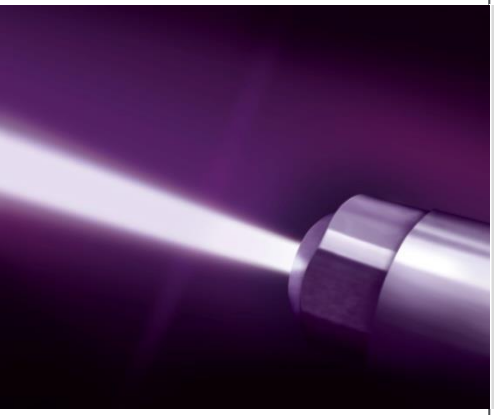
GfE Coating Materials
Freiberg/Brand-Erbisdorf, Germany

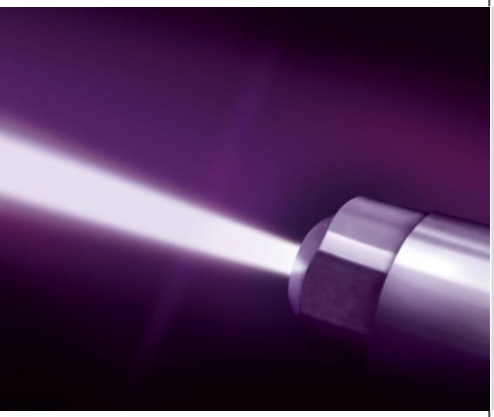


CSAT Fall Meeting

Cold Spray Coatings on Hard Surfaces

October 31st, 2012

GfE Materials Technology Inc.
Wayne, PA
Cameron R. May

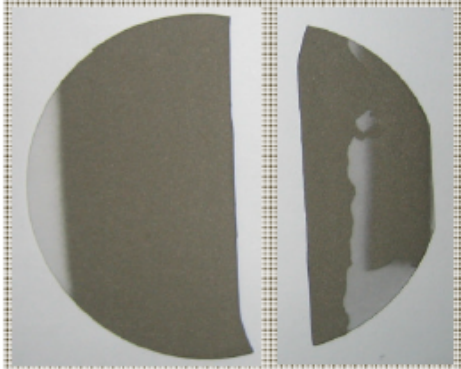


Cold Spray Coating on Hard Surfaces

Effect of the Surface Roughness

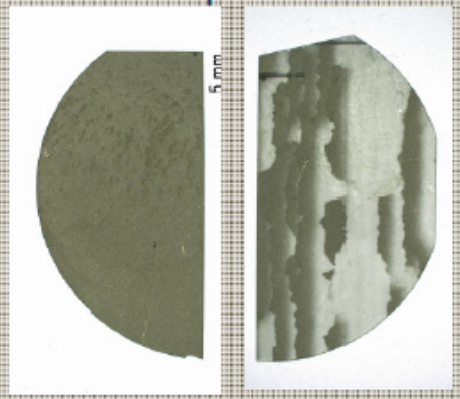
CGS-Ti on Sapphire Substrate

C-plane



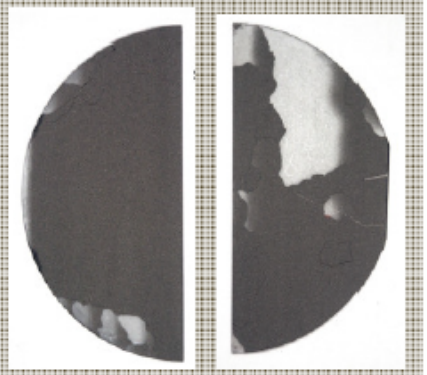
$R_a < 0.3nm$ $R_a < 1\mu m$

A-plane



$R_a < 0.3nm$ $R_a < 1\mu m$

R-plane



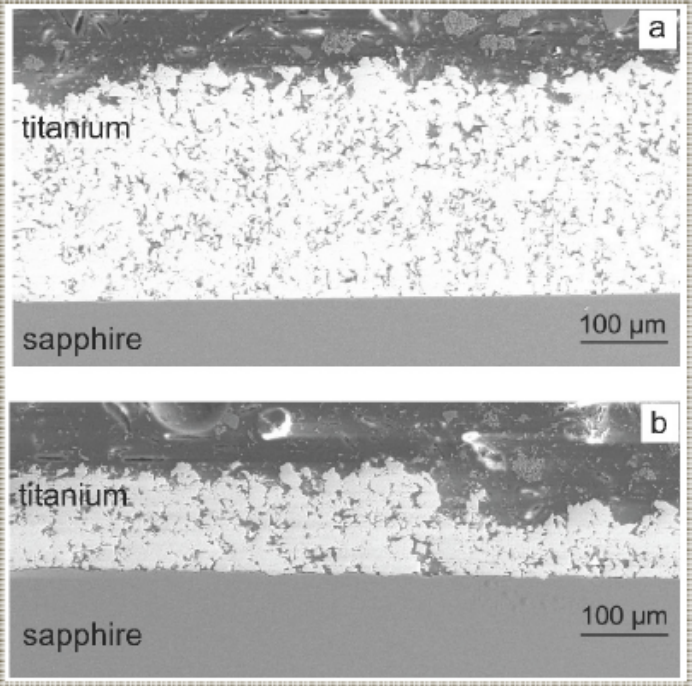
$R_a < 0.3nm$ $R_a < 1\mu m$

CGS Ti / Al coatings adhere on corundum surfaces with almost atomic surface roughness (i.e. no mechanical interlocking possible)

