Interaction of Iridium with Silicon Carbide in Diffusion Couples in Wide Temperature Range

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Introduction

SiC

- T_{melt} = 2830°C
- Semiconductor with a wide bandgap
- High thermal conductivity (490 $Wm^{-1}K^{-1}$)
- High specific strength characteristics
- High resistance to oxidation

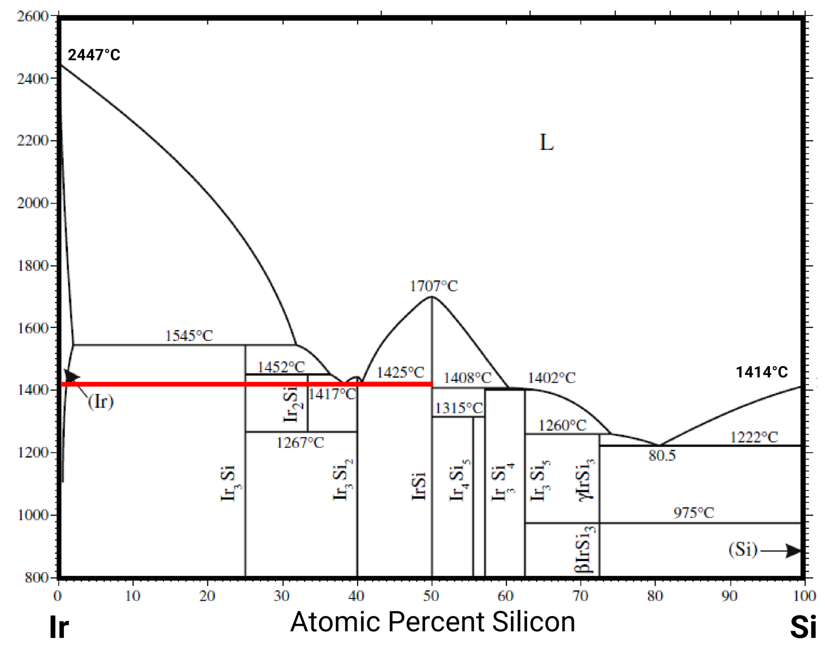
+

Ir

- T_{melt} = 2447°C
- Noble metal
- High strength and hardness
- Chemical stability
- Low oxidation rate up to 2000°C
- Extremely low oxygen permeability

=?

Ir-Si Phase Diagram



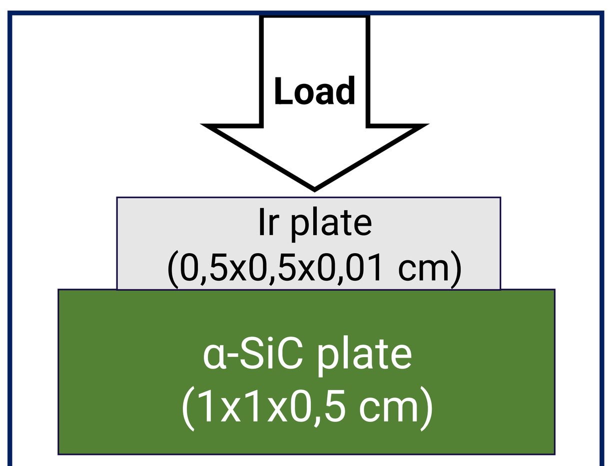
Promising areas of application

High temperature electronics | **Nuclear energy materials** | **High temperature materials**

- **T<1417°C – solid state interaction**
- **T>1417°C – interaction through liquid**

