the voids formed by the unevenness due to the mating of the surfaces. Then the middle layer melts and penetration into the base metal causes isothermal freezing. The result of this process is a good joint with the same structure as the base metal without any temperature affected zone. Other advantages of TLP connections compared to solid state penetration connections are low connection temperature, pressure and low surface roughness required. The middle layer has an important role in the specification of the junction regions. At first, researchers used alloys with a chemical composition including Ag, Zt and Ti, which instead of creating a connection with good strength, caused the formation of various intermetallic compounds. Alloy foils are expensive and have a complex production process. Therefore, the middle layer of copper replaced the previous materials due to the reduction of the formation of intermetallic compounds, low price and availability. The results of Moradi et al.'s connection of commercial pure titanium by the transient liquid phase process by a copper intermediate and at two different times were successfully performed and the results are as follows:

The microstructure of the joint in both times has a relatively wide area affected by penetration, which is formed due to the penetration between titanium and copper in the joint area. The connection made at a temperature of 900 degrees and a time of 45 minutes has discontinuities in the center of the connection, which is due to insufficient time to perform the process. The connection made in 45 minutes has a connection without discontinuity, and in this sense, the time of 45 minutes is better, but the connection still needs more time to complete its isothermal freezing. The microhardness profile in the joint region shows that the hardness value in the joint region is higher than the titanium base metal, which confirms the existence of Ti-Cu intermetallic compounds in the joint region. By examining the shear strength of connections at different times, it

can be concluded that the connection made in 45 minutes has a higher strength than the one made in 51 minutes. Because more penetration is done at higher times and more plastic destruction occurs between the contacting surfaces, which results in improved mechanical properties of the connection.

The article with the title of investigation of the effective factors in the production of titanium dioxide nanoparticles in the liquid phase.

Reofi and Ebrahimi in 2013 in an article titled Inspection of effective factors in the production of titanium dioxide nanoparticles in the liquid phase stated that very small particles with a grain size of nanometers are known as nanostructures and any material that consists of grains or Molecular bundles or layers and threads with a size of 100 nm or smaller can be made in this group.

A small amount of excess in the structure of these materials and their high surface to volume ratio has caused these compounds to exhibit unique mechanical, optical, electronic and magnetic properties. For example, nanostructured metals and ceramics have completely different and prominent mechanical properties compared to their common and ordinary samples. The high hardness and resistance to corrosion and breakage make nanoparticles suitable for industrial coatings, and the high contact surface for oxidation and reduction with the environment causes attention to their catalytic applications, and the high specific surface that causes the rapid development of the interaction of materials on each other. The properties of these materials depend on the following four factors:

- ✓ Particle size and particle size distribution.
- ✓ Molecular composition and structure.
- ✓ Particle surface.
- ✓ Interaction of components.

Based on this, during the last ten years, many researchers have focused on the production methods of nanoparticles and tried to provide optimal production methods. Since the range of use of nanoparticles is constantly increasing, according to the type of application of these materials, the granularity and percentage of phase and shape of the particles are also important, which also depends on the production method. For example, titanium dioxide nanoparticle consists of two main forms, anatar and rutile. If it is used as a photocatalyst, a sample formed from anatase phase containing a small amount of rutile has a higher photoactivity than pure anatase or a high percentage of rutile. Also, the effect of particle size is such that smaller particles of 10-20 nm have higher photoactivity than larger particles. Therefore, special attention should be paid to the production processes of nanoparticles and the desired process should be selected according to the type of application. In addition, by changing important parameters in each process, nano materials with different characteristics can be obtained. Some of these processes are: thermal hydrolysis, cell process, bulk deposition, spray drying, freeze drying, spray heating, laser evaporation and controlled condensation, microemulsion, aerosol. Some methods are performed in the liquid phase and others in the gas phase. In this article, two methods of producing titanium dioxide nanoparticles in the liquid phase are examined. From the comparison of the above two methods, they found that the reaction volume has a significant effect on the particle size and it is enough to provide conditions to reduce the reaction volume as much as possible, which is done in the microemulsion method by controlling the diameter of the micelle droplets and in the hydrolysis method in a tubular reactor by controlling the diameter. The reactor is done. The presence of HPC, which prevents agglomeration by surrounding the titania particles, also plays a similar role.

