

# EFFECT OF STRONTIUM AND CALCIUM CONCENTRATION ON MICROSTRUCTURE AND IN VITRO DEGRADATION RATE

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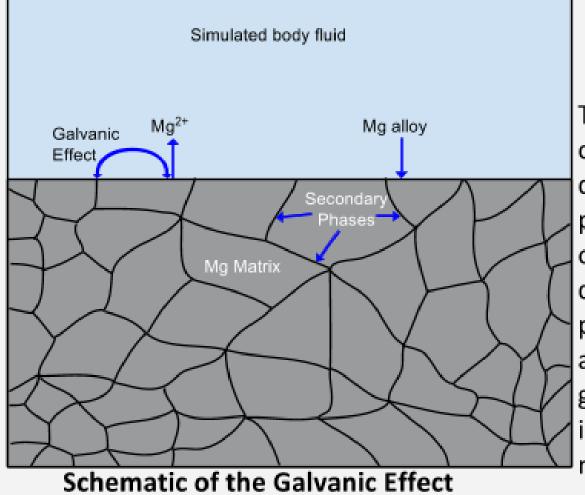


#### **A**BSTRACT

Magnesium is an attractive choice for biomedical applications due to its potential to degrade safely in in vivo environments. Calcium and strontium are promising alloying additions because of their low toxicity levels. These elements form secondary phases that affect the rate of degradation through galvanic corrosion with the Mg matrix. Mg degradation forms H<sub>2</sub> gas, so it is desirable to control the degradation rate of the implants to fit their desired applications. This study investigates the relationship between the as-cast microstructure and degradation rate (as measured in simulated body fluid) in a systematic review of the Mg-rich corner of Mg-Ca-Sr. Of particular interest is the effect that second phase contiguity has on degradation rate.

