



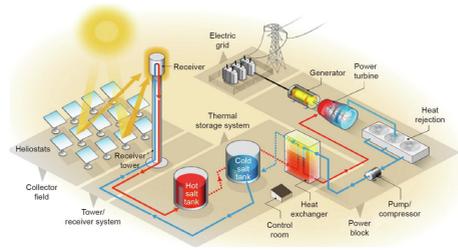
Corrosion Behaviors of Diamond Coated Stainless Steel 316 in Molten Chloride Salts

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Research Background

- Thermal energy storage is a key performance parameter for improving the viability of the concentrated solar power (CSP) plants.
- Molten nitrate salts (MS) have been extensively used in CSP to transfer and store heat given their unique thermal properties.
- The construction of the hot tank requires the use of materials with good corrosion resistance.



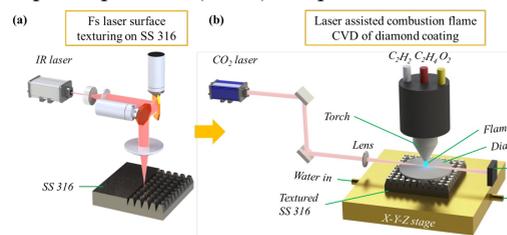
A state-of-the-art power tower second generation CSP plant with molten nitrate salts as TES/HTF materials

Motivation and Objectives

- Fast deposition of large-area diamond coatings on curved surfaces of pipes and vessels in open air using LCVD with interface engineering to improve the adhesion of diamond coatings on metallic substrates.
- Characterizing the microstructures of diamond coatings and diamond/substrate interfaces
- Determining the molten-salt corrosion resistance, wear resistance, and thermal conductivity of the diamond coatings.

Experimental Setup

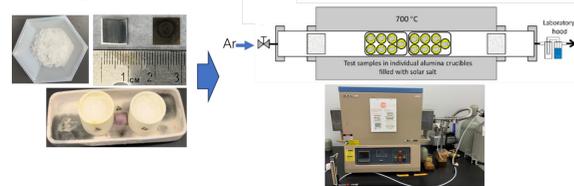
- Diamond films were deposited stainless steel (SS) 316 using a laser-assisted combustion chemical vapor deposition (CVD) in open air.



Compositions of SS 316

Element	C	Cr	Mn	Fe	Mo	Ni	P	S	Si
Percentage	0.08	18	2	82	3	14	0.045	0.03	1

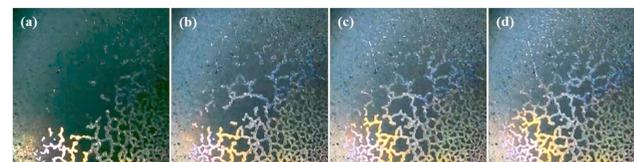
- The corrosion test was performed at 700 °C in a horizontal tube furnace with samples placed in alumina boats and covered with the salt mixture (45.4MgCl₂:33NaCl:21.6KCl).



Schematic setup for the corrosion test in molten chloride salts.

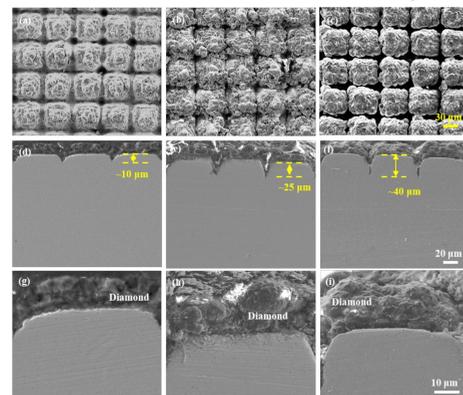
Characterization of Diamond Films

- Observations of diamond film morphologies post-flame removal at varying time intervals.

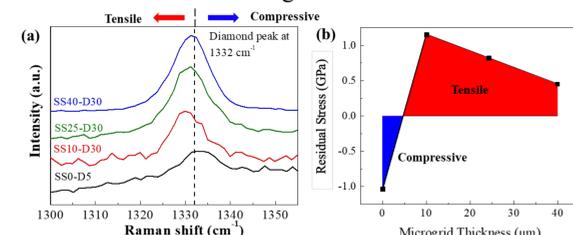


Photographs of the diamond film on the SS 316 substrate without laser treatment after being removed from the flame for (a) 3s, (b) 4s, (c) 5s and (d) 6s.

- Microstructures of the diamond coatings deposited on the SS 316 substrates with different microgrid depths.



SEM micrographs of diamond-coated SS 316 substrates with a microgrid depth of (a) 10, (b) 25, (c) 40 μm and their cross sections at the center of microgrids.



Raman spectra near 1332 cm⁻¹ and calculated residual stress of the diamond coatings deposited on the fs-laser textured SS 316 substrates with the microgrid depths of 0, 10, 25, and 40 μm after 30 min deposition.

