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Mochizuki et al.

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[54] **LASER PLASMA X-RAY GENERATOR CAPABLE OF CONTINUOUSLY GENERATING X-RAYS**

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**[4] **H05H 1/24**

[52] **U.S. Cl.** **378/119**; 378/120; 378/160

[58] **Field of Search** 378/119, 120, 34, 160

[56] **References Cited**

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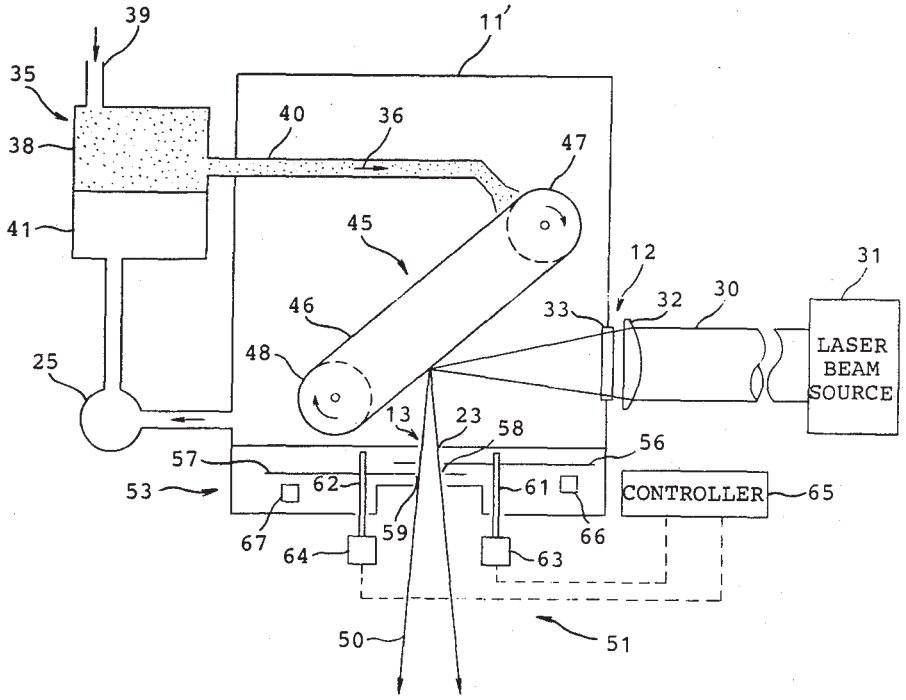
[57] **ABSTRACT**

In a laser plasma X-ray device for use in generating X-rays by bombarding a target material by a pulsed laser beam, the target material is selected from materials which are in a gas phase at the room temperature and which are cooled in a selected one of liquid and solid phases. Such a selected phase of the target material is continuously supplied to a focal point of the pulsed laser beam to be subjected to bombardment and to generate the X-rays. On generation of the X-rays, the target material is rendered into the gas phase to be recycled into the selected phase. The X-rays are guided outside of the chamber through an X-ray gate unit opened in synchronism with a repetition frequency of the pulsed laser beam.