Experimental

1. Heat treatment in a hot press



Atmosphere: Ar

T = 1300 – 1800°C

Time: 1 – 56 h

Load:
20 MPa at 1300 – 1400°C
0 MPa at 1500 – 1800°C

2. Sample preparation:

- Cutting
- Fixing in epoxy
- Grinding, polishing

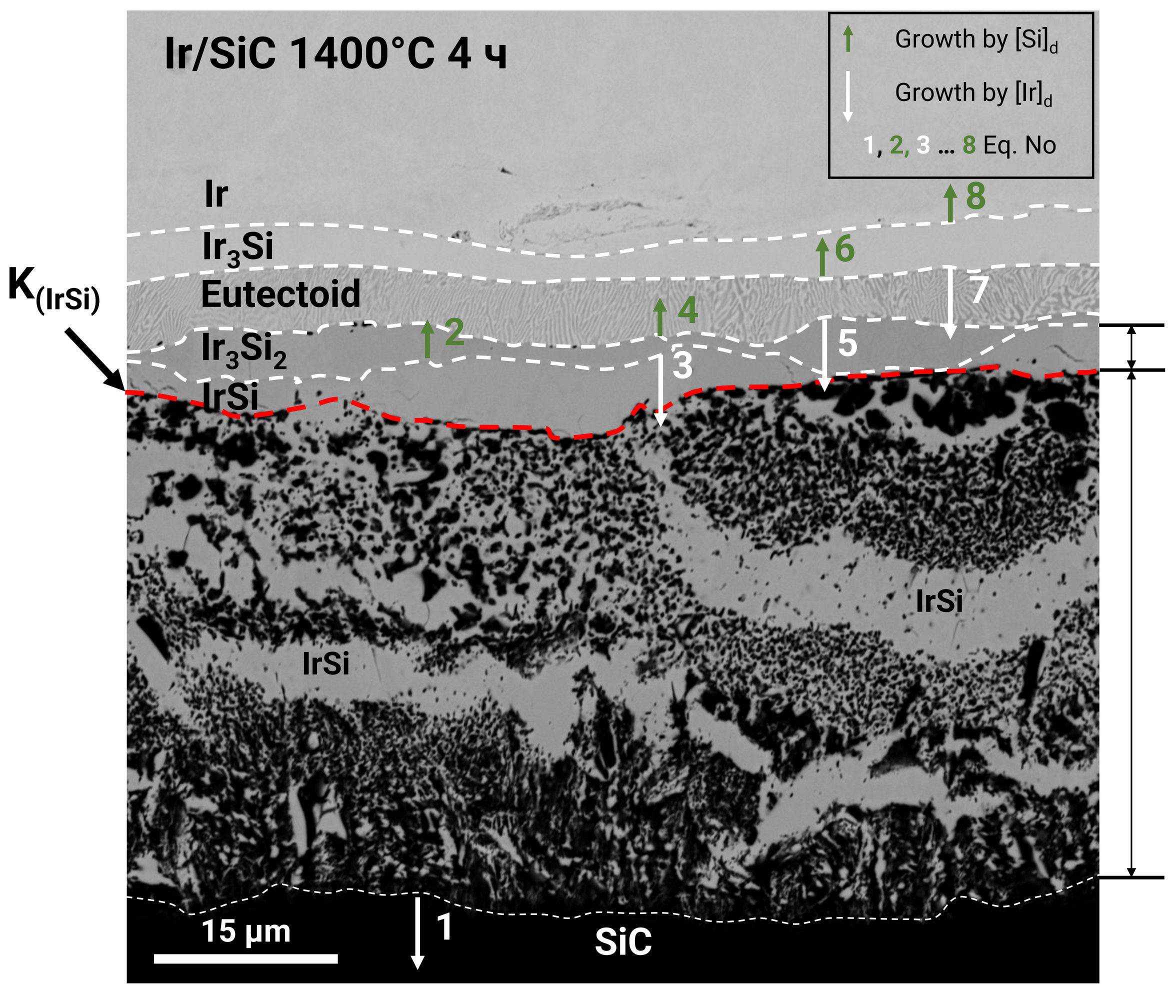
3. Study by analytical methods:

- XRD – Bruker D8 Advance
- SEM/EDX – Hitachi TM 1000, Tescan MIRA 3
- Raman spectroscopy – LabRam HR Evolution, λ = 633 нм

Results and Discussion

Solid state interaction

Phase composition. Diffusion



Diffusion Equations for the Growth of Product Layers Phases

1. $SiC + [Ir]_D \rightarrow IrSi + C$
2. $Ir_3Si_2 + [Si]_D \rightarrow 3IrSi$ — **IrSi**

L_1

3. $2IrSi + [Ir]_D \rightarrow Ir_3Si_2$
4. $3Ir_2Si + [Si]_D \rightarrow 2Ir_3Si_2$ — **Ir_3Si_2**
5. $Ir_3Si_2 + [Ir]_D \rightarrow 2Ir_2Si$
6. $2Ir_3Si + [Si]_D \rightarrow 3Ir_2Si$ — **Ir_2Si**

L_2

7. $Ir_2Si + [Ir]_D \rightarrow Ir_3Si$
8. $3Ir + [Si]_D \rightarrow Ir_3Si$ — **Ir_3Si**