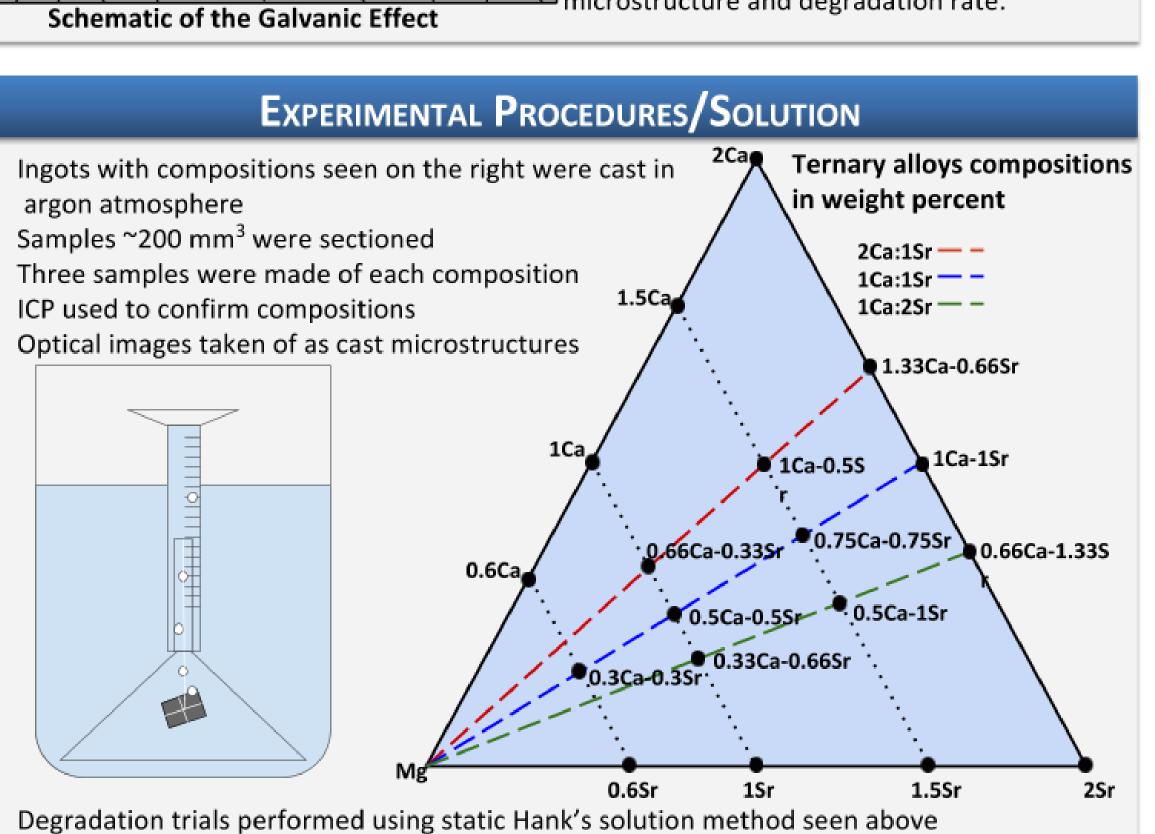
## BACKGROUND

Magnesium alloys containing small additions of calcium and strontium have proven to be viable for biodegradable implants due to their high specific strength [1][2][3] and low levels of toxicity [4]. As these systems degrade, they release hydrogen gas, which can form subcutaneous gas pockets whose absorption into the body depends upon the local blood flow and water content of the surrounding tissue [5]. It is therefore important to determine ways of controlling the degradation rate of these alloys. One way of achieving this is through the manipulation of microstructure.





These systems degrade through galvanic corrosion; therefore, the degradation process depends upon the formation of secondary phases. It has been found that the formation the Mg<sub>17</sub>Sr<sub>2</sub> phase accelerates the degradation of the Mg matrix due to this phase acting as a cathode and the Mg matrix acting as the anode; thus increasing the galvanic effect [7]. The goal of this study is to investigate the correlation between as cast microstructure and degradation rate.

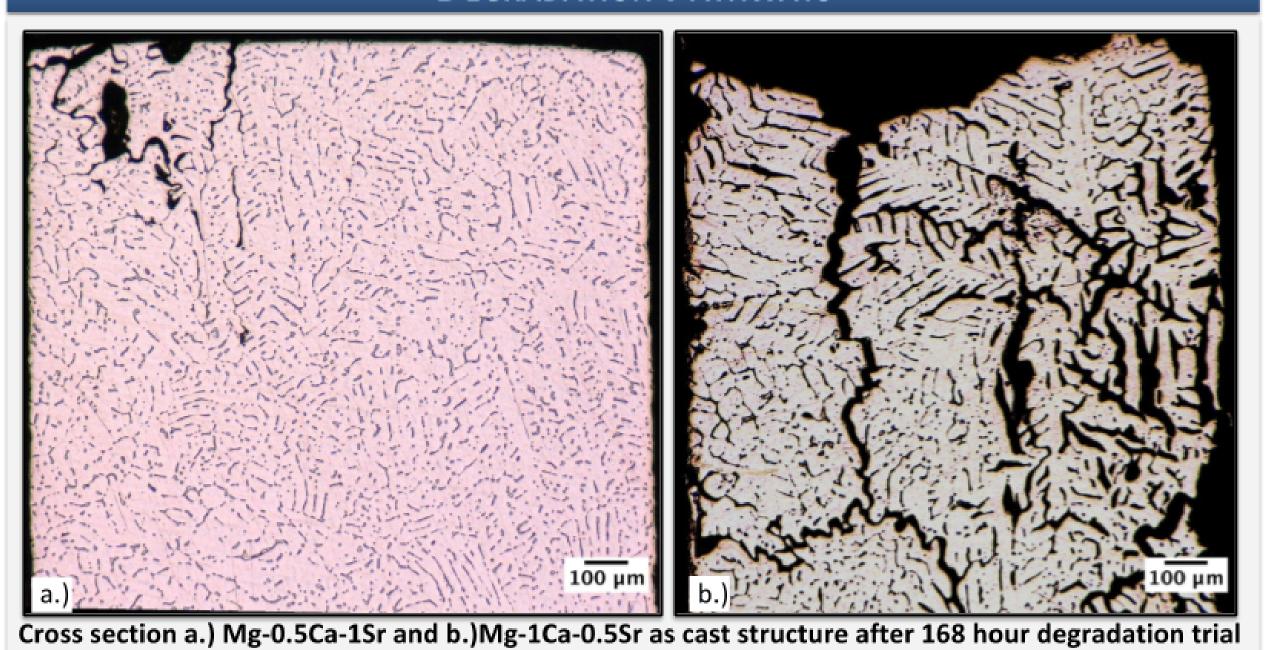


Incubation performed at 37°C

Samples were sectioned through the center and analyzed

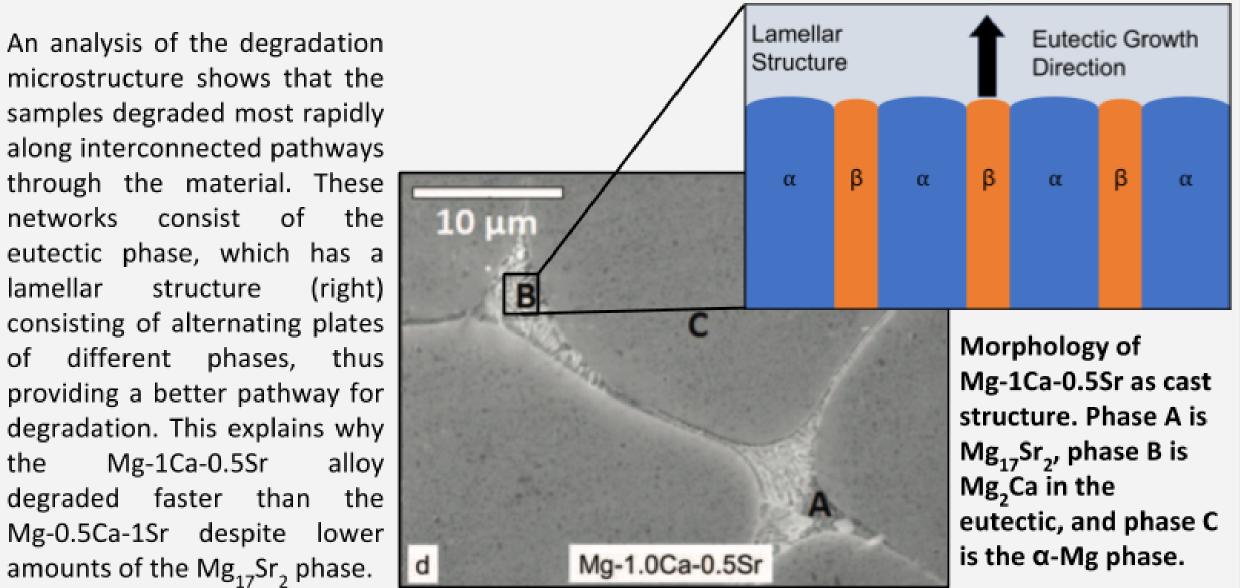
**DEGRADATION RESULTS** alloys with a higher percent of reinforcement generally had a faster degradation rate, the 1Ca:2Sr alloys had a much lower degradation rate than expected based upon their reinforcement volume percent. [mL/day/cm<sup>2</sup>] 1Ca:1Sr — \_ 2Ca:1Sr 1Ca:2Sr \_\_ \_ 2.5 3.0 3.5 4.425 Reinforcement Volume% Reinforcement volume percent relation to degradation 3.542 displayed significantly higher degradation rates than those 3.941 **9**0.182 calcium. However, ternaries with a higher ratio of calcium concentrations have **∞**0.008 faster degradation rates. This is due to microstructural effects providing a better structure for galvanic degradation in the 8.077 calcium rich ternaries.

# **DEGRADATION PATHWAYS**

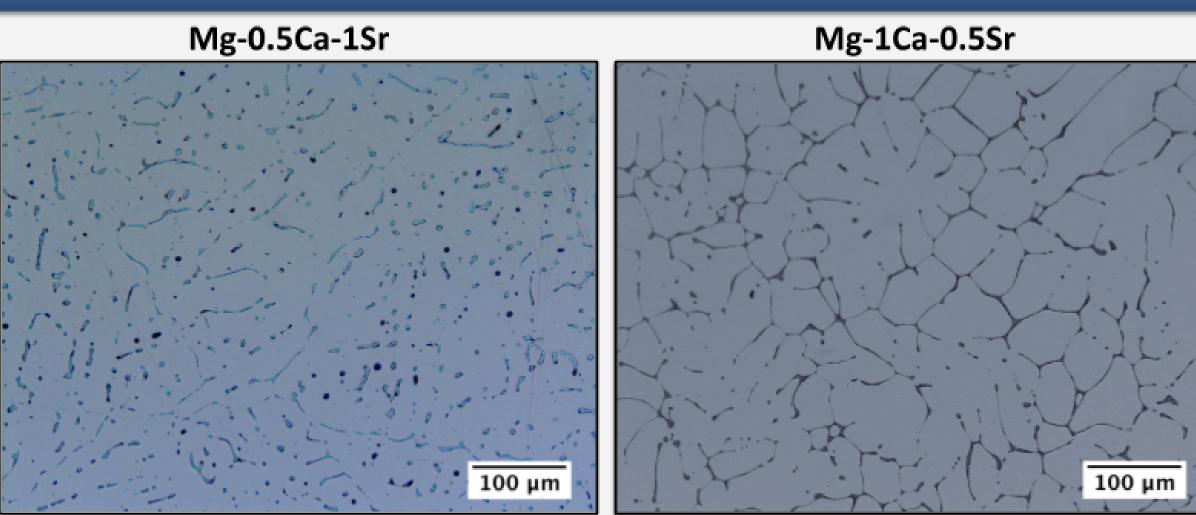


samples degraded most rapidly along interconnected pathways through the material. These networks consist eutectic phase, which has a (right) structure consisting of alternating plates

different phases, thus providing a better pathway for degradation. This explains why Mg-1Ca-0.5Sr alloy degraded faster than the Mg-0.5Ca-1Sr despite lower amounts of the Mg<sub>17</sub>Sr<sub>2</sub> phase.



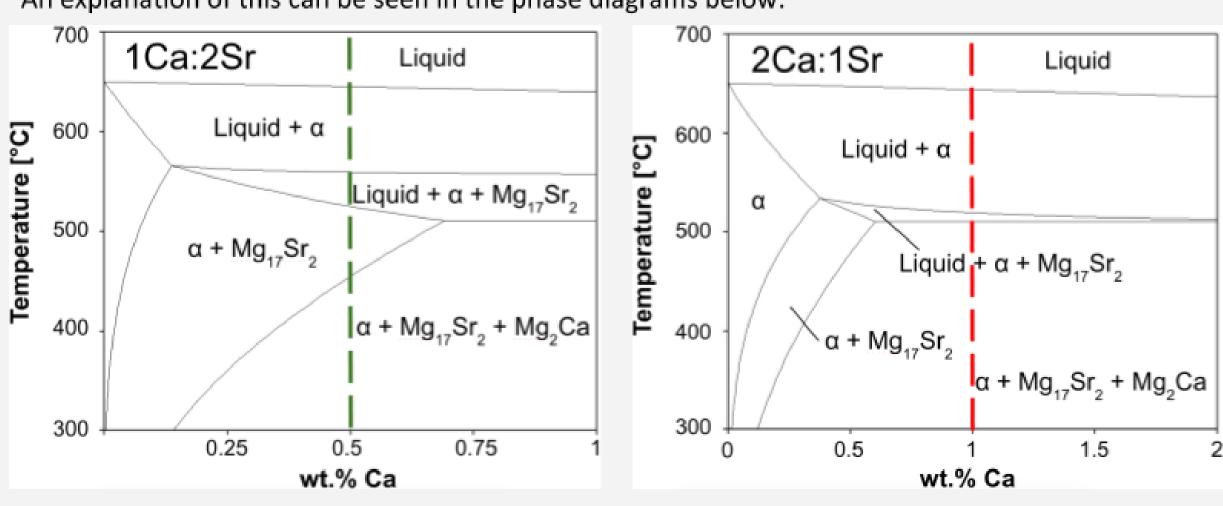
### MICROSTRUCTURE COMPARISON



200x image of Mg-0.5Ca-1Sr as cast structure

200x image of Mg-1Ca-0.5Sr as cast structure

Comparison of microstructures shows that Mg-1Ca-0.5Sr is more interconnected than Mg-0.5Ca-1Sr. An explanation of this can be seen in the phase diagrams below:



Phase diagrams of 1Ca:2Sr and 2Ca:1Sr systems constructed in Pandat

The larger temperature range for forming Mg<sub>17</sub>Sr<sub>2</sub> in the 1Ca:2Sr system results in formation of this phase before the eutectic is allowed to form, thus yielding globular eutectic microconstituents.

## Summary/Conclusions

Analysis of this system has shown that when investigating degradation rate, it is important to consider both composition and microstructure. It has been observed that a more contiguous secondary phase results in a faster degradation rate. This can be explained due to the nature of the eutectic structure which consists of a lamellar structure, which provides a continuous anode and cathode pathway allowing for galvanic corrosion. Thus, while it is expected that Sr rich ternary alloys would have a faster degradation due to the higher content of the Mg<sub>17</sub>Sr<sub>2</sub> phase that forms, it is actually the Ca rich ternary alloys that form the microstructure that is better suited for degradation. This is due to the shorter amount of time allowed to nucleate the Mg<sub>17</sub>Sr<sub>2</sub> phase, resulting in a more rapid solidification consisting of an interconnected microstructure. However, all compositions formed contiguous structures at high enough concentrations of Ca and Sr.

#### **A**CKNOWLEDGEMENTS

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