PHOTONIC PROPULSION - A PROMISING TECHNOLOGY FOR INTERSTELLAR MISSION

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ABSTRACT

Using the traditional techniques, such as physical or magnetic forces, to move or propel an item is relatively easy. The conventional methods like chemical or cryogenics propulsion have been used till now for the aerospace propulsions. But since the use of photons to induce movement has been highly intriguing for a few decades, mastering photonic propulsion is the key to getting over the constraints of the available propulsion technology. Here, a method of creating a substance that can be used for photonic propulsion and, on a larger scale, for both interplanetary and interstellar space missions, is illustrated. Utilizing a higher scale to illustrate or move items or spaceships at a higher level, a perspective on the movement of metallic foil utilizing LASER light has been presented here. Along with reducing the mass of spacecraft, traditional fuel usage, and pollution, this kind of interest and investment will yield positive financial returns.

1. INTRODUCTION

Using photons (light particles) to create thrust and move spacecraft is referred to as photonic propulsion, also known as laser propulsion or photonic thrusters. It is a method for theoretically and experimentally achieving fast space travel. The transfer of momentum from photons to the spacecraft is the fundamental idea behind photonic propulsion. This idea is based on the idea that light has momentum, which it transfers to objects when it reflects off of them or is absorbed by them. Despite having no mass, photons nonetheless contain energy and velocity since they are electromagnetic particles.

Several strategies for photonic propulsion have been put forth:

1. Light Sail Propulsion: This idea includes utilizing a sizable, reflective sail to collect photons from a laser or other strong light source. The sail is often constructed of a lightweight material like Mylar. The photons impart momentum to the sail when they hit it, moving the spaceship forward. This method is a very effective mode of propulsion because it doesn't require onboard propellant.

2. Laser Propulsion: In laser propulsion, the spaceship is propelled directly by a powerful laser. A unique substance installed in the spacecraft allows it to absorb the laser light and transform it into thermal energy. The material expands quickly as a result of the heat produced, producing a high-velocity exhaust that propels the spaceship in the opposite direction. The term "photonic laser thruster propulsion" is sometimes used to describe this technique.

3. Photonic Laser Thruster Array: The spaceship is propelled using an array of laser thrusters installed on it. These thrusters may be fired in a precise pattern that allows the spacecraft to adjust its course and orientation in space.

The possible benefits of photonic propulsion include the capacity to sustain extremely high velocity over time, particularly in the vacuum of space where there is no air resistance. Its supply of onboard propellant is not finite, which is a major drawback of conventional chemical rocket engines.

It all starts with a question that '**Is light massless?**'

Yes, light is thought to be massless according to the current consensus in science. Light particles called photons have no rest mass. Photons have zero rest mass, which is the mass of an item when it is at rest.

Despite having no rest mass, photons do contain energy and velocity since they are electromagnetic particles. One of the cornerstones of Einstein's theory of relativity is the idea that massless objects like photons can carry both energy and motion. Photons can transfer their energy and momentum when they interact with matter or other particles, leading to a variety of physical phenomena including the photoelectric effect or radiation pressure.

Our knowledge of the basic forces and interactions in the universe depends on the fact that light has no mass, which has important ramifications for physics. Additionally, it has real-world applications, such as photonic propulsion theories; employ the momentum of light to drive spacecraft.

Some researchers have provided and claimed a theoretical strategy for carrying out an interstellar journey using photonic propulsion using a plasma source or a monochromatic light source, such as a laser.[1] With further development of the necessary existing technologies, interstellar manned roundtrip flight may be accomplished within a century within the framework of current scientific concepts. The viewpoint on photon propulsion provided leads to the conclusion that the key to breaking the limit of the current propulsion technology based on conventional rocketry and perhaps ushering in a new space era is mastering photon propulsion that directly employs photon momentum.[2]

In all this cases a vital role is played by radiation pressure. The pressure that electromagnetic radiation, such as light, exerts on a surface or an object is known as radiation pressure. Photons, which are light particles, impart momentum to matter when they collide with a surface or interact with it. As a result of this momentum transfer, pressure is applied to the surface or object. Due to their energy and masslessness, photons each have a very little amount of momentum, but a large number of them working together can produce a quantifiable force.

