9-17-2017

Novel Ir-X thermal protection coatings designed for extreme aerodynamic heating environment

Kaili Zhang
National University of Defense Technology, kellybox315@sina.com

Yicong Ye
National University of Defense Technology

Li`an Zhu
National University of Defense Technology

Shuxin Bai
National University of Defense Technology

Novel Ir-X Thermal Protection Coatings Designed for Aerospace Heating Environment

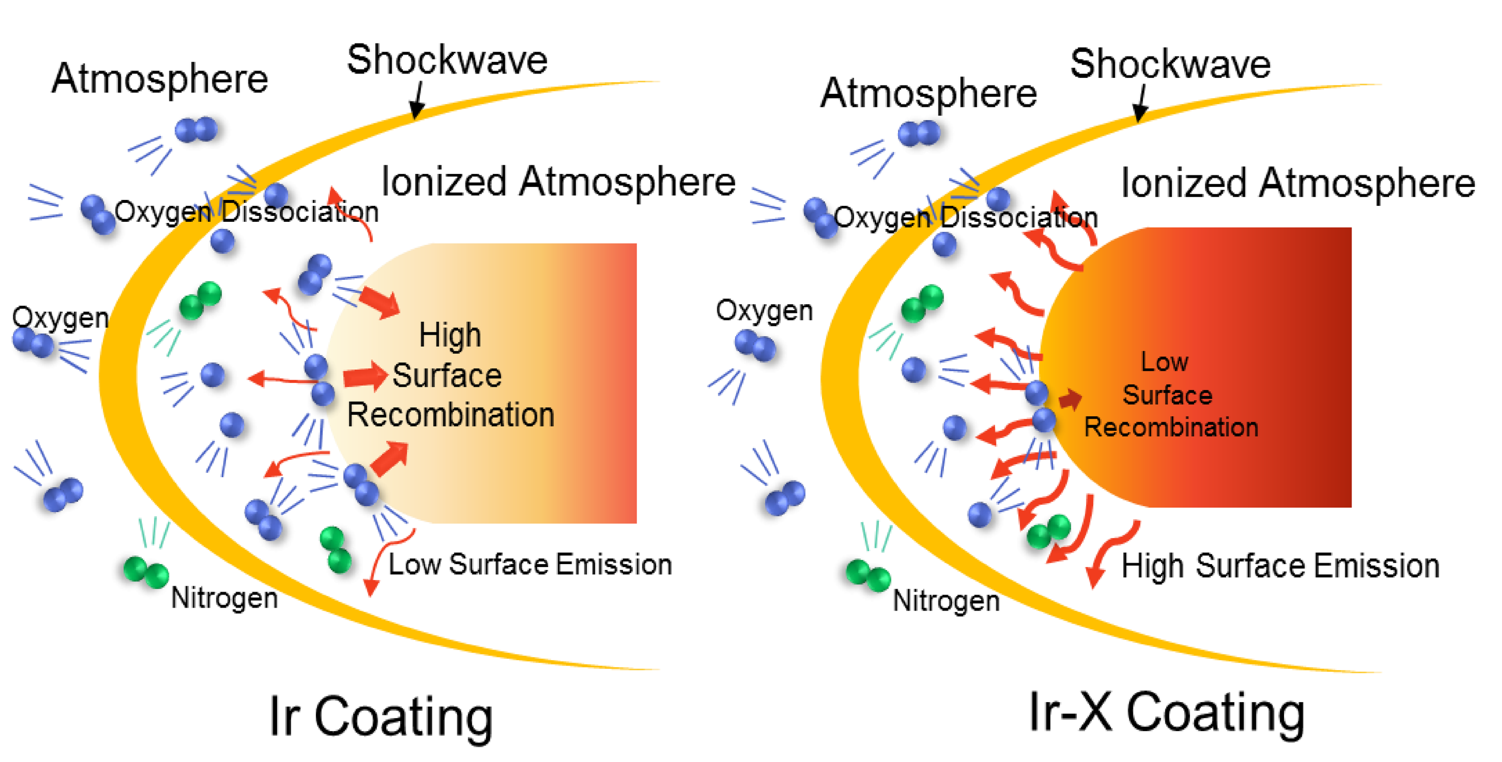
Kaili Zhang, Shuxin Bai, Li'an Zhu, Yicong Ye

Department of Materials Science and Engineering, College of Aerospace Science and Engineering, National University of Defense Technology, China