Cold Spray Coating on Hard Surfaces

Effect of the Surface Roughness

CGS-Ti on Sapphire Substrate



Polished side ⟶ R_a<0.3nm

Uniform thickness of the coating of 250µm

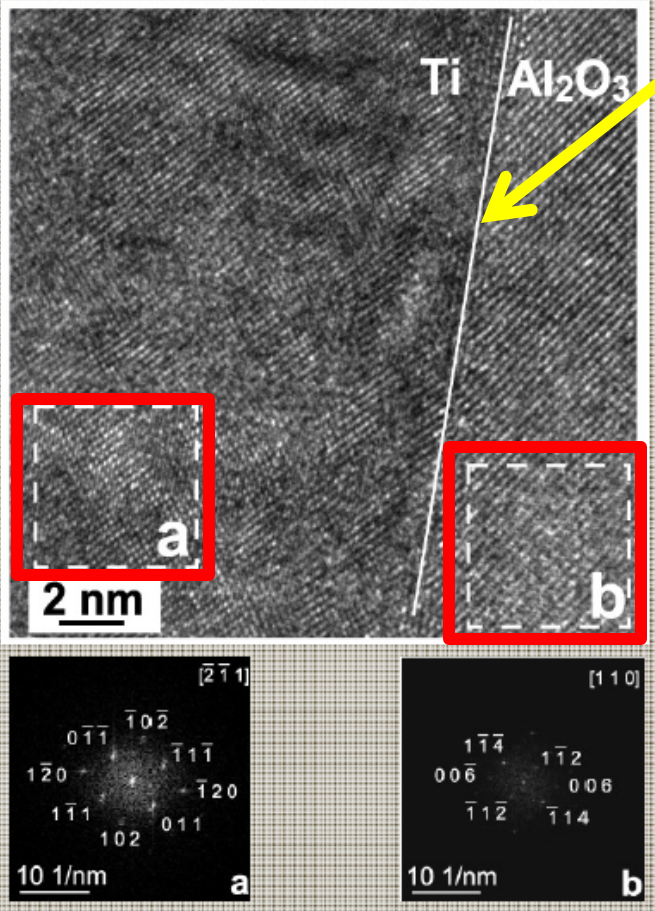
Ground side (R_a<1µm)

Non-uniform thickness of the coating of max. 150µm

Much better adhesion on the polished substrate!!

Cold Spray Coating on Hard Surfaces

Effect of the Surface Roughness



CGS-Ti / Sapphire Interface (HRTEM)

Bonding mechanism between CGS titanium & polycrystalline sapphire:

Strong plastic deformation, especially at the sapphire surface

Deformation energy resulting from impact energy triggers recrystallization

Crystallites immediate to the polycrystalline surface show partial hetero-epitaxy due to energy of recrystallization.

Source: Microstructural characterisation of titanium coatings deposited using cold gas spraying on Al2O3 substrates, David Rafaja, Torsten Schuknecht, Volker Klemm, Alexander Paul, Harry Berek, Surface & Coating Technology 203 (2009) 3206-3213

Cold Spray Coating on Hard Surfaces

Hetero-epitaxy is a kind of epitaxy performed with materials that are different from each other. In heteroepitaxy, a crystalline film grows on a crystalline substrate or on a film of a different material.

This technology is often used to grow crystalline films of materials for which crystals cannot otherwise be obtained and to fabricate *integrated* crystalline layers of different materials.

Bonding Discussion

Dense titanium coatings with a good adhesion to sapphire (aka corundum, alumina, Al_2O_3) substrates were successfully deposited using cold gas spraying. The porosity of the coatings was approximately 10%.

Severe plastic deformation of titanium particulates and elevated temperature at the Ti/sapphire interface, caused by the impact of titanium particles on the substrate, supplied additional energy promoting re-crystallization of titanium next to the surface of the sapphire substrate.

The re-crystallization of titanium supported re-organization of atoms, which is necessary for establishing the partial hetero-epitaxy between Ti and Al_2O_3. The hetero-epitaxy between Ti and Al_2O_3 is regarded as a phenomenon that enhances the adhesion of Ti coatings to Al_2O_3 substrates.

Another consequence of the partial hetero-epitaxy at the Ti/Al_2O_3 interface and the re-crystallization of titanium was the nano-size of the Ti grains at the surface of the substrate.

As the formation of the partial hetero-epitaxy and the formation of the re-crystallized titanium decline with increasing distance from the Ti/Al_2O_3 interface, a gradient of increasing grain size was observed in the CGS Ti.

Commercial Application

CPS Ti or Al have a special bonding ability to ceramic surfaces through hetero-epitaxial formation.

This special bonding mechanism was observed only for Al and Ti (unfortunately). This is our level of knowledge at the present time.

GfE has used this knowledge to enhance bond strength on one commercial application area where the substrate is a plasma sprayed oxide ceramic coating.