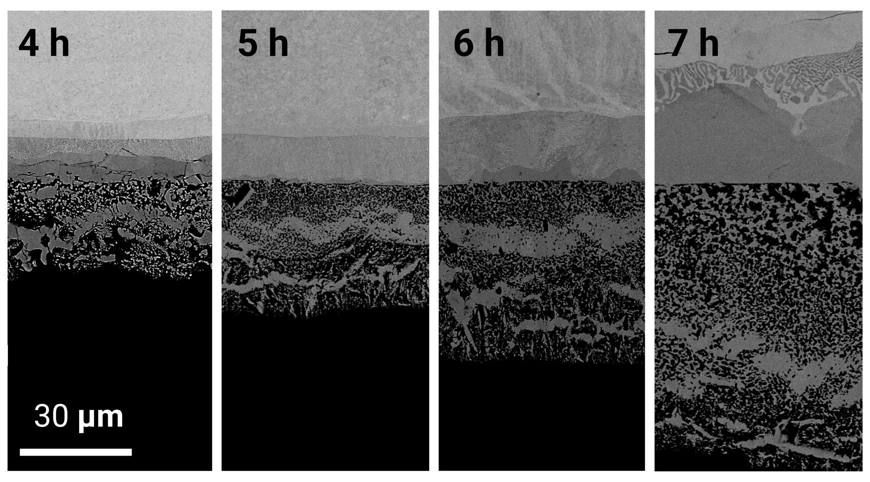
Carbon is a marker of the Kirkendall plane for IrSi layer

$L_2 >> L_1$ => $D(Ir) >> D(Si)$

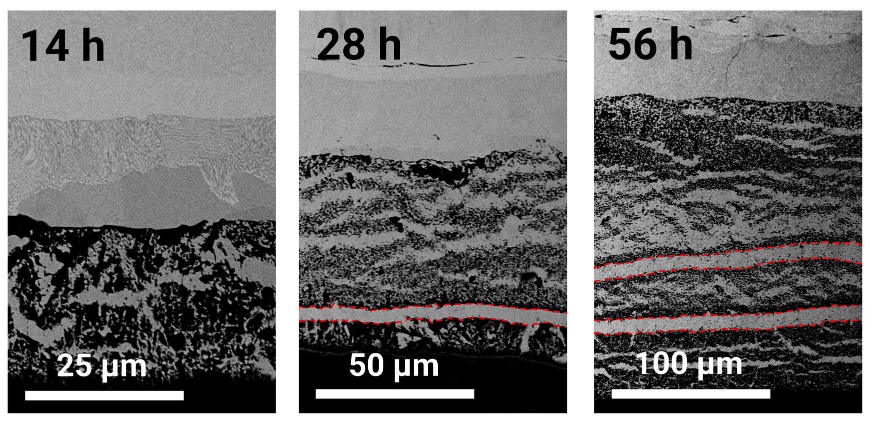
- The **diffusion rate of Ir** atoms is **much higher** than the counter diffusion rate of Si atoms

Evolution of morphology

1400°C

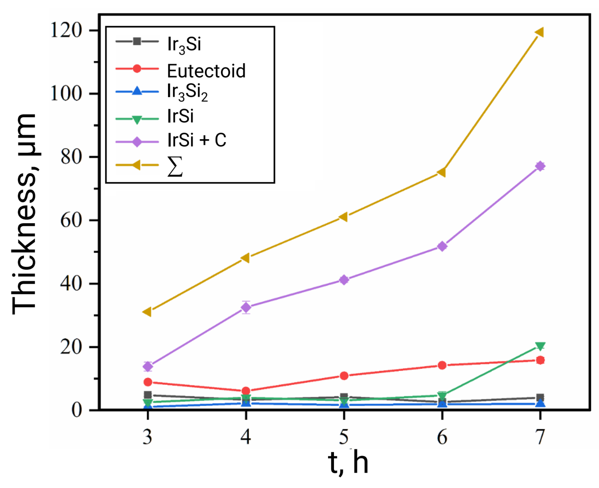


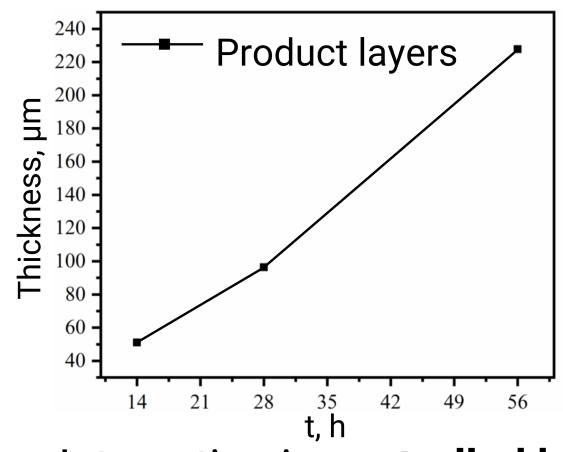
1350°C



- **Alternating sublayers of IrSi and IrSi+C** are observed in the C-containing layer at 28, 56 h