Abstract

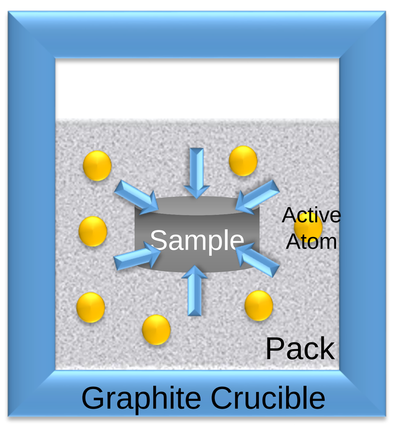
Though being promising in ultra-high temperature application, Iridium coating exhibit low emissivity(ε) and high catalycity(γ) in dissociative atmosphere, which lead to additional heat for hypersonic application. By adding alloy elements X (Al, Cr, Zr…) through pack cementation, Ir-X diffusion coatings were prepared to improve the above properties. Microstructure, element distribution of Ir-X coating were characterized and ε and γ of the coatings were measured. The results showed that Ir-X coatings had a much lower catalycity and higher emissivity, and meanwhile decreased surface temperature in dissociative environment.

Graphic Abstract



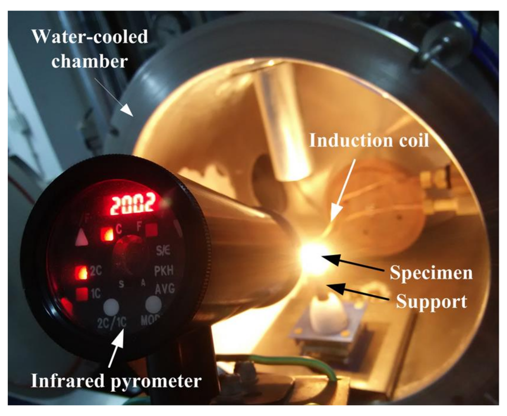
Experiment & Characterization

- **Pack Cementation Pre-Oxidation**



- Element: X=Al, Cr, Zr, Y, Ta
- Pack component: X+XO+NH_4Cl/XCl.
- Temperature: 800℃-1600℃

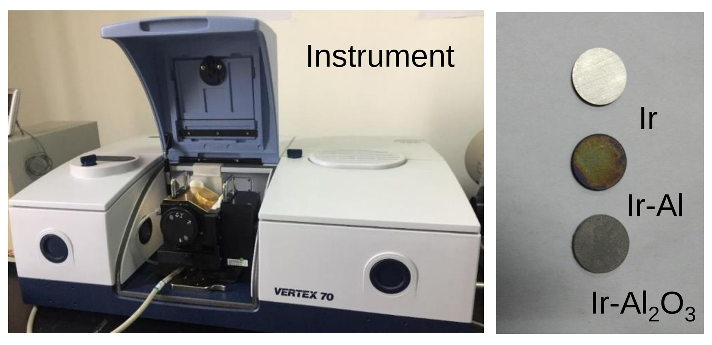
- **Pre-Oxidation**



- Aim: Oxide Scale Formation
- Induction heating
- Infrared thermometry
- 1200℃/30min 1atm

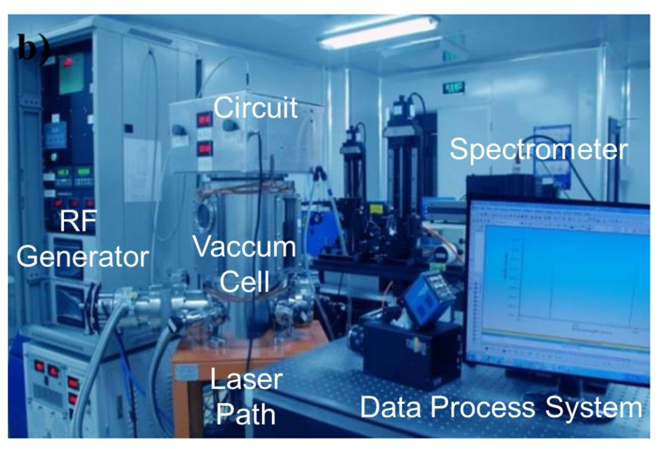
- **Microstructure Characterization**
  - SEM
  - XRD
  - EDS

- **Emissivity Measurement**



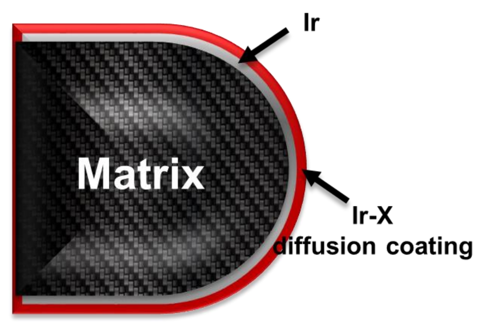
- Bruker Vertex70 FTIR
- Wavelenth: 400-4000nm
- Sample: Ir Ir-X Ir-XO