**Conclusion**

In 2018, Abdi et al., in an article titled Effect of bonding temperature in transient liquid phase bonding process on microstructure, mechanical properties and corrosion resistance of 316L stainless steel bonding to commercial pure titanium used in medical implants stated that the phase bonding process Transient liquid is a process in which metals are connected using an intermediate layer of base metal or other materials. The interface layer between the two metals is connected and by melting it and forming a molten phase between the two surfaces of the metal to be connected and penetrating into the base metals and freezing at the same temperature, the connection is created. In this process, after the complete penetration of the intermediate layer and homogenization, the strength of about 90% of the base metal can be achieved. In this process, unlike penetration welding, the amount of pressure applied to the parts to be connected is not very important. Transient liquid phase joining process is a new method, which is due to the possibility of execution for complex and large parts, the possibility of simultaneous execution of a large number of parts, no need for special equipment, the high melting temperature of the joint and, as a result, increasing the working temperature. The piece and the low amount of distortion and welding defects are superior to other processes. This process includes four steps: closing the parts together using a holder, melting the interface layer, freezing at the same temperature and homogenization. In the first stage, the parts are closed using a holder in such a way that the interface layer between the two metals is connected. In the next step, the liquid phase is formed by increasing the temperature of the assembly up to the melting temperature of the interface layer or creating a eutectic compound. In the next step, with the penetration of this liquid phase into the base metals and changing the chemical composition, freezing takes place in

isothermal form. If the bonded sample is placed in the furnace for a longer period of time, the concentration of the interface layer will be more uniform throughout the base metals and the mechanical properties of the connection will be very close to the base metals. Among the applications of connecting 316L steel to pure titanium, we can mention the medical applications of this connection, such as artificial joints, bone plates, etc. Both 316L steel and titanium in direct contact with biological fluids are resistant to corrosion and provide a benign and safe biological response. It is very important that the surgical implant is not exposed to corrosion when placed in the human body to prevent the possibility of infection. Unfortunately, titanium is easily contaminated when exposed to hydrogen, nitrogen, and oxygen, which can affect the corrosion process in this metal and may jeopardize its use in some medical applications. On the other hand, features such as titanium's low weight, high strength against repeated pressures, and a lower modulus of elasticity than steel, which causes the stress to be unconcentrated and causes the force to spread in the bone, encourage the use of titanium. Therefore, connecting titanium to 316L steel becomes important. They investigated the effect of TLP operation temperature parameter on the mechanical properties, microstructure and corrosion resistance of commercial pure titanium connection to 316L steel with the presence of copper interface layer and reached the following results:

- ✓ The lowest shear strength of the sample bonded at a temperature of 950 degrees Celsius and a time of 120 minutes was about 12 MPa, and the highest shear strength of a sample bonded at a temperature of 1000 degrees Celsius and a time of 120 minutes was about 46 MPa.
- ✓ .‧The results of the microhardness test showed that there are areas in the common season where the microhardness of those areas is much higher than the base metals. These points are formed by intermetallic compounds and the corrosion rate is highly dependent on the formed intermetallic compounds. The samples that had less intermetallic composition showed more corrosion resistance. Also, iron-titanium intermetallic compounds had lower corrosion resistance than copper-titanium intermetallic compounds.

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**Authors' Contributions**

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

**References**

[1] Fu, Y., Zhao, Y., Liu, M., Wang, J., & Yan, J. (**2022**). Optimization of cold-end system of thermal power plants based on entropy generation minimization. *Frontiers in Energy, 16*(6), 956–972.

[2] Li, J., Li, Z., & Wang, J. (**2019**). Thermo-economic performance evaluation of emerging liquid-separated condensation method in single-pressure and dual-pressure evaporation organic Rankine cycle systems. *Applied Energy, 256*, 113974.

[3] Sunder Raj, K. S. (**2004**). Multi-pressure surface condenser performance evaluation: A case study. *ASME 2004 Power Conference*, 65–72.

[4] Fu, Y., Zhao, Y., Liu, M., Wang, J., & Yan, J. (**2022**). Optimization of cold-end system of thermal power plants based on entropy generation minimization. *Frontiers in Energy, 16*(6), 956–972.

[5] Sunder Raj, K. S. (2004). Multi-Pressure Surface Condenser Performance Evaluation: A Case Study. *ASME 2004 Power Conference*, 65–72.

[6] Li, J., Liu, Q., & Duan, Y. (**2017**). Thermo-economic analysis and optimization of a zeotropic fluid organic Rankine cycle with liquid-vapor separation during condensation. *Energy Conversion and Management, 148*, 517–532.

[7] Pattanayak, L., Padhi, B. N., & Kodamasingh, B. (**2019**). Thermal performance assessment of steam surface condenser. *Case Studies in Thermal Engineering, 14*, 100484.

[8] Shin, D., Jeon, J., Kim, T., Park, J. H., & Kim, S. J. (**2020**). Development of the thermal performance model using temperature gradient analysis for optimized design of steam surface condenser. *International Journal of Heat and Mass Transfer, 163*, 120411.

[9] Eslampoor, Y and Abedini, N. (**2026**). Comparison of Hemodynamic Responses to 50 Microgram Fentanyl Administration Across Different Age Groups During General Anesthesia. *Medicinal, Psychological, and Health Research Journal (MPHRJ), 2*(4), 295-305.