12 Claims, 3 Drawing Sheets



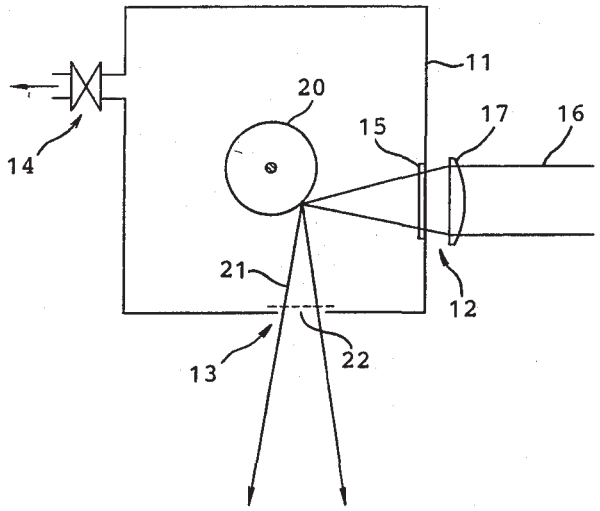


FIG. 1 PRIOR ART

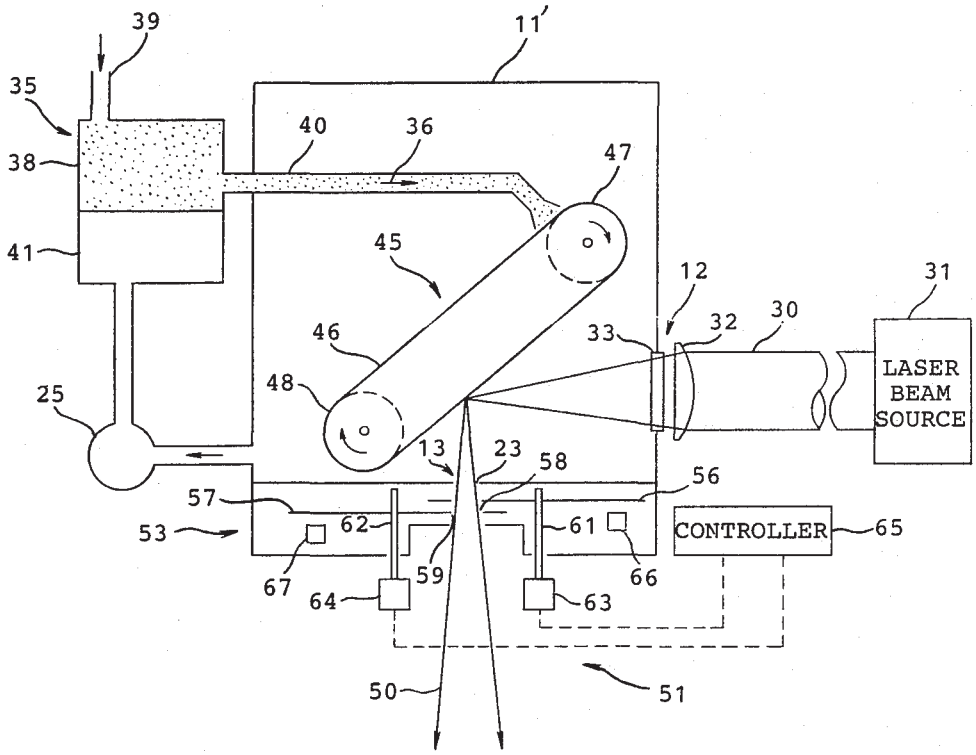


FIG. 2

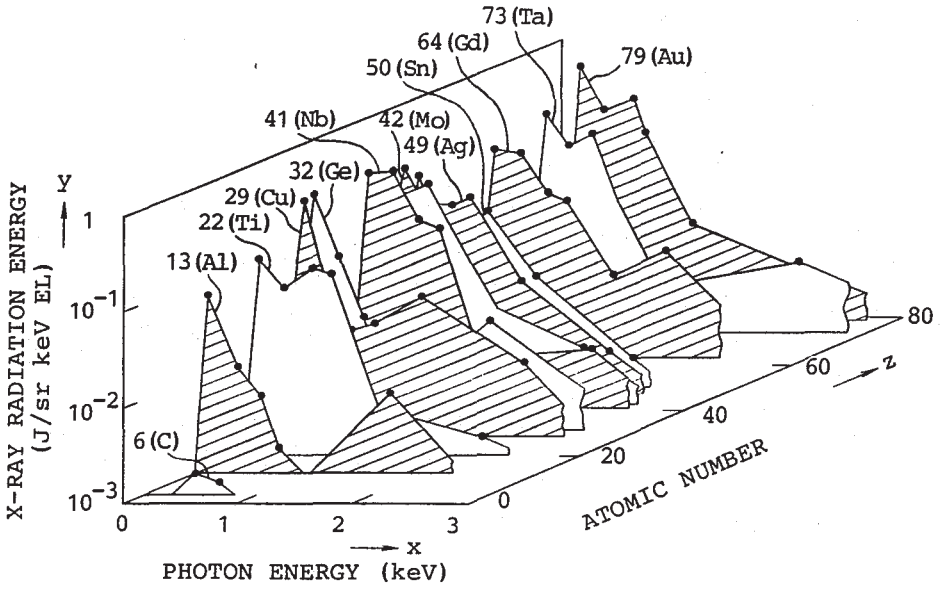


FIG. 3

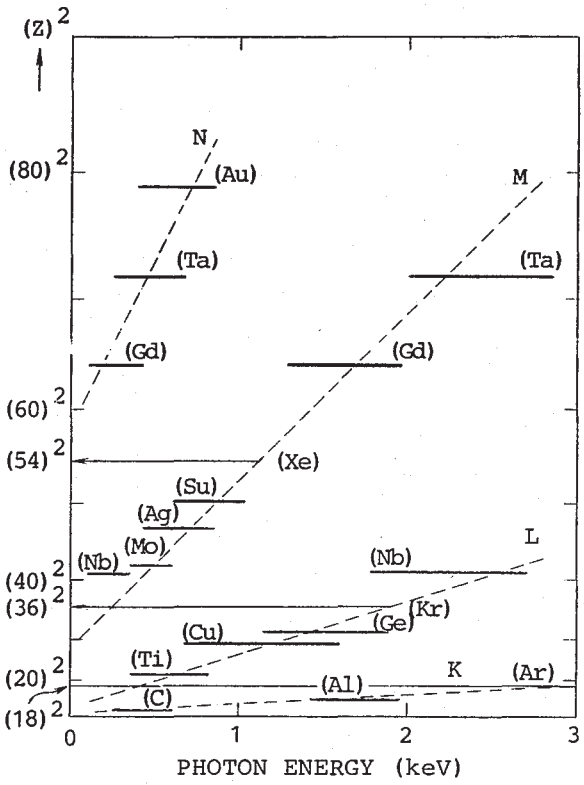


FIG. 4

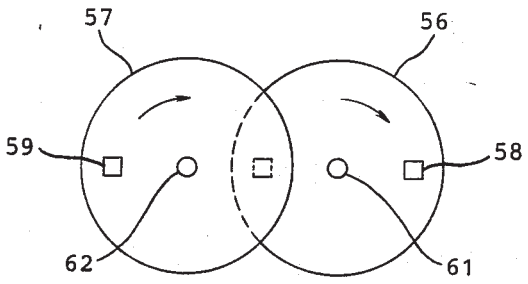


FIG.5

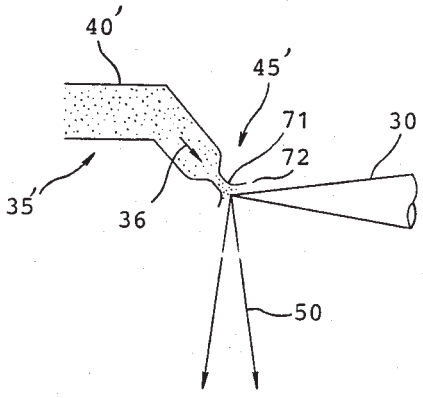


FIG.6

LASER PLASMA X-RAY GENERATOR CAPABLE OF CONTINUOUSLY GENERATING X-RAYS

BACKGROUND OF THE INVENTION:

This invention relate to a laser plasma X-ray generator which is mainly used as an X-ray source for X-ray lithography, X-ray microscopy, and the like.

In a conventional laser plasma X-ray generator of the type described, X-rays are generated by emitting a pulsed laser beam of high power onto a target placed in a chamber and by producing plasma due to emission of the target by the pulsed laser beam. Such plasma has a high temperature and a high density. The chamber is usually kept at a low pressure in comparison with ambient pressure.

It is common that the target is formed by a target material in a solid-state and may be called a solid-state target. For X-ray lithography or the like, it is preferable that energy of X-rays is between 0.1 keV and 3 keV. Taking this into account, either copper or aluminum is frequently used as the target material. Such a target of a metal is subjected to emission or bombardment of the pulsed laser beam. In this event, the pulsed laser beam is focused on a focal point to bombard the target at the focal point and to generate the X-rays. As a result of bombardment of the pulsed laser beam onto the target, evaporation of the target material takes place at and near the focal point and undersirably roughens the surface of the target with a crater. Such roughness of the target makes convergence of the pulsed laser beam objectionably unstable on the target surface. Accordingly, the pulsed laser beam must always converge onto a pure or unbombarded surface of the target. To this end, the target is formed into a conical or a cylindrical shape and is rotated around an axis of the target.