- **Surface Recombination Test**

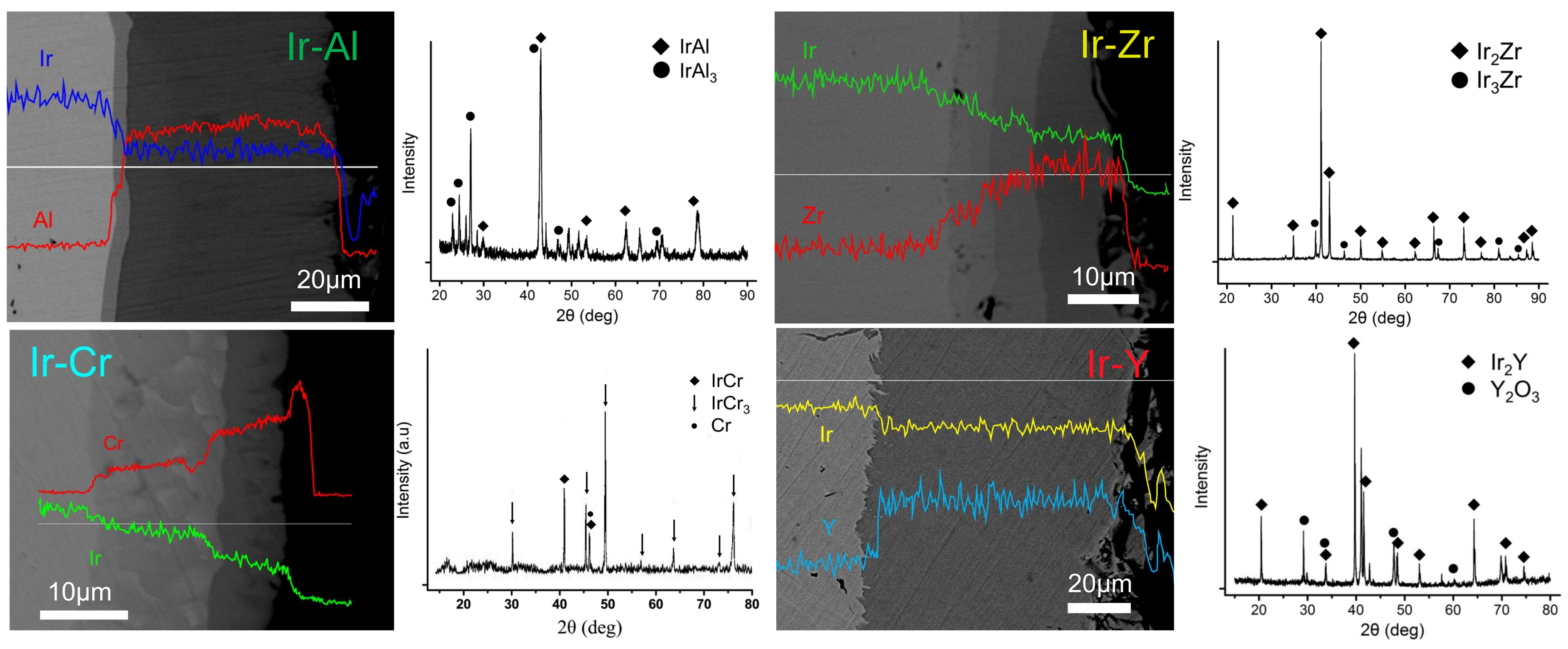


- RF Generator for O_{atom}
- Laser Sample Heating
- MESOX Method for γ
- Double colorimeter for T