The following formula can be used to determine the radiation pressure:

Radiation Pressure (P) = $\frac{2\times E}{c}$

- P being the radiation pressure,
- E is the incident radiation's energy (per square meter).
- The speed of light in a vacuum, or about 3 x 10^8 meters per second, is given by the constant c.

One newton per square meter (N/m^2) is equal to one pascal (Pa), which is the standard unit of radiation pressure.

In numerous branches of science and technology, radiation pressure has a number of significant applications and effects:
1. Light Sail Propulsion: Radiation pressure is employed in photonic propulsion to move spacecraft equipped with a big reflective sail. The sail gains speed when photons from a laser or other light source hit it, propelling the spacecraft forward.
2. Solar Sails: Using the pressure of sunlight itself, solar sails are a particular type of light sail propulsion. Without the need for onboard propellant, spacecraft with big, reflective sails can use the radiation pressure from the Sun to drive themselves.
3. Radiation Pressure in Astronomy: Dust, gas, and cosmic debris in space can move and behave differently due to radiation pressure from stars and other astronomical objects.
4. Optomechanical Devices: In optomechanical systems, where light is utilized to affect and control the motion of mechanical components, radiation pressure can be harnessed. Precision measurements and quantum technologies both use this.
5. Levitation of Dust Particles: In some situations, radiation pressure can work to defy gravity and lift microscopic dust grains or other particles into space.

A fascinating phenomena, radiation pressure is important in many natural processes and has practical uses in space travel and other branches of research and engineering.

Here an another word is introduced i.e. plasma. Space is frequently home to the condition of stuff known as plasma. With solid, liquid, and gas, it is regarded as the fourth fundamental state of matter. Ionized gases, such as plasma, contain about equal amounts of charged particles like ions and free electrons. Plasma differs from other states of matter due to the special characteristics and behaviors that these charged particles give it.

Plasma is prevalent in space and is essential to many astrophysical phenomena. Here are a few significant features of plasma in space:
1. Stars: Stars, such as our Sun, are essentially large, hot, dense balls of plasma. Nuclear fusion of hydrogen atoms into helium and the subsequent release of enormous amounts of energy in the form of light and heat occurs at the cores of stars due to the intense heat and pressure there.
2. Solar Wind: The solar wind is a steady stream of charged particles, primarily electrons and protons, that the sun continuously discharges into space. The solar wind is a plasma that travels throughout the solar system and affects planetary magnetospheres, causing auroras on planets with magnetic fields, among other phenomena.

3. Interstellar Medium (ISM): The interstellar medium is a flimsy plasma that fills the space between stars. Ionized gas and dust particles make up the ISM, which is the starting point for the creation of new stars and planetary systems.

4. Nebulae: In space, nebulae are enormous clouds of gas and dust, and a lot of them are made of plasma. Because nearby stars may illuminate these regions, which are frequently the sites of active star formation, stunning and colorful astronomical objects can be produced.

5. Accretion disks: Plasma-filled accretion disks are present around some celestial objects, such as black holes and young stars. These disks are made of material that spirals inward due to gravity, and as the plasma particles collide and heat up, they release a huge quantity of energy.

6. Magnetospheres and Space Weather: Magnetospheres, which interact with the solar wind to prevent the atmosphere from being stripped away, are present on planets with magnetic fields, such as Earth. The interactions between the solar wind and planetary magnetospheres have an impact on space weather phenomena like geomagnetic storms.

For astrophysics, space science, and space exploration, an understanding of plasma in space is crucial. In order to better understand the dynamics of stars, galaxies, and the cosmos as a whole, scientists study plasma. The development of technologies to cope with space-based plasmas, such as spacecraft propulsion and magnetic confinement in fusion research, also depends on plasma physics.

