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Analyzing SiC/Co materials for radar absorption and EMI shielding using ARL X'TRA Companion XRD

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Introduction

SiC–Co composites represent a new class of engineered materials designed to combine dielectric and magnetic loss mechanisms for effective absorption of electromagnetic radiation. By dispersing cobalt or cobalt ferrite phases within a silicon carbide or SiOC matrix, these composites achieve tunable permittivity and permeability, enabling efficient impedance matching across radar and microwave frequencies. For defense and aerospace applications, where low radar cross section and stable electromagnetic shielding are critical, such composites are attractive because they also retain thermal and mechanical stability beyond the capabilities of polymer-based absorbers.

X-ray diffraction (XRD) plays a central role in the development and quality control of these materials. It allows unambiguous identification of SiC polytypes that influence dielectric behavior, while simultaneously detecting cobalt, cobalt oxide, or ferrite phases that govern magnetic response. XRD quantification provides insight into crystalline-to-amorphous ratios, crystallite size, and micro strain directly linked to electromagnetic performance and high-temperature durability. By correlating phase composition with measured S-parameters, researchers can optimize absorber formulations and processing conditions to achieve reliable, broadband EMI shielding.

Figure 1: ARL X'TRA Companion X-ray diffraction system.

Instrument & software

The Thermo Scientific™ ARL™ X'TRA Companion X-Ray Diffractometer (c.f. Figure 1) is a simple, easy-to-use benchtop instrument for routine phase analysis as well as more advanced applications. The ARL X'TRA Companion XRD uses a θ/θ goniometer (160 mm radius) in Bragg-Brentano geometry coupled with a 600 W X-ray source (Cu or Co). The radial and axial collimation of the beam is controlled by divergence and Soller slits, while air scattering is reduced by a variable beam knife. An integrated water chiller is available as an option. Thanks to the state-of-the art solid state pixel detector (55x55 µm pitch), the ARL X'TRA Companion XRD provides very fast data collection and comes with single-click Rietveld quantification capabilities and automated result transmission to a LIMS (Laboratory Information Management System) seamless integrated into Thermo Scientific™ SolstiX™ Pronto instrument control software.

Experimental

A SiC/Co sample was manually pressed in top loading sample cup and measured in reflection mode using Cu Kα (1.541874 Å) radiation for 10 minutes with sample spinning. (Figure 2).

Rietveld refinements were carried out using Profex software [1], and amorphous content was quantified, applying the PONKCS method [2].

Results and discussion

From Rietveld refinements of the SiC–Co composite, the crystalline phases were identified as Si (minor), SiC polytypes (3C, 6H), and fcc-Co nanoparticles with an average coherent domain size of ~25–30 nm. (see figure 2 and table 1) The amorphous hump was modeled as SiOC/oxide shell (≈14 wt%) using the PONKCS method. No significant hcp-Co contribution was detected, with the phase fraction converging to zero. The refined lattice parameter of the fcc-Co phase (a ≈ 0.3555 nm) is consistent with metallic cobalt. Anisotropic peak broadening indicates dislocation-related strain rather than stacking faults, in line with nanoscale, mechanically processed Co. The outcome supports the interpretation of a SiC–Co composite containing fcc-Co nanoparticles with oxide shells, well-suited for EMI shielding and radar-absorbing applications. The Co fraction corresponds to ~15 vol%, which is close to the percolation threshold and therefore highly relevant for tuning dielectric–magnetic loss balance in EMI shielding and radar-absorbing applications.