Results & Discussion

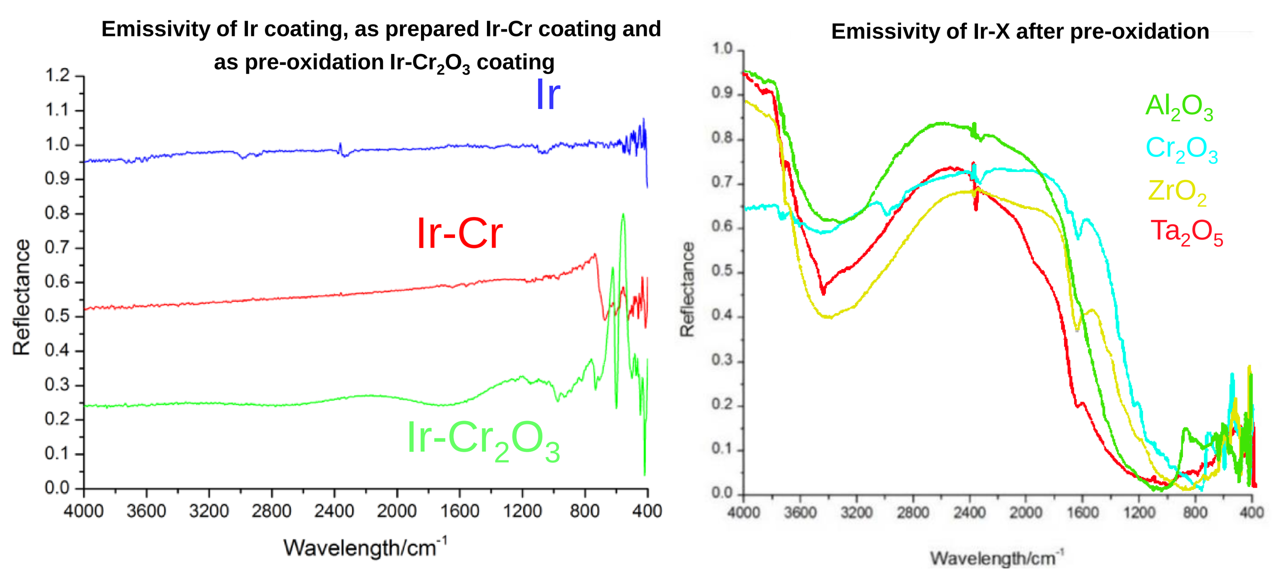


- **Coating Microstructure**



Several Ir-X diffusion coatings were prepared through pack cementation

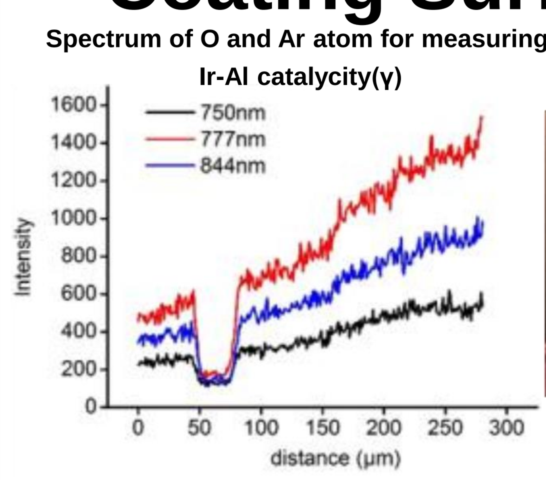
- **Coating Emissivity**

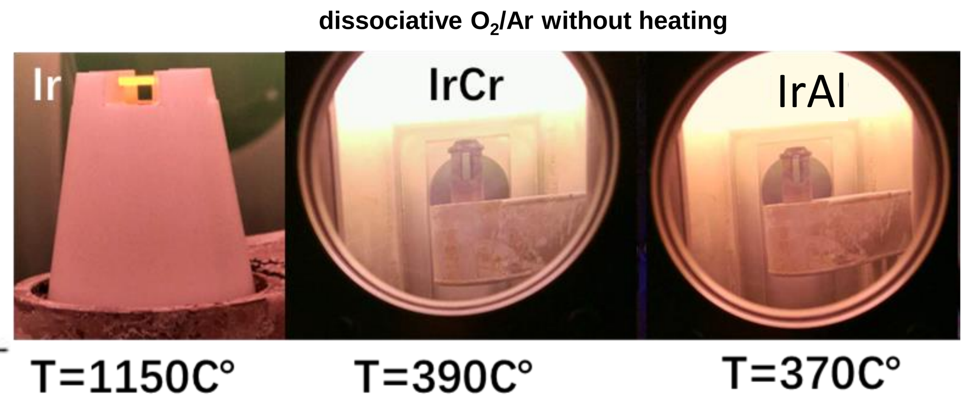


Coating	Emissivity(ε)
Ir	0.017
IrCr	0.433
IrAl	0.465
Cr_2O_3	0.723
Al_2O_3	0.759
ZrO_2	0.547
Ta_2O_5	0.57

※ Measured at Room Temperature

- **Coating Surface Recombination**





Coating	Catalycity(ε)
Ir	0.65
Ir	0.7
IrAl	0.004(RT)
IrAl	0.47(1400℃)
Ir-Al_2O_3	0.009(RT)
Ir-Al_2O_3	0.55(RT)

※ Measured at 20Pa

$$\gamma = \left\langle \frac{\left.\frac{I_O}{I_{Ar}}\right|_{x=L}}{\left.\frac{I_O}{I_{Ar}}\right|_{x=0}} \cdot \frac{T_s}{T_L} - L \right\rangle \frac{4D_0}{V^{*}L}$$

Temperature of Ir and Ir-X coating in dissociative O_2/Ar without heating

Coating	Ir	Ir-Al	Ir-Cr	Ir-Zr	Ir-Ta	Ir-Y
Surface T(℃)	1150	370	390	345	424	369

Conclusions

- Ir-X(X=Al, Cr, Zr, Y, Ta) intermetallic coatings with compact single or multilayer scale could be prepared through pack cementation.
- After cementation, Ir-X diffusion coating could largely increase emissivity and decrease catalycity, resulting in a lower surface temperature at dissociative atmosphere.

Acknowledgments

National Natural Science Foundation of China (51501224、51371196); Harbin Institute of Technology