[10] Eslampoor, Y and Abedini, N. (**2026**). Hemodynamic Effects and Complications of Bone Cement Utilization in Orthopedic Operations.

*Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(4), 317-328.

[11] Ranjbar, R., Dehkordi, F. S., & Heiat, M. (**2020**). The frequency of resistance genes in Salmonella enteritidis strains isolated from cattle. *Iranian Journal of Public Health*, *49*(5), 968.

[12] Abdolmaleki, Z., Mashak, Z., & Safarpoor, D. F. (**2019**). Molecular and virulence characteristics of methicillin-resistant Staphylococcus aureus bacteria recovered from hospital cockroaches. 2019;12(12):e98564.

[13] Dehkordi, F. S., Yahaghi, E., & Darian, E. K. (**2014**). Prevalence of antibiotic resistance in Escherichia coli isolated from poultry meat supply in Isfahan. *Iran J Med Microbiol: 8*(2), 41-7.

[14] Rostami, F., Rahimi, E., Yahaghi, E., Khodaverdi Darian, E., & Bagheri Moghadam, M. (**2014).** Isolation and evaluation virulence factors of Salmonella typhimurium and Salmonella enteritidis in milk and dairy products. *Iranian Journal of Medical Microbiology*, *8*(1), 54-61.

[15] Mashak, Z., Banisharif, F., Banisharif, G., Reza Pourian, M., Eskandari, S., Seif, A., …., & Alavi, I. (**2021**). Prevalence of listeria species and serotyping of Listeria monocytogenes bacteria isolated from seafood samples. *Egyptian Journal of Veterinary Sciences*, *52*(1), 1-9.

[16] Nayebpoor, F., Momeni, M., & Dehkordi, F. S. (**2013**). Incidence of Ochratoxin A in raw and salted dried fruits using High Performance Liquid Chromatography. *American-Eurasian Journal of Toxicological Sciences*. 2013; 5 (1): 01-06.

[17] Ranjbar, R., Mahmoodzadeh Hosseini, H., & Safarpoor Dehkordi, F. (**2020**). A review on biochemical and immunological biomarkers used for laboratory diagnosis of SARS-CoV-2 (COVID-19). *The Open Microbiology Journal*, *14*(1).

[18] Dehkordi, F. S., & Rafsanjani, M. S. (**2012**). Prevalence study of Coxiella urnetiid in aborted fetuses of small ruminants in various partum and seasons in Iran. *African Journal of Microbiology Research*, *6*(27), 5594-5600.

[19] Safarpour dehkordi, F., Hosseini, S., Rahimi, E., Yahaghi, E., & Momeni, M. (**2026**). Investigate the frequency of virulence genes Vibrio parahaemolyticus isolated from fish, lobsters and crabs caught from Persian Gulf. *Iranian Journal of Medical Microbiology*, *8*(2), 1-7.

[20] Safarpourdehkourdi, F., Momtaz, H., Esmailzade, S., Khayyat Khameneie, M., & Yahaghi, E. (**2026**). Detection of virulence factors of Uropathoigenic Escherichia coli isolates from infertile women high vaginal swabs. *Iranian Journal of Medical Microbiology*, *7*(4), 1-8.

[21] Momeni Shahraki, M., Shakerian, A., Rahimi, E., & Safarpoor DEHKORDI, F.. (**2020**). Study the frequency of enterotoxin encoding genes and antibiotic resistance pattern of methicillin-resistant Staphylococcus aureus isolated from vegetable and salad samples in Chaharmahal Va Bakhtiari province. Journal of food microbiology, 7(2 ), 55-69.

[22] Dormanesh, B., Mirnejad, R., Khodaverdi Dariyan, E., Momtaz, H., Yahaghi, E., Safarpour Dehkordi, F., & Pilevarzadeh, M. (**2026**). Characterization and study the antibiotic resistance of Uropathogenic Escherichia coli isolated from pediatrics with pyelonephritis and cystitis in Iran. *Iranian Journal of Medical Microbiology*, *7*(2), 27-39.

[23] Mousavi, S., SAFARPOOR, D. F., & Valizadeh, Y. (**2017**). Genotyping of Helicobacter pylori strains isolated from raw milk and dairy products. 4(3):41-53.

[24] Rashidiani, J., Eskandari, K., Ranjbar, R., Kooshki, H., Afshar, D., & SAFARPOOR, D. F. (**2021**). Application of gold core-shell magnetic nanoparticles immunosensor for detection of vibrio cholera. 8(1):71-75.

[25] Madahi, H., Rostami, F., Rahimi, E., SAFARPOOR, D. F., & Jalali, M. (**2013**). Detection of classical enterotoxins of Staphylococcus aureus isolates from chicken nugget and ready to eat foods in Esfahan province by ELISA technique. 3(3): 9.