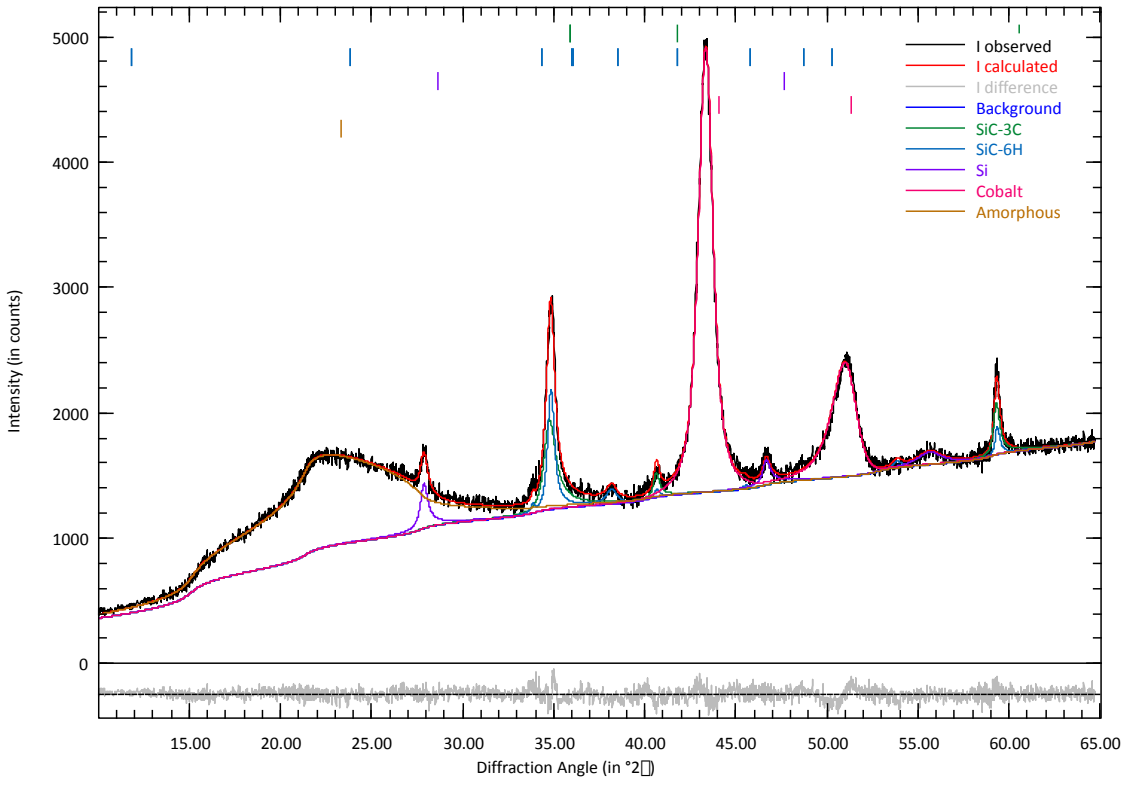

Figure 2: Measurement (10 minutes) of a SiC-Co sample.

The refined micro strain further highlights the ability to tailor physical properties: dislocation-driven strain broadens the magnetic loss response and lowers coercivity, enabling broader microwave absorption, while annealing or controlled processing can reduce strain and promote the fcc->hcp transformation. This provides a handle to fine-tune the electromagnetic behavior of the composite depending on whether broadband absorption or higher coercivity is desired.

Your benefits

The ARL X'TRA Companion XRD system delivers high-quality data in 10 minutes, enabling phase quantification, reliable identification of SiC polytypes, and advanced interpretation of anisotropic micro strain in Co. With the PONKCS method, the amorphous fraction can be quantified accurately. These structural insights directly link to physical properties such as dielectric–magnetic balance, EMI shielding efficiency, and radar absorption performance, providing a basis for fine-tuning materials to application needs.

[1] N. Döbelin, R. Kleeberg,
J. Appl. Crystallogr. 2015, 48, 1573-1580.
[2] N.V.Y. Scarlett, I.C. Madsen,
Powder Diffraction, 2006, 21(4), 278-284.

Table 1: Phase quantities and crystallite size (CS) from a Rietveld refinement of a SiC/Co sample

Phase	Formula	CS (in nm)	Quantity (in wt%)
Silicon carbide 3C	SiC	14	23.6
Silicon carbide 6H	SiC	31	14.9
Cobalt	Co	30	39.0
Silicon	Si	9	8.3
Amorphous	Si-C-O	-	14.3