International Journal of Surface Engineering and Interdisciplinary Materials Science
Volume 9 • Issue 1 • January-June 2021

Capability Resurrection of DC Sputtering Machine:
A Case Study

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ABSTRACT

Nanocoatings are gaining popularity owing to their widespread applications and the physical vapour deposition constitutes an effective method of deposition of coatings onto a suitable substrate. This work comprises of capability resurrection of a newly installed DC sputtering machine through troubleshooting, calibration, and establishment of process parameter mainly in terms of critical-to-performance (CTP) characteristic identified as the sputtering voltage. This work exercises the identification of potential causes for the breakdown of the sputtering machine through Ishikawa diagram and root cause is identified through the why-why analysis. Prioritization of corrective actions through process failure modes and effects analysis (PFMEA). Correct functioning of the DC sputtering machine after taking corrective action, is validated and confirmed through experimentation. This work shall serve as a reference to the maintenance and process personnel and guide them to perform the experiments related to DC sputtering in a laboratory environment.

KEYWORDS

Critical-to-Performance (CTP) Characteristic, Failure Modes and Effects Analysis (FMEA), Ishikawa Diagram, Physical Vapour Deposition (PVD), Sputtering, Why-Why Analysis

1. INTRODUCTION

Sputtering is the process whereby coating material is ejected from coating target due to bombardment of high energy particles of an inert gas. The ejected particles from the target stick on to the substrate and form a coating layer. It is a physical vapour deposition process. The sputtering operation is a very precise, prolonged and meticulous process. The downtime of sputtering machine is very costly and leads to a cascading effect on other related operations down the manufacturing process flow. The sputtering operation deals with ionization process at high vacuum pressures. Minute leakage of atmospheric air into the sputtering working chamber can lead to inconsistent results. Any small

DOI: 10.4018/IJSEIMS.2021010104

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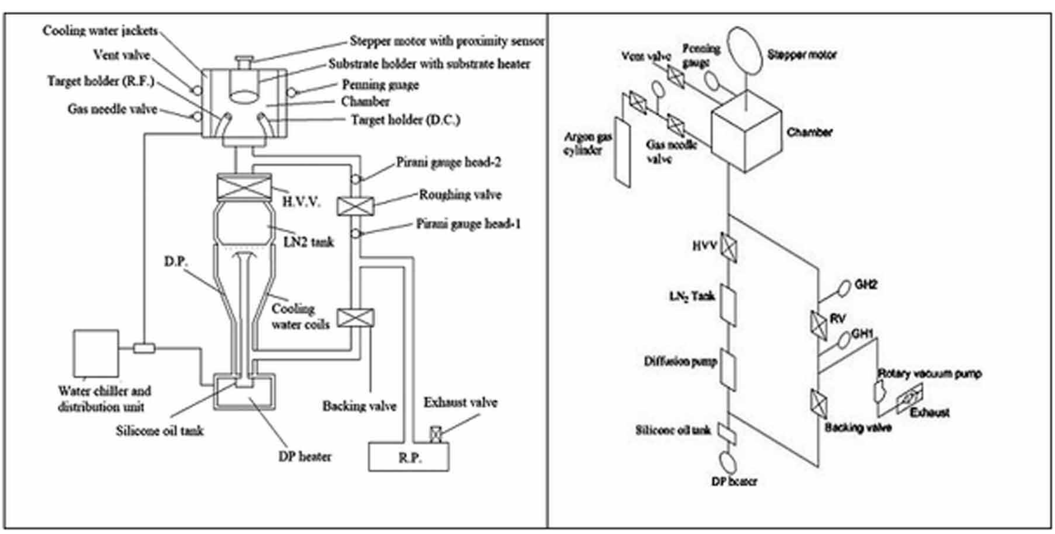
variation in the process parameters leads to a catastrophic failure of the sputtering machine. This leads to decrease in MTBF (Mean Time Between Failure) leading to ineffective utilization time of the sputtering equipment. Thus, the aim is to minimize the MTTR (Mean Time To Repair) so that the MTBF and ultimately MTTF (Mean Time To failure) is maximized in order to improve the average lifespan of the equipment (Mortazavi, Mohamadi, & Jouzdani, 2018).

The present work focuses on one such case study where the industrial engineering principles are applied for resurrection of capability of a sputtering machine. The sputtering machine under preview of this work is manufactured by VR Technologies, DC/RF sputtering unit, of Bengaluru in India, consists of a cylindrical chamber which is pumped by 250 lit / min double stage direct driven rotary vacuum pump. The chamber is fabricated from polished stainless steel. The chamber is mounted on the Mild Steel frame. The cooling water pipe line is coiled on the outer wall of the chamber to prevent overheating. There are two target guns one is for DC sputtering and another one is for RF sputtering which are controlled by independent controllers provided on the machine.

The typical base pressure in vacuum chamber is about 1×10^{-5} mbar. The pressure inside the chamber is created by using rotary vacuum pump and diffusion pump. Diffusion pump uses silicone oil to entrap the air molecules inside the chamber. There are no mechanical parts in diffusion pump, so it uses rotary vacuum pumps to exhaust the air molecules. Sputter gases are fed into the system through gas needle valve. Typical sputtering gas applied is argon. Sputtering gas is supplied to the vacuum chamber by adjusting the mass flow rate according to the type of target used. The line diagram of sputtering machine is depicted in Figure 1 and the pictorial view is captured in Figure 2. Table 1 tabulates the specifications of the sputtering equipment.

This paper is an application of industrial engineering principles of problem solving and troubleshooting into the domain of sputtering operation. Firstly the knowledge gap in the industrial engineering area and the PVD area is focused in the introduction section. This is succeeded by a detailed literature survey on FMEA, Ishikawa diagrams and sputtering operations. The problem identification and definition is elucidated in the subsequent session. The Critical-To-Performance (CTP) characteristic is identified and then all the potential causes are enlisted by employing the Ishikawa diagram. The Why-Why analysis is employed for tracing the root cause. The PFMEA (Process Failure Modes and Effects Analysis) is employed for prioritizing the corrective actions for the potential causes traced. In next section, the validation of the corrective actions is done through

Figure 1. Line diagram of sputtering machine



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