[26] Shahreza, M., Dehkordi, F., Kurbanova, S. K. S., & Sapayev, V. S. V. (**2025**). Occurrence of Staphylococcus aureus, Campylobacter jejuni, Listeria monocytogenes and Arcobacter butzleri in poultry meat. *International Journal of Health and Medical Innovation (IJHMI)*, *2*(1), 10-17.

[27] Shahreza, M. S., Jafariaskari, S., Al-Aouadi, R. F. A., & Dehkordi, F. S. (**2024**). Molecular genotyping and antimicrobial resistance characters of Helicobacter pylori isolates from raw milk of naturally infected animal species. *International Invention of Scientific Journal*, *8*(4), 793-803.

[28] Jafariaskari S, Shahreza MS, Al-Aouadi RFA, Dehkordi FS. (**2020**), Hydroxychloroquine Therapeutic effects on COVID19: a systematic review and meta-analysis. International Invention of Scientific Journal 8 (4), 804–817

[29] Alijani, H. Q., Fathi, A., Amin, H. I. M., Lima Nobre, M. A., Akbarizadeh, M. R., Khatami,

M., … & Shafiee, A. (**2024**). Biosynthesis of core–shell α-Fe2O3@ Au nanotruffles and their biomedical applications. *Biomass Conversion and Biorefinery*, *14*(14), 15785-15799.

[30] Rezaei-Tazangi, F., Mirhosseini, A. F., Fathi, A., Roghani-Shahraki, H., Arefnezhad, R., & Vasei, F. (**2024**). Herbal and nano-based herbal medicine: New insights into their therapeutic aspects against periodontitis. *Avicenna Journal of Phytomedicine*, *14*(4), 430.

[31] Mirzaei, K., Fathi, A., Asadinejad, S. M., & Moghadam, N. C. (**2022**). Study the antimicrobial effects of Zataria multiflora-based mouthwash on the microbial community of dental plaques isolated from children: A candidate of novel plant-based mouthwash. *Acad J Health Sci*, *37*, 58-63.

[32] Mohammad, W. T., Alijani, H., Faris, P., Salarkia, E., Naderifar, M., Akbarizadeh, M. R., … & Khatami, M. (**2023**). Plant-mediated synthesis of sphalerite (ZnS) quantum dots, Th1-Th2 genes expression and their biomedical applications. *South African Journal of Botany*, *155*, 127-139.

[33] Mehrabanian, M., Ahari, U. Z., Fathi, A., & Parizi, M. M. (**2021**). Comparison of Dental Health Status in Schizophrenic Patients with Healthy Individuals: A Case Study in Iran. *Clinical Schizophrenia & Related Psychoses* 15 (2).

[34] Zadeh, S. M. M., Elyaskhil, M., Fathi, A., & Asadinejad, S. M. (**2021**). Evaluate Risk Markers For Periodontal Disease In Children With Type 1 Diabetes: A Systematic Review And Meta-Analysis. *Turkish Online Journal of Qualitative Inquiry*, *12*(8).

[35] Barjoee, S. S., & Fathi, A. (**2020**), A Systematic Review on the Applications of Nanoparticles in Dentistry. *International Journal of Health Sciences*, *6*(S6), 4864-4876.

[36] Fathi, A., Rahnama, S., Alesaeidi, S., Mousavi, E., Bagherboum, N., Gholami, M., & Fotovat, F. (**2023**). Comparing knowledge and opinions of medical and dental students in the field of pediatric anesthesia. *Journal of Family Medicine and Primary Care*, *12*(4), 632-636.

[37] Fathi, A., Natanzian, Y., Ghorbani, M., & Mosharraf, R. (**2024**). Evaluation of the Bonding Shear Strength between Enamel and Dentin Feldspathic Porcelain and Two Different Monolithic Zirconia with Low and High Translucency. *International Journal of Dentistry*, *2024*(1), 5921637.

[38] Makiya, A., Moghaddam, M. A., Faghihinia, F., Anzabi, R. M., Asadi, H., & Fathi, A. (**2024**). Pro-inflammatory Cytokines may Associate Periodontitis with Pregnancy Complications: A Short Review. *New Emirates Medical Journal*, *5*(1), e02506882262319.

[39] Ghasemi, E., Fathi, A., Mohammadi, D., & Salehi, S. (**2025**). Stress distribution analysis in bone adjacent to implant in various abutment-implant connection designs using finite element analysis. *Journal of Oral Implantology*, *51*(2), 134-141.

[40] Mosharraf, R., Fathi, A., Rismanchian, M., Ghasemi, E., & Givehchian, P. (**2025**). Customized versus titanium healing abutments for preimplant tissue healing in fresh socket implants: A systematic review. *Dental Research Journal*, *22*(1), 10-4103.

[41] Moazzam, M., Fathi, A., Ghorbani, M., & Mosharraf, R. (**2025**). Comparison of Vertical Marginal Discrepancy in High and Low Translucent Monolithic Zirconia Crowns in Repeated Firing Cycles. *European Journal of Dentistry*, *19*(03), 843-850.

