

Surface Modification of Magnesium Using Kinetic Metallization



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Motivation

- Most magnesium alloys have poor wear and corrosion resistance
- Problem: thermal spray coatings are not suitable for magnesium alloys due to surface melting and oxidation
- Solid state coatings such as Cold Spray and Kinetic Metallization enable coating heat-sensitive substrates without affecting the microstructure, with little preparation
- They also enable the use of thermally sensitive coating materials

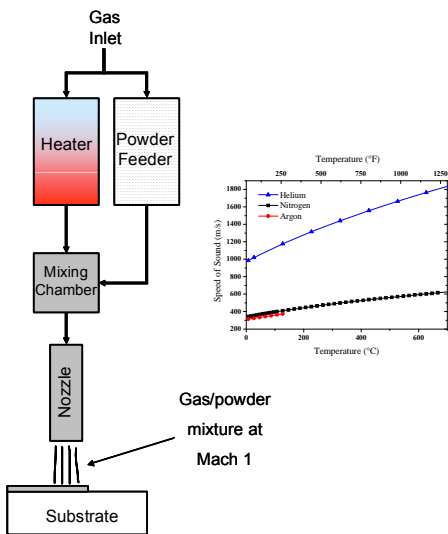
Process

- Kinetic Metallization (KM) is a cold spray variant – both heat the powders well below T_{Rx}

Differences between KM and cold spray:

- KM heats the gas to higher temperatures
- KM accelerates the gas to sonic velocity
- Cold spray is a supersonic process
- KM uses a lower gas pressure

How it Works

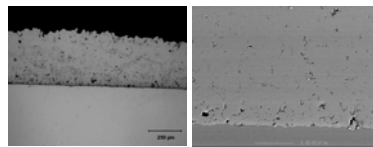


Surface Quality and Bonding

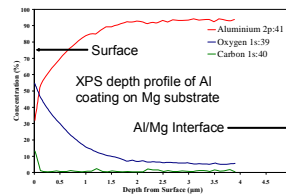


Bond strength measurements of pure Al powder KM sprayed on a pure Mg substrate

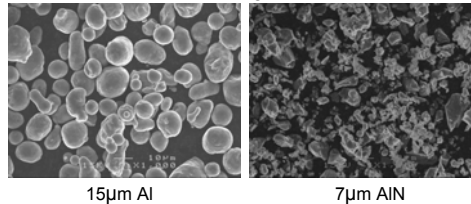
| Condition | Bond Strength [MPa] | Failure Mode |
|-------------------------------|---------------------|---|
| As-Sprayed | 29.8 | Cohesive – within coating |
| Heat Treated 2 hours at 400°C | 28.4 | Adhesive – at coating/substrate interface |



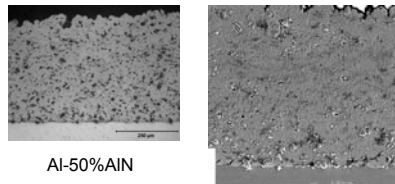
Pure Al powder sprayed on Pure Mg substrate



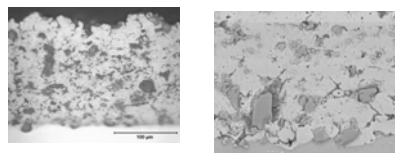
Mixtures of Al and AlN, Al₂O₃ or SiC



- Mix Al powders with hard reinforcing phase for improved corrosion and wear resistance



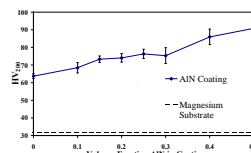
Al-50%AlN



Al-30%Al₂O₃

- Coatings are high-density with a good interface

Increase of hardness of Al coating with increasing volume fraction of AlN particles

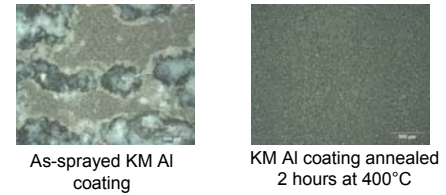


Corrosion Behaviour

KM coating shows mixed corrosion behaviour:

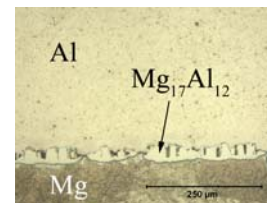
| Coating Material on Pure Magnesium | Time to Initiate Pitting in a 5% NaCl Solution |
|---|--|
| Pure Mg | 1 hour |
| As-Sprayed KM Al Coating on Pure Mg Substrate | Instantaneous |
| Annealed KM Al Coating on Pure Mg Substrate | ~24 hours |
| Cast Pure Al | No pitting observed |

Pitted surface of pure Al coatings on a pure Mg substrate in a 5% NaCl solution, after a 24 hour immersion

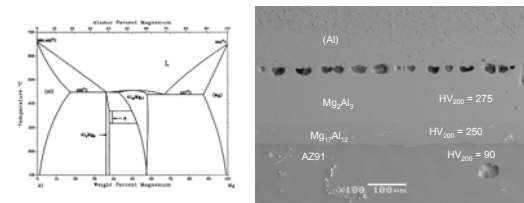


Heat Treatment of Coatings

Al coating on a Mg substrate, annealed for 2 hours at 400°C.

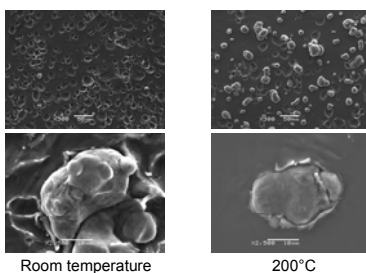


Al coating on an AZ91 substrate, annealed for 20 hours at 400°C.



- Intimate bond between coating and substrate enables sintering of coating and growth of diffusion layers
- Corrosion properties of coating improves
- Mg₂Al₃ and Mg₁₇Al₁₂ are not noticeably attacked in 5% NaCl solution – these layers can be used to create coating of high corrosion resistance
- Heat treatment temperature is low enough to be used as solutionising treatment for AZ91 substrate

Effect of Gas Temperature on Surface: Al Powder on Mg Substrate



Room temperature

200°C

Summary

- KM offers a simple means of generating metal or metal/ceramic composite coatings so that surface properties can be tailored
- Bond strength is very high – similar to thermal spray coatings
- High hardness and wear resistance can be achieved in the as-sprayed condition
- Heat treated coatings show superior corrosion resistance; wear resistance and bond strength may also be improved