2. EXPERIMENTAL PROCESS:-

Based on the above literature survey and the proposed theories the research have been conducted to generate a thin film which could be used for this propulsion technique. For the synthesis of sail material 2,2'-Bis(trifluoromethyl)benzidine (TFDB) and 4,4′-(Hexafluoroisopropylidene)diphthalic anhydride(6FDA) were used as the source material. The precursor materials were purchased and used without any further purification, the Dimethylacetamide (DMAC) was used as solvent to prepare the solution for the reaction of the precursor compounds. 5g of TFDB ($C_{14}H_{10}F_6N_2$) was added into the 30ml of DMAC solution and the mixture was well stirred for 30 minutes at 0ºC under nitrogen atmosphere. After 30 minutes 7g of 6FDA ($C_{19}H_6F_6O_6$) was added very slowly to the mixture and the mixture was left for stirring for around 2 hours under the same condition. After this the mixture was stirred at room temperature for the next 23 hours and the PAA solution was obtained. Two different clays namely MMT and KAOLIN were added in the above obtained solution. After this the product was dried in the vacuum hot air oven at 65ºC for 24 hours then was dried at 100ºC in furnace for 2 hours and further at 150ºC, 200ºC and 250ºC subsequently was heated. After this a very thin layer of film namely PAA+KAOLIN & PAA+MMT were obtained. The synthesis procedure is shown in the following flow chart. Both the synthesized films were subjected to SEM analysis, XRD analysis, FTIR spectroscopy & DSC analysis to investigate the structural, morphological properties and functional groups of the composite material.

The thin film obtained from the above experiment was inserted in a plasma gun, and the plasma was shot, after that the movement of the films was observed in that gun.

3. RESULTS AND DISCUSSION

3.1. XRD analysis of thin films obtained:-

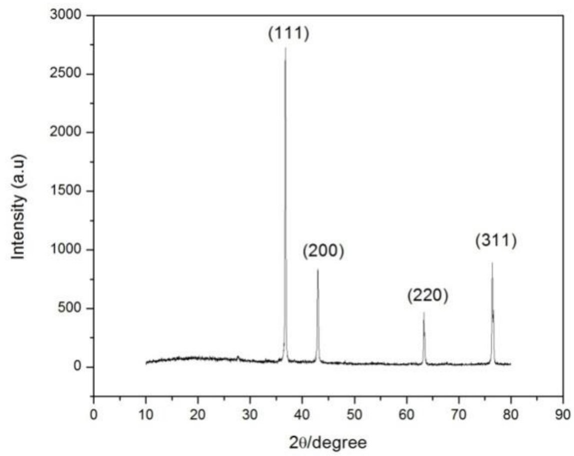

Fig.1. XRD of PAA with KAOLIN

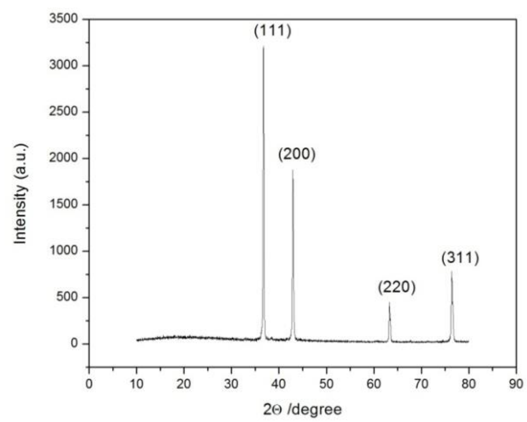

Fig.2. XRD of PAA with MMT

The recorded XRD patterns of PAA with KAOLIN and PAA with MMT are shown in Fig. 1 and 2. In both the above XRD the peaks are observed at about 36º, 44º 65º and the peaks were indexed as (111), (200), (220), (311). The XRD patterns are well matched with standard JCPDS data which confirm the crystal structure of PAA. No extra peaks were observed related to KAOLIN and MMT possibly due to the presence of low content in the PAA matrix. However , the presence of the organoclay was found to have no effect on the location of the peak, which indicates that perfect exfoliation of the clay layer structure of the organoclay in PI did not occur in these nanocomposites.

4. CONCLUSION

The thin hybrid film of PAA with KAOLIN and PAA with MMT clay nanoparticles were obtained could be used for the space propulsion. In space, plasma is in abundance amount and there is no atmosphere so the radiation pressure of plasma can be utilized as source of energy for the photonic propulsion which can lead to the achievement of the interstellar missions which is impossible with the help of the conventional propulsion methods. However, there are drawbacks to photonic propulsion as well. The creation and maintenance of high-power lasers or other light sources necessary for efficient propulsion is one of the fundamental obstacles. The size, weight, and requirement for exact alignment with the light source present additional difficulties for the light sail method.

Photonic propulsion is still largely being explored in lab settings and in the context of hypothetical future space missions. The technique is still not extensively used for actual space flight. Long-distance interstellar expeditions or other types of space travel could employ it in the future, nevertheless, as a result of continued research and technological development.

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