[42] Fathi, A., Borhani, S., Salehi, S., Mosharraf, R., & Atash, R. (**2025**). Effect of Thermodynamic Cyclic Loading on Screw Loosening of Tightened Versus New Abutment Screw in Bone Level and Tissue Level Implants in DIO Implant Company (In-Vitro Study). *Clinical and Experimental Dental Research*, *11*(4), e70162.

[43] Ebadian, B., Fathi, A., & Beiranvand, N. (**2022**). Investigation of the effect of bonding factors on strength of porcelain bond to soft metal alloys after application of thermal cycle. *Dental research journal*, *19*(1), 91.

[44] Fathi, A., Nadian, F., Ghorbani, M., Razavi, P., Mosharraf, R., & Ebadian, B. (**2024**). Enhancing oral function: a case report on mandibular overdenture utilization with custom-made subperiosteal implant. *Journal of Prosthodontics*, *33*(9), 835-840.

[45] Secundar, B., Fathi, A., Baghaei, K., & Atash, R. (**2024**). Effect of ceramic thickness on the polymerization quality and film thickness of dual-polymerizing versus heated light-polymerizing adhesive cement. *The Journal of Prosthetic Dentistry*, *132*(6), 1328-e1.

[46] Hatami, M., Jalali, E., Kamran, M. H. L., Kazemi, A. D., & Fathi, A. (**2025**). Evaluating the Effect of High-Translucent Zirconia Thickness and Substrate Shade on the Final Color of the Restoration. *Clinical and Experimental Dental Research*, *11*(1), e70091.

[47] Fathpour, K., Astaraki, E., Zandian, A., Fathi, A., & Mirmohammadi, H. (**2023**). Shear bond strength of composite resins to lithium disilicate ceramics using universal bonding and different methods of surface preparation. *Dental research journal*, *20*(1), 82.

[48] Atash, R., Fathi, A., Salehi, H., Abedian, Y., Bottenberg, P., & Baghaei, K. (**2024**). Evaluation of the effectiveness of four composite Polishing systems: an in vitro study. *International Journal of Prosthodontics and Restorative Dentistry*, *14*(1), 16-22.

[49] Fathi, A., Mosharraf, R., Ghorbani, M., & Saberipour, S. (**2024**). Effect of shape and design of the internal connection of tissue-level and bone-level implants on detorque values and removal forces: An in vitro study. *The Journal of Prosthetic Dentistry*, *131*(6), 1135-e1.

[50] Shahreza MH, Rahimi E, Momtaz H. (**2017**), Antibiotic resistance pattern of Shiga-toxigenic Escherichia coli isolated from ready-to-eat food stuffs. Bioscience Biotechnology Research Communications; 10(2): 155-9.

[51] Shahreza MS, Jafariaskari S, Al-Aouadi RF, Dehkordi FS. (2024), Molecular genotyping and antimicrobial resistance characters of Helicobacter pylori isolates from raw milk of naturally infected animal species. *International Invention of Scientific Journal*. 2024; 8(04): 793-803.

[52] Jafariaskari S, Sakhaei Shahreza M, Aboqader Al-Aouadi RF, Safarpoor Dehkordi F. (**2024**), Hydroxychloroquine Therapeutic effects on COVID19: a systematic review and meta- analysis. *International Invention of Scientific Journal*. 2024; 8(04): 804-817.

[53] Sakhaei Shahreza M, Zendehdelmoghadam H, Rafiee Jelodar N, Safarpoor dehkordi F. (**2024**), Autoimmune disease, its general features and treatment. *Scholars' press*.:96.

[54] Badjadi, M. A., Zhu, H., Zhang, C., & Safdar, M. (**2023**). A Bayesian network model for risk management during hydraulic fracturing process. *Water*, 15(23), 4159.

[55] Badjadi, M. A., Zhu, H., Zhang, C., & Naseem, M. H. (**2023**). Enhancing water management in shale gas extraction through rectangular pulse hydraulic fracturing. *Sustainability*, 15(14), 10795.

[56] Badjadi, M. A., Zhu, H., Zhao, P., Zhang, F., Hou, D., Huang, L., & Micheal, M. (**2025**). Hybrid CNN-LSTM Model for predicting wettability alterations in shale reservoir based on experimental techniques. *Geoenergy Science and Engineering*, 214217.

[57] Mokhtari Torshizi, H., Salehnia, N., & Ahmadi Shadmehri, M. T. (**2026**). Are the Different Dimensions of Globalisation Necessary and Sufficient for Human Development?(A Worldwide Study). *Journal of Human Development and Capabilities*, 1-31.