In addition, the X-rays are derived from the chamber through an outlet portion which comprises a thin film of, for example, beryllium which is attached to an outlet and which has a good transmissivity to the X-rays.

As is readily understood from the above, the solid-state target is eventually worn out and can not be reused. This means that a new solid-state target must be exchanged for a used one after a predetermined time of, for example, one hour. Such exchange of the solid-state target is troublesome and results in interruption of operation or processing carried out by the use of the laser plasma X-ray generator.

Consideration might be made about automatic exchange of the solid-state target. However, the automatic exchange makes the laser plasma X-ray generator undersirably large in size and brings about an increase of an expense for faulities.

Moreover, the target material is evaporated during the emission of the pulsed laser beam onto the solid-state target, as mentioned before. Such evaporation results in deposition of the target material onto an internal wall surface of the chamber and the thin film of the outlet portion. The deposition of the target material on the thin film reduces the transmissivity of the X-rays and objectionably attenuates an intensity of the X-rays. Therefore, use of the solid-state target makes it difficult to keep the X-rays stable in intensity.

In addition, it should be considered that the X-rays are also inevitably attenuated by the thin film of beryllium or the like attached to the outlet, although the beryllium itself exhibits a good transmissivity to the X-rays. It is mentioned here that the thin film must be thick when a difference of pressures is large between an inside and an outside of the chamber and when an area of the outlet is wide. Under the circumstances, the attenuation of the X-rays becomes serious due to the thin film with an increase of thickness of the thin film.

In order to avoid the attenuation of the X-rays, the outlet might be opened at the outlet portion with the thin film removed. However, this makes it difficult to keep the chamber at a predetermined degree of vacuum and brings about leakage of a vapored target material. Such a vapored target material might be deposited onto an object, such as an X-ray mask, to be processed by the X-rays. As a result, the object might be mechanically destructed or degraded in its characteristics.

In Unexamined Japanese Patent Publication No. Syô 60-7130, namely, 7130/1985, proposal is made as regards a device wherein an object, such as a mask, a substrate with a resist layer, is located within a vacuum chamber to avoid attenuation of X-rays. However, undesirable deposition of a vapored target material onto the object and the resultant destruction of the object can not be avoided in the proposed device.

In Unexamined Japanese Patent Publication No. Syô 58-225636, namely, 225636/1983, an X-ray emission device is disclosed which comprises a first chamber kept at a high degree of vacuum, a second chamber filled with a helium gas having a low X-ray attenuation factor, and an intermediate chamber between the first and the second chambers. X-rays are generated in the first chamber by bombarding a solid-state target by a pulsed laser beam and is guided through the intermediate chamber to the second chamber. The second chamber is kept at a pressure substantially equal to the ambient pressure and serves to allow the X-rays to pass through an outlet. With this structure, it is possible to make a thickness of a film on the outlet considerably thin and to widen an area irradiated by the X-rays. However, maintenance of a high degree of vacuum in the first chamber encounters with a difficulty because the first chamber which must be kept at a high degree of vacuum is associated with the second chamber of a high pressure through the intermediate chamber. In addition, attenuation of the X-rays is unavoidable due to the helium gas filled in the second chamber, which might cancel an effect of making the film thin.

In order to avoid undersirable deposition of a target material, a radio frequency (RF) oscillation coil is disposed outside of a chamber in Unexamined Japanese Patent Publication No. Syô 58-40757, namely, 40757/1983. Specifically, the RF oscillation coil is energized with a gas of, for example, chlorine filled in the chamber. The gas is rendered into plasma by energization of the RF oscillation coil. A deposited target material, such as aluminum, is gasified by the plasma into a predetermined gas, which may become Al_2Cl_3 according to the description.

In this event, it is necessary to introduce the gas into the chamber and to cause the plasma to occur in the chamber each time on deposition of the target material. Such an operation for removing the undesirable deposition is very combersome and inevitably suspends a continuos run of operation.

Furthermore, a device is disclosed in Unexamined Japanese Patent Publication No. Syô 58-158842, namely, 158842/1983, and uses a target formed by a target material such that a product which appears after occurrence of plasma is in a gas phase. Such a product

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