New Materials Research

Case Study: Removing roadblocks using basic materials science

Mountain View Energy

Introduction

In developing a new materials-based technology at a start-up, the client engaged us to develop commercialization plans for some never-before manufactured materials. Some of these materials had a very little published research in academic literature. After delving into the program details for one particular material, it was realized that the state of the technology was instead at an earlier applied science stage and required further materials research. Furthermore, there were some aspects of the technology were considered to be “show-stoppers” by several of the client’s staff.

Challenge

There were two problems in particular about this material, the process temperature damaged the substrate, and the adhesion performance was erratic. As for the thermal load, the client had exhausted all process flows and product designs and was not able to deposit the material without thermal damage. The intermittent adhesion failure, was a major yield-loss issue and caused reproducibility problems. As long as these two issues remained, it was impossible to demonstrate proof-of-concept for the technology.

Action

Dealing with the thermal issue required a basic understanding of the physics of the process. The material was efficiently deposited through compound-based thermal evaporation. The process used multiple compounds and relied on surface reactions to form the material. Maintaining the minimum flux required a source temperature high enough, that radiative heating from the source orifice alone was enough to create damage.

We therefore performed a thermodynamic analysis of the process to understand what reaction processes were likely occurring. In looking at the details, it turned out that about 90% of the energy going into evaporating one of the components was for

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dissociation. Since the material was being reactively formed from these components, heat of dissociation was effectively wasted energy. Looking at elemental evaporation instead, we demonstrated that process temperatures could be substantially reduced, reducing the thermal load on the substrate by 80%.

The second issue was related to large-scale and intermittent film delamination. When the film adhered, it performed quite well, but one could not predict when failures would occur. In fact, adhesion was only a requirement for fabrication, in the product it was no requirement. Observing the samples, one could see that delamination occurred at substrate imperfections, and tended to increase with handling. Since some samples did not have problems, it showed that there was a regime in which adhesion was adequate. both issues (imperfections and downstream handling) were related to sample handling, it was clear that minimizing handling would improve the process. We designed a test platform on which we could deposit the material with minimal handling and induced stress. We ended up deposited films on the substrates which were 100x higher than the previous sample, and did so without any delamination defects, and with a run-to-run yield of >90%. This demonstrated that there was no fundamental problem with depositing the material on substrate, and we now had some specifications against which to base our future designs and experiments.

Results

In the end we demonstrated that both show-stopping issues, substrate overheating, and delamination could be controlled to produce high-performance and repeatable films. The process used elemental compounds had a 2x higher deposition rate, and as an added benefit, much better interfacial properties. Furthermore, we gave the client a platform and methodology on which to perform systematic and wide-ranging materials discovery experiments that were not confounded by these two issue. This enabled the client to start working on the next phase of the program to scale the process into pilot production.

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