Kinetic

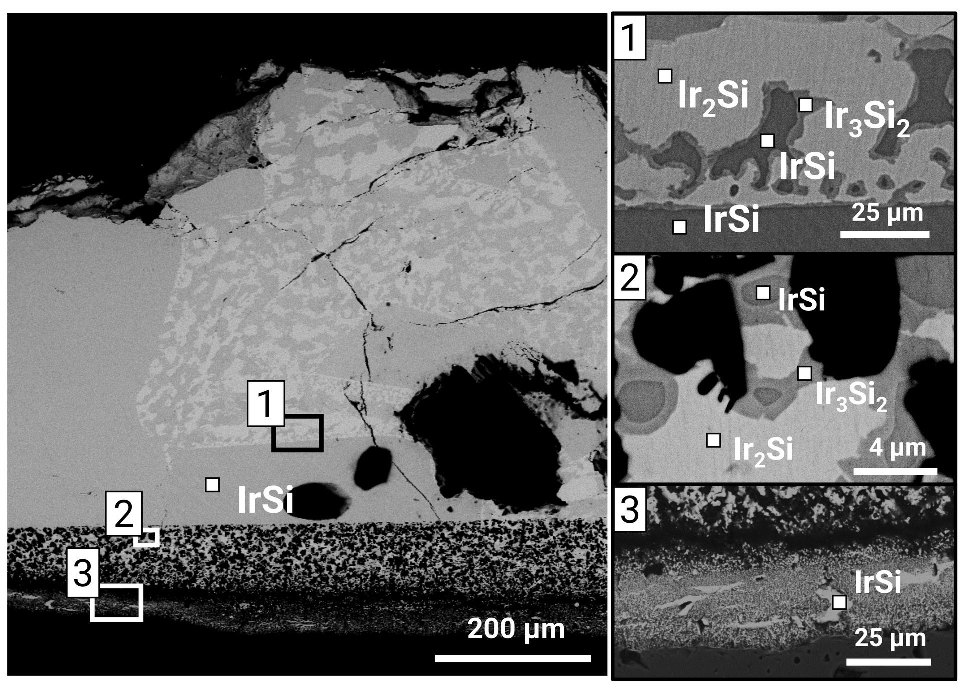




- Interaction is **controlled by kinetics**

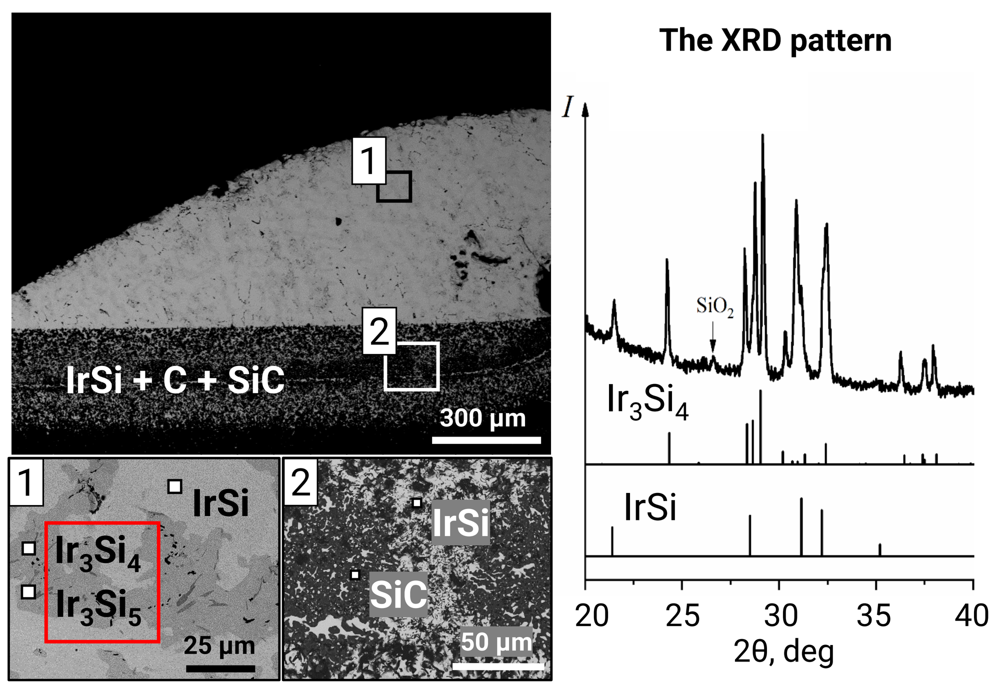
Interaction through liquid

1500 – 1700°C, 1h



- Phase composition: **IrSi, Ir_3Si_2, Ir_2Si, C**
- **The Ir_2Si is stabilized due to high cooling rate**