[58] Mokhtari Torshizi, H., Salehnia, N., & Ahmadi Shadmehri, M. T. (**2026**). Are the Different Dimensions of Globalisation Necessary and Sufficient for Human Development? (A Worldwide Study). *Journal of Human Development and Capabilities*, 1–31.

[59] Zarini, M. K., & Amouzad Mahdiraji, E. (**2024**). Examining the secure communication network for the reliable use of micro-grids in the power system. *Journal of Engineering in Industrial Research*, *5*(2), 101–115.

[60] Mahdiraji,E. A. and Zarini,M. K. (**2025**). Integration of Smart Materials in Loss of Excitation Protection Schemes for Synchronous Generators in Renewable Energy Systems. *Journal of Chemical Engineering and Energy Materials*, *1*(2), 78-87.

[61] Mahdiraji, E. A., & Zarini, M. K. (**2025**). Integration of smart materials in loss of excitation protection schemes for synchronous generators in renewable energy systems. *Journal of Chemical Engineering and Energy Materials*, *1*(2), 78–87.

[62] Khodadadi Zarini, M., & Amouzad Mahdiraji, E. (2024). Review of energy management in micro grid in power engineering. *Journal of Engineering in Industrial Research*, *5*(2), 90–99.

[63] Amouzad Mahdiraji, E., & Sedghi Amiri, M. (**2020**). Locating, sizing, and optimal planning of the distribution substations using vanadium flow battery storage to improve the efficiency of the power distribution network. *International Journal of Smart Electrical Engineering*, *9*(1), 13–21.

[64] Amouzad Mahdiraji, E., & Khodadadi Zarini, M. (**2025**). Advanced material-based cooling and insulation strategies for enhanced protection of synchronous generators under fault conditions. *Journal of Chemical Engineering and Energy Materials*, 1(3), 119–125.

[65] Amouzad Mahdiraji, E., & Khodadadi Zarini, M. (**2024**). Smart frequency control in multi-carrier micro-grid with the presence of V2G electric vehicles. *Journal of Artificial Intelligence in Electrical Engineering*, *12*(45), 53–69.

[66] Amouzad Mahdiraji, E., & Amiri, M. S. (**2021**). Adaptive control of network frequency by doubly-fed induction generators using a data-driven method. *Eurasian Journal of Science and Technology*, *1*(2).

[67] Amouzad Mahdiraji, E. (**2022**). Multi-Objective Optimization of Distributed Generation Despite Energy Storage Systems for Optimal Management. *International Journal of Engineering and Innovative Research*, *4*(1), 44-59.

[68] Amouzad Mahdiraji, E. (**2022**). Microgrid control to ensure stability and increase flexibility in storage applications. *Journal of Engineering in Industrial Research*, *3*(2), 69–76.

[69] Fakhari, S, Bilehjani, A and Bilehjani, E. (**2026**). Effect of Intraoperative Intravenous Dexmedetomidine on Oxidative Stress in Patients Undergoing Cardiac Surgery: A Systematic Review. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(5), 351-359.

[70] Fakhari, S, Bilehjani, A and Bilehjani, E. (**2026**). Intravenous Dexmedetomidine in Cardiomyocyte Biology: A Systematic Review. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(5), 360-371.

[71] Hussam Elddin Nabeih Khasawneh, AA., et al., (**2025**), A Novel Thiazole-Sulfonamide Hybrid Molecule as a promising Dual Tubulin/Carbonic Anhydrase IX Inhibitor with Anticancer Activity, Frontiers in Chemistry 13 (13), 13

[72] Karami, F. (**2026**). A Systematic Review and Meta Analysis: Impact of Emergency Department Nursing Interventions on Patient Safety and Clinical Outcomes, *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(3), 199-211.

[73] Karami, F. (**2026**). Effectiveness of Nurse Led Triage Interventions on Patient Outcomes in Emergency Departments: A Systematic Review and Meta Analysis. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(3), 226-235.

[74] Lotfi, A R and Nouri Bayat, L. (**2026**). Incidence of Postoperative Complications Following Nasal Fracture Surgery in Adults. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(2), 175-182.

[75] Mehrasa, P and Eghdam Zamiri, R. (**2026**). Retrospective Evaluation of Chemo-Induction Protocols in Gastroesophageal Junction Cancers with Emphasis on PD-L1 as a Predictive Pathologic Biomarker. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(4), 276-284.

[76] Mehrasa, P Eghdam Zamiri, R. (**2026**). Prognostic Value and Predictive Utility of CA15 3 and CRP as Pathophysiological Biomarkers in Patients with Breast Cancer Undergoing Chemotherapy. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(5), 329-338.

[77] Moghadam, A M. (**2025**). Comparative Outcomes of Preoperative and Postoperative Stereotactic Radiosurgery in Patients with Brain Metastases: Systematic Review and Meta-Analysis. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *1*(11), 392-402.

[78] Moghadam, A M. (**2025**). Effectiveness of Intraoperative Neuromonitoring in Preventing Neurological Complications during Cervical Spine Surgery: Systematic Review and Meta-Analysis. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *1*(11), 378-386.

[79] Moghadam, A M. (**2025**). Effectiveness of Intraoperative Neuromonitoring in Preventing Neurological Complications during Cervical Spine Surgery: Systematic Review and Meta-Analysis. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *1*(11), 403-411.

[80] Moghadam, A M. (**2025**). Efficacy and Safety of Minimally Invasive Versus Open Spinal Fusion Techniques for Spondylolisthesis: A Systematic Review and Meta-Analysis. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *1*(11), 370-377.

[81] Moghadam, A M. (**2026**). Comparative Outcomes of Preoperative and Postoperative Stereotactic Radiosurgery in Patients Undergoing Resection for Brain Metastases: Systematic Review and Meta-Analysis. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(2), 137-146.

[82] Moghadam, A M. (**2026**). Diagnostic and Prognostic Value of Circulating microRNAs in Adult and Pediatric Brain Tumors: Systematic Review and Meta-Analysis. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(3), 156-167.

[83] Moghadam, A M. (**2026**). Diagnostic and Prognostic Value of Circulating microRNAs in Adult Brain Tumors: Systematic Review and Meta-Analysis. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(1), 42-49.

[84] Moghadam, A M. (**2026**). Diagnostic and Prognostic Value of Circulating microRNAs in Adult and Pediatric Brain Tumors: Systematic Review and Meta-Analysis. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(3), 156-167.

[85] Moghadam, A M. (**2026**). Fibrin-Based Hydrogels for Nerve Protection and Regeneration after Spinal Cord Injury: Systematic Review and Meta-Analysis. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(2), 106-116.

[86] Moghadam, A M. (**2026**). Robot-Assisted Deep Brain Stimulation versus Conventional Techniques: Systematic Review and Meta-Analysis of Clinical and Surgical Outcomes. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(2), 147-155.

[87] Mohammadzadeh Abachi, E and Montazer Bavil Olyaee, M. (**2026**). Granulomatous Mastitis: A Systematic Review of Diagnosis and Management. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(2), 141-149.

[88] Mohammadzadeh Abachi, E and Montazer Bavil Olyaee, M. (**2026**). Incidence of Re Expansion Pulmonary Edema During Chest Tube Placement Compared With Video Assisted Thoracoscopic Surgery in Massive Pleural Effusion. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(2), 167-174.

[89] Mohammadzadeh Abachi, E and Montazer Bavil Olyaee, M. (**2026**). Neutrophil to Lymphocyte Ratio as a Diagnostic and Prognostic Biomarker for Complication Prediction in Acute Appendicitis. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(2), 134-140.

[90] Rahmani, A and Abadi, P M S. (**2026**). Effectiveness of Skin Graft Fixation Techniques in Plastic Surgery: A Systematic Review and Meta-Analysis. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(4), 309-325.

[91] Rahmani, A and Abadi, P M S. (**2026**). Efficacy of Negative Pressure Wound Therapy Compared to Conventional Wound Closure in Plastic and Reconstructive Surgery: A Systematic Review and Meta-Analysis. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(4), 383-396.

[92] Rahmani, A and Abadi, P M S. (**2026**). Preventive Negative Pressure Wound Therapy versus Standard Postoperative Dressings in Plastic and Reconstructive Surgery: A Systematic Review and Meta-Analysis. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(3), 212-225.

[93] Ranjkesh, M and Maroufi, P. (**2026**). The Value of Serial Radiography in the Long Term Follow Up of Patients After Total Knee Arthroplasty: A Systematic Perspective. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(2), 150-156.

[94] Rebout, F. (**2026**). Artificial Intelligence in Early Detection of Skin Cancer. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(3), 236-250.

[95] Rebout, F. (**2026**). The Impact of Oral Hygiene Practices on the Prevention of Periodontal Diseases. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(4), 332-345.

[96] Rebout, F. (**2026**). The Relationship between Oral Health and Systemic Diseases: A Comprehensive Review of Bidirectional Linkages and Pathophysiological Mechanisms. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(4), 359-370.

[97] Rebout, F. (**2026**). The Role of Saliva in Oral Health and Disease Diagnosis. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(3), 168-176.

[98] Rezaei, M and Abedini, N. (**2026**). Prevalence of Acute Postoperative Pain and Its Associated Risk Factors in Patients Undergoing Laparoscopic Hysterectomy. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(4), 251-258.

[99] Rezaei, M and Dehghani, A. (**2026**). Association Between Age and the Incidence of Acute Postoperative Pain After Laparoscopic Hysterectomy. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(5), 383-390.

[100] [104] Rezaei, M and Dehghani, A. (**2026**). The Effect of Dexmedetomidine on Preventing Postoperative Delirium by Modulating Tumor Necrosis Factor-Alpha (TNF-α) Levels in Patients Undergoing Esophagectomy. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(5), 391-399.

