

Substitution of Hydroxyapatite with a Bioactive Glass-Ceramic for Implant Coatings

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INTRODUCTION: Building on the proven success of hydroxyapatite (HA) as a coating for orthopedic and dental implants, the incorporation of Silicated Ceramic (SiC), a DSM-Firmenich proprietary bioactive glass-ceramic, presents a facile approach for tailoring the chemical and physical properties of titanium implant surfaces. Important factors, such as coating hydrophilicity, degradation rate, and dissolution products, can be modified to enhance bone-to-implant contact and primary stability - offering critical advantages in cases of low bone density and immediate loading [1], [2], [3]. This study examines how the inclusion of SiC into an HA-based feedstock for plasma spray coating influences the surface characteristics of titanium (Ti) discs. Four HA-based feedstock blends containing 0, 15, 50, and 100 wt% SiC were evaluated, with an uncoated titanium (Ti) disc serving as the negative control. Increasing the SiC content in the coatings is hypothesized to enhance surface energy and reactivity, thereby improving the bioavailability of calcium and phosphate ions at the surface and accelerating mineralization.

METHODS: The coated Ti discs were prepared by Himed via an atmospheric spray system. All discs were cleaned and blasted with Himed's MCD Apatitic Abrasive, passivated, and then coated with their respective mixture of HA/SiC for all groups except for the blast only Ti control group. Coating thickness (>50um) was verified for all groups via eddy current inspection. Discs were gamma sterilized at 25-40 kGy. Chemical composition was analyzed via SEM/EDX (Phenom) (n=1). Percent crystallinity measurements were calculated from XRD diffraction patterns (Bruker) (n=1). Surface wettability was assessed using both water and blood via the sessile drop method at t=0, 10, and 60 seconds and analyzed via ImageJ. Mineralization of coated discs after 24 hours, 1-week, 2-weeks, and 4-weeks incubation at 37°C in simulated body fluid (SBF) was evaluated by SEM (Hitachi). A one-way ANOVA with post-hoc Tukey test ($\alpha=0.05$) was used to determine statistical significance between groups, all tests were completed in triplicate (n=3).

RESULTS: Incorporation of silicon, via SiC substitution, reduced the deposited amounts of calcium and phosphate by approximately 35% and 85%, respectively, from the HA-coated disc. Additionally, the crystalline content decreased significantly, from 84.13% to less than 10% in the 100% SiC group. Sessile drop testing revealed a distinct decrease in the measured contact angle, relative to silicated ceramic content, indicating increased surface energy and wettability due to SiC substitution (Image 1). Finally, mineralization studies demonstrated rapid mineralization within 24h for discs coated with SiC-containing blends (Image 2). Mineral formation was observed for all groups, except the Ti control group, within the 4-week study.

DISCUSSION: The partial or complete substitution of HA with SiC altered both the chemical and physical properties of the titanium coating. Rapid mineralization of discs coated using SiC-containing blends indicates high surface energy and reactivity despite reduction in deposited calcium and phosphate content. This was further supported by SiC concentration-dependent changes in surface wettability and crystallinity - often closely related to glass-ceramic degradation rate which is to be directly studied in the future. Additionally, ongoing cell-based studies will further evaluate biomineralization and cellular interactions, while planned *in vivo* investigations will assess osteostimulative properties and preclinical performance.

SIGNIFICANCE/CLINICAL RELEVANCE: The increasing prevalence of implant surgeries and associated revisions, driven by an aging population, highlights the need for a next generation coating for orthopedic and dental implants to address failures associated with both aseptic and septic loosening. Partial or complete substitution of hydroxyapatite with silicated ceramic may present a facile route to enhance osteointegration in medical implants.

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IMAGES AND TABLES:

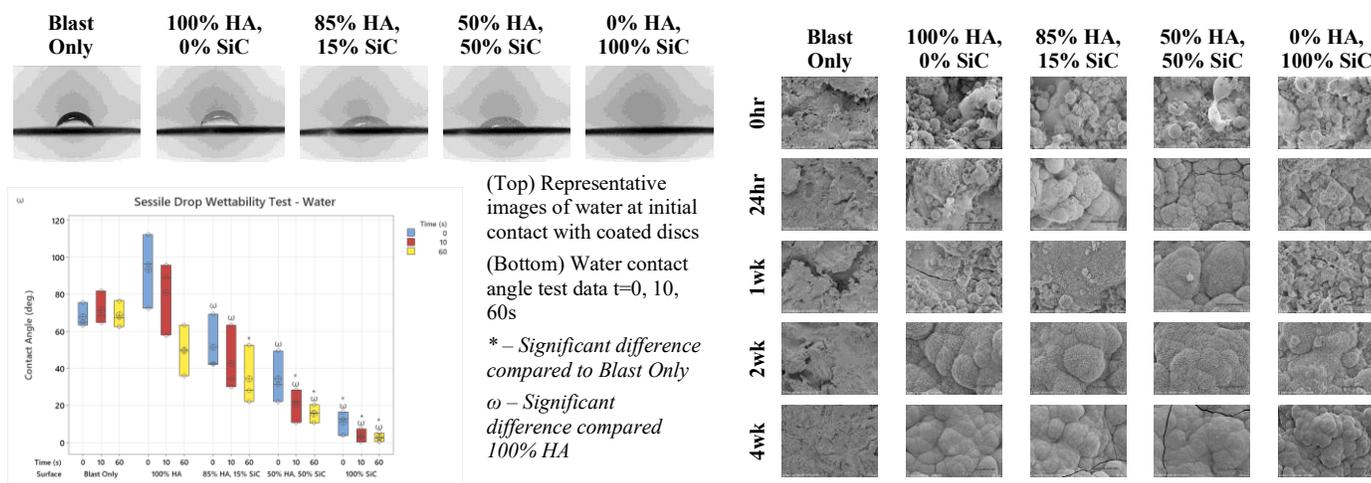


Image 1: Results from sessile drop test showing contact angles for plasma-sprayed coatings with varying HA/SiC ratios.

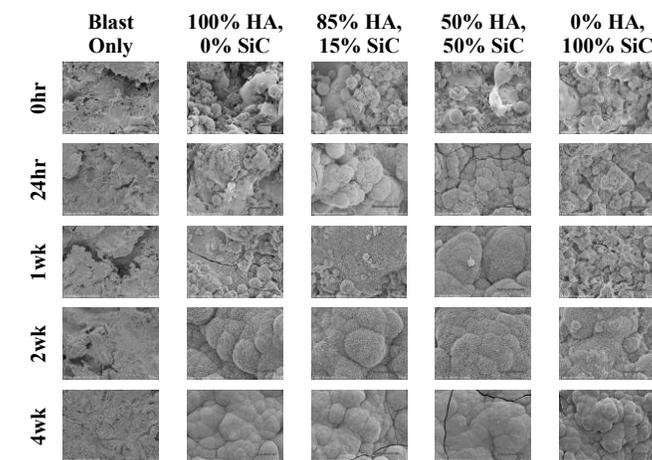


Image 2: SEM images of coated Ti-discs at 0hr, 24hr, 1wk, 2wk, and 4wks (1kx) incubation in SBF at 5kx magnification.