Corrosion Behaviors

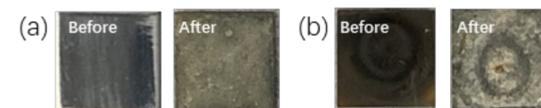
- Corrosion rate (CR):

$$CR(\mu\text{m}/\text{yr}) = \frac{87600\Delta m}{\rho t}$$

Δm – descaled mass loss per unit area (mg/cm²);

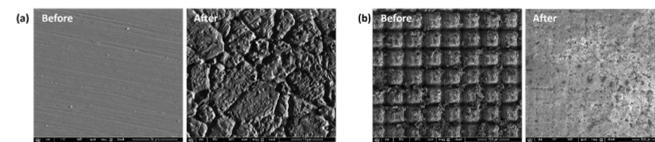
ρ – density (g/cm³): $\rho = 7.99\text{g}/\text{cm}^3$; t – corrosion time (h).

- Following the tests, the surfaces of all specimens underwent a transition from their initially smooth appearance to a rougher and darker texture.



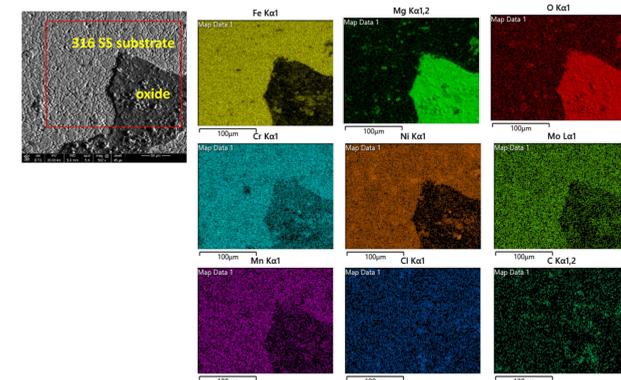
Macroscopic surface changes of (a) SS 316, and (b) diamond-coated SS 316 before and after corrosion test.

- After corrosion test for 100h, bare SS 316 displayed noticeable grain boundaries and pits while diamond-coated SS 316 maintained its texture pattern.

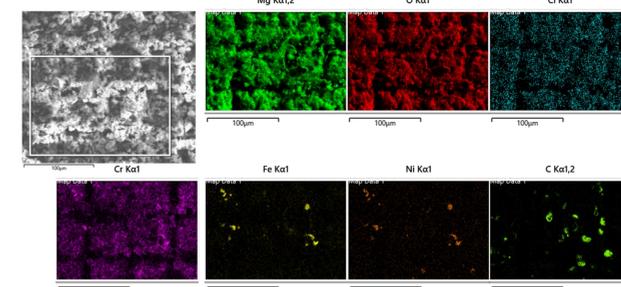


SEM image of surface morphology of (a) SS 316, and (b) diamond-coated SS 316 after corrosion test

- The mapping confirms that the layer of corrosion products generated on the surface of the samples consists predominantly of complex oxides.

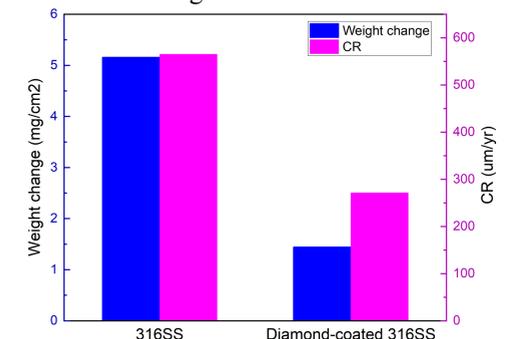


Elemental distribution of bare SS 316 after corrosion test



Elemental distribution of diamond-coated SS 316 after corrosion test

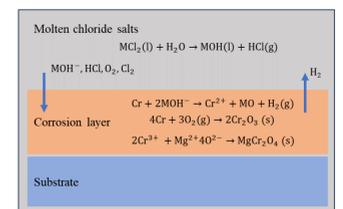
- The weight change and corrosion rate for SS 316 and diamond-coated SS 316 are 5.158 mg/cm² and 565 μm/yr, and 1.443 mg/cm² and 271 μm/yr, respectively.
- The diamond-coated SS 316 sample exhibited superior resistance to chloride salts and a protective behavior from the diamond coating.



Weight change and corrosion rate of two samples after corrosion test

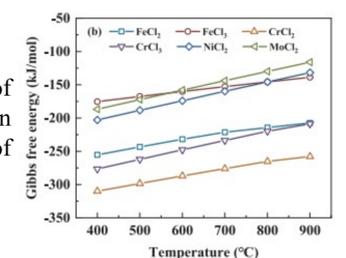
Corrosion Mechanism

- Impurities (moisture) may accelerate corrosion by reacting with chlorides to generate gaseous HCl.
- The smaller the Gibbs free energy, the easier the reaction will occur. Cr and Fe in the alloy are preferentially oxidized and chlorinated over Ni and Mo.



The possible corrosion reactions occurred in alloys.

Gibbs free energy of metal elements in alloys as a function of temperature



Acknowledgement

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