[101] Rezaei, M and Owaysee Osquee, H. (**2026**). Prevalence of Deep Vein Thrombosis in Patients with COVID 19 Admitted to the Intensive Care Unit. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(4), 267-275.

[102] Sadeghzadeh, A. (**2026**). Adverse Events Associated with Facial Filler Injections: : A Systematic Review and Meta-analysis. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(2), 114-133.

[103] Sadeghzadeh, A. (**2026**). Effectiveness of Different Injection Depths for Facial Fillers: A Systematic Review and Meta-analysis. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(2), 157-166.

[104] Sadeghzadeh, A. (**2026**). Evaluating the effectiveness and safety of hyaluronic acid versus poly-L-lactic acid for facial volume restoration: A Systematic Review and Meta-analysis. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(2), 102-113.

[105] Sadeghzadeh, A. (**2026**). Parametric Design and Personalized Facial Reconstruction: Lessons from Contemporary Architecture. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(4), 296-308.

[106] Samimi, A. Zarinabadi, S. (**2011**), Reduction of greenhouse gases emission and effect on environment, Aust. j. basic appl. sci., 5(12), 752-756

[107] Samimi, A., Zarinabadi S., Shahbazi Kootenaei AH., Azimi A., Mirzaei M., (**2019**), Use of data mining in the corrosion classification of pipelines in catalytic reforming units (CRU), *Eura. Chem. Commu.*, 1(6), 571–581

[108] Samimi, A., Zarinabadi, S. (**2012**), Application solid polyurethane as coating in oil and gas pipelines, *Chisa*, 20th International Congress of Chemical and Process Engineering and 15th Conference Pres, 2012

[109] Samimi,A. (**2025**). Investigating the Effect of Temperature and Pressure Changes in CCR Unit Reactors on Catalyst Wear and Black Dust Increase. *Iranian Journal of Chemistry and Chemical Engineering*, *44*(12), 3039-3051.

[110] Shiri, H and Ashrafi, N. (**2026**). Enhanced Recovery After Thoracotomy in the Intensive Care Unit: Current Evidence, Clinical Strategies, and Future Perspectives. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(5), 372-382.

[111] Shiri, H and Ashrafi, N. (**2026**). Post Esophageal Surgery Dysphagia and Nutritional Support in the Intensive Care Unit. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(5), 339-350.

[112] Sundaramurthy, S., Salam, J.J. Titinchi Abdal-Kareem M.A. Dawagreh, Mohammad M. Hailat, Al Khasawneh, H., (**2019**), STUDY OF THE PRESENCE OF METAL ELEMENTS IN SEA WATER IN THE STATE OF KUWAIT, *Ecology, Environment and Conservation*, 25,

[113] Zbuzant, M. (**2026**). Advances in Digital Dentistry Applications of CADCAM Technology. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(4), 346-358.

[114] Zbuzant, M. (**2026**). Dental Implants vs. Traditional Bridges: A Comparative Clinical Review. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(3), 189-198.

[115] Zbuzant, M. (**2026**). Early Detection of Oral Cancer: Diagnostic Methods and Challenges. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research (JAMPBR)*, *2*(4), 371-382.

[116] Zbuzant, M. (**2026**). Minimally Invasive Techniques in Modern Restorative Dentistry. *Medicinal, Psychological, and Health Research Journal (MPHRJ)*, *2*(3), 177-188.

[117] Hashemloo, A., Milanifard, M. (**2025**). Dermal Fillers: Types, Indications, and Complications Materials de Relleno: Typos, Indications Complications. Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research, 1(6), 161-170

[118] Hashemloo, A., Milanifard, M. (**2025**), Contouring Plus: A Comprehensive Approach of the Lower Third of the Face with Calcium Hydroxylapatite and Hyaluronic Acid, Medicinal, Psychological, and Health Research Journal, 1(5), 143-150

[119] Sunder Raj, K. S. (**2004**). Multi-Pressure Surface Condenser Performance Evaluation: A Case Study. *Proceedings of the ASME Power Conference.*

[120] Jabari, M., Ekinci, S., Izci, D., Bajaj, M., Blazek, V., & Prokop, L. (**2025**). Efficient pressure regulation in nonlinear shell-and-tube steam condensers via a novel TDn(1+PIDn) controller and DCSA algorithm. *Scientific Reports, 15,* 2090.

[121] Hrebeniuk, V., et al. (**2023**). The problem of the surface condenser overall heat transfer coefficient determining at high temperatures of cooling water. *Results in Engineering*, *18,* 101193.

[122] Gañán, J., Verda, V., & Tiseira, A. (**2005**). Influence of the cooling circulation water on the efficiency of a thermonuclear power plant. *Applied Thermal Engineering*, *25.*