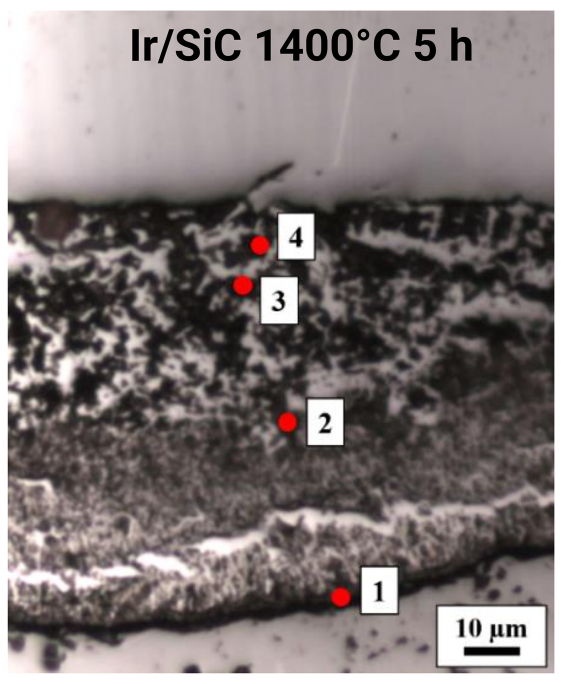
1800°C, 1h



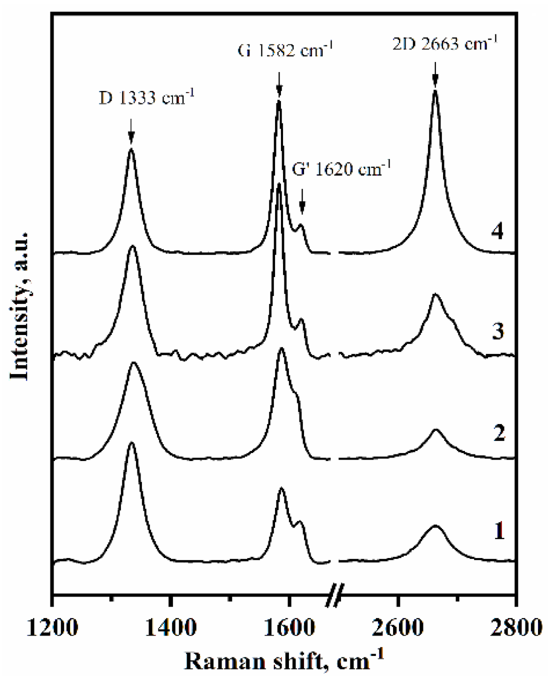
- The silicides **Ir_3Si_4 and Ir_3Si_5 are observed at 1800°C.**

Carbon graphitization vs location

SEM image



Raman spectra



	I_D/I_G
1	1.63
2	0.84
3	0.74
4	0.69

- **The carbon graphitizes and agglomerates over the exposure time.**

Conclusion

1. During the solid-state reaction of Ir with SiC the following layers of products are formed: **Ir/Ir_3Si/Eutectoid (Ir_3Si+Ir_3Si_2)/IrSi/IrSi+C**. The Ir-SiC system is pseudo-binary; **no Ir-Si-C ternary compounds** are formed.

2. Solid-state interaction is controlled by the kinetics due to the strong covalent Si-C bond.

3. Periodic morphology occurs at long exposure times and **consists of alternating sublayers IrSi and IrSi+C.**

4. The silicides Ir_3Si_4 and Ir_3Si_5 are observed at 1800°C. Previously, these silicides have not been observed in Ir-SiC powder mixtures treated under similar conditions.

5. The carbon formed during the reaction **agglomerates and graphitizes with exposure time** according to SEM and Raman spectroscopy data

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References: Golosov et al, J. Am. Cer. Soc. 10.1111/jace.17978; Golosov et al, Materialia. 10.1016/j.mtla.2022.101647

